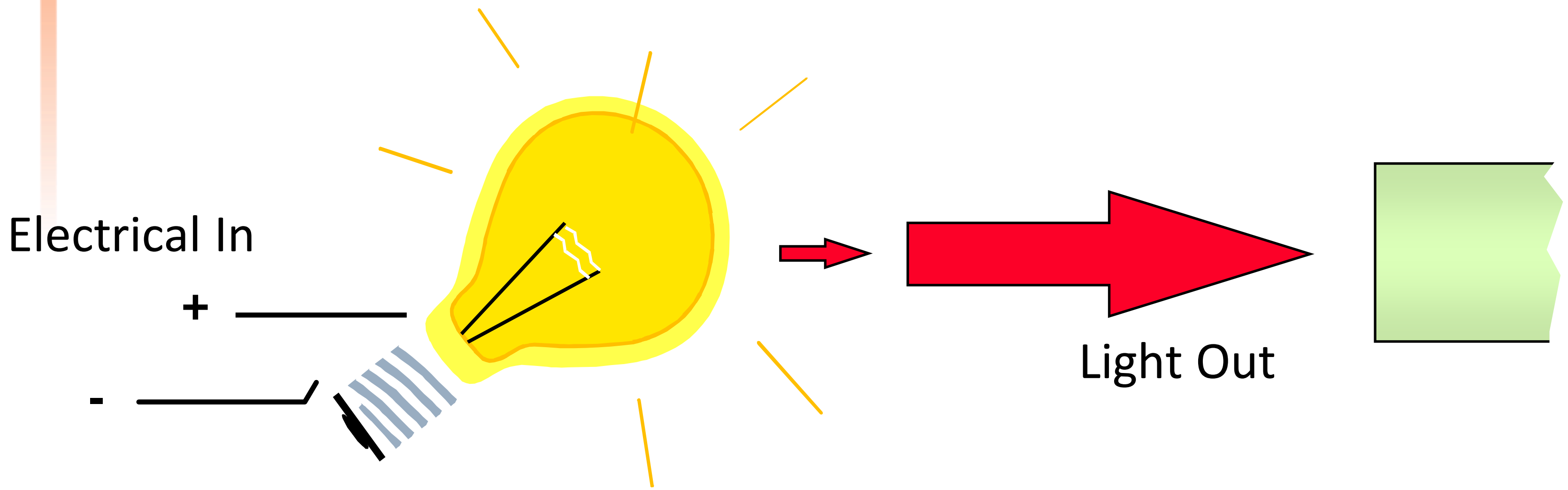
NTEST

ANTÓK MÉRNÖKI IRODA

Fényvezető ismeretek
OTDR mérés
Optikai szálfelügyelet

Transmitter

Electrical to Optical (E-O) Converter



Variable Intensity = Analog
Blink On & Off = Digital

Optical Waveguide

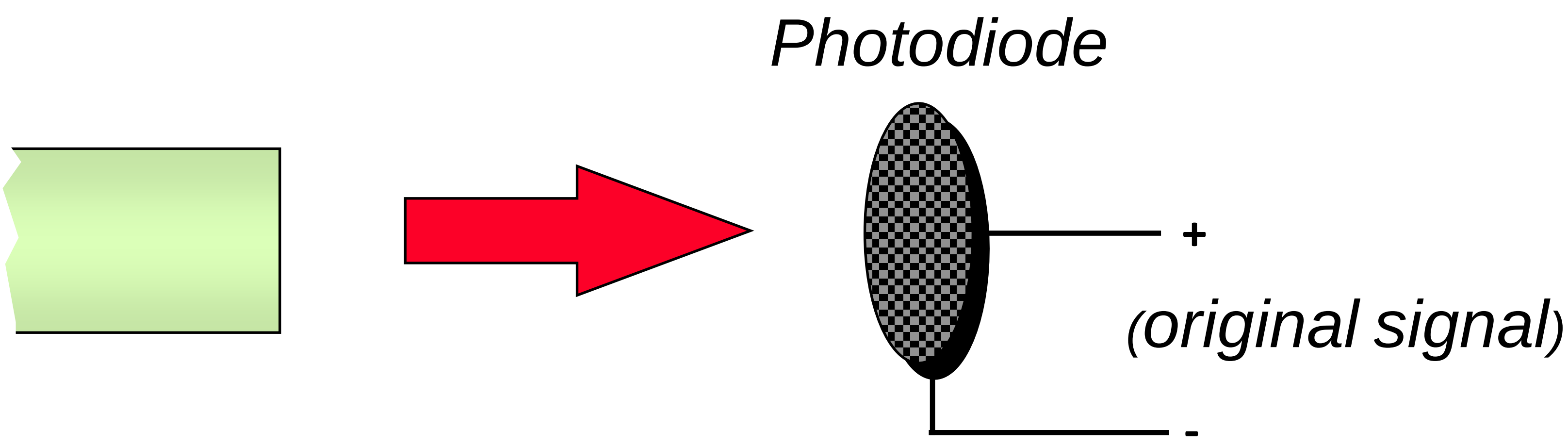
Silica-Glass Optical Fiber

Light In

Light Out

Receiver

Optical to Electrical (O-E) Converter



Light In

Electrical Out

Classifying Light

Power (Watts or Decibels)

dBm is typical measurement unit of optical power

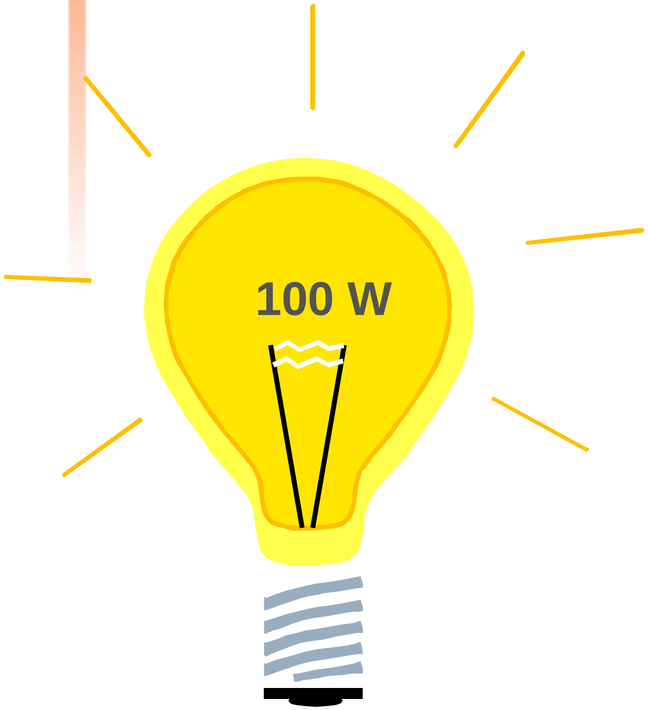
measured with an Optical Power Meter

Color (Wavelength)

300nm (blue) to 700nm (red) is visible to humans

FO systems use *ONLY Infrared* (850, 1310, & 1550nm)

Power



Like a light bulb:
more wattage = brighter light

FO transmitters:
about 1mw (0 dBm)

Power ranges:
+20 dBm to -70 dBm

Wavelength

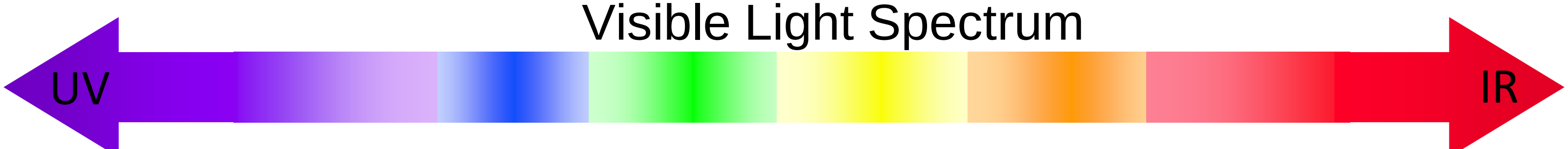
Measure of Color of light

Units in nanometers (nm) or microns (um)

Different colors (wavelengths) exhibit different characteristics:

ex: red & orange sunsets; yellow fog lights

Visible Light Spectrum



300nm

700nm

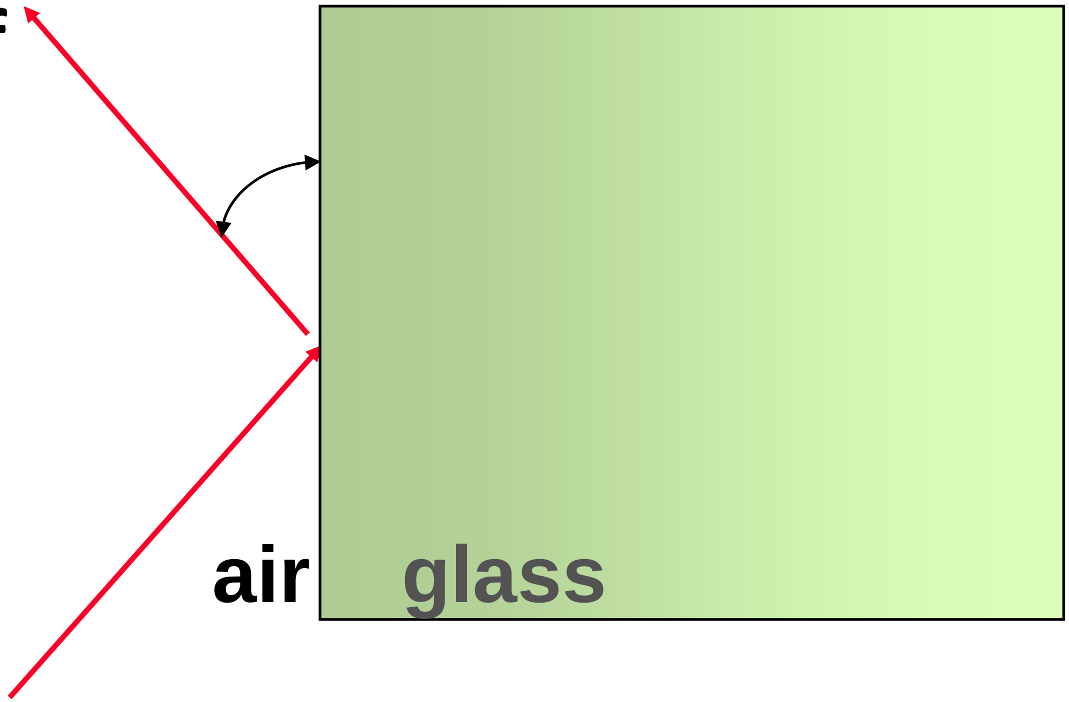
Reflection & Refraction

Reflection is a light ray BOUNCING off of the interface of two materials

Refraction is the BENDING of the light ray as it changes speed going from one material to another

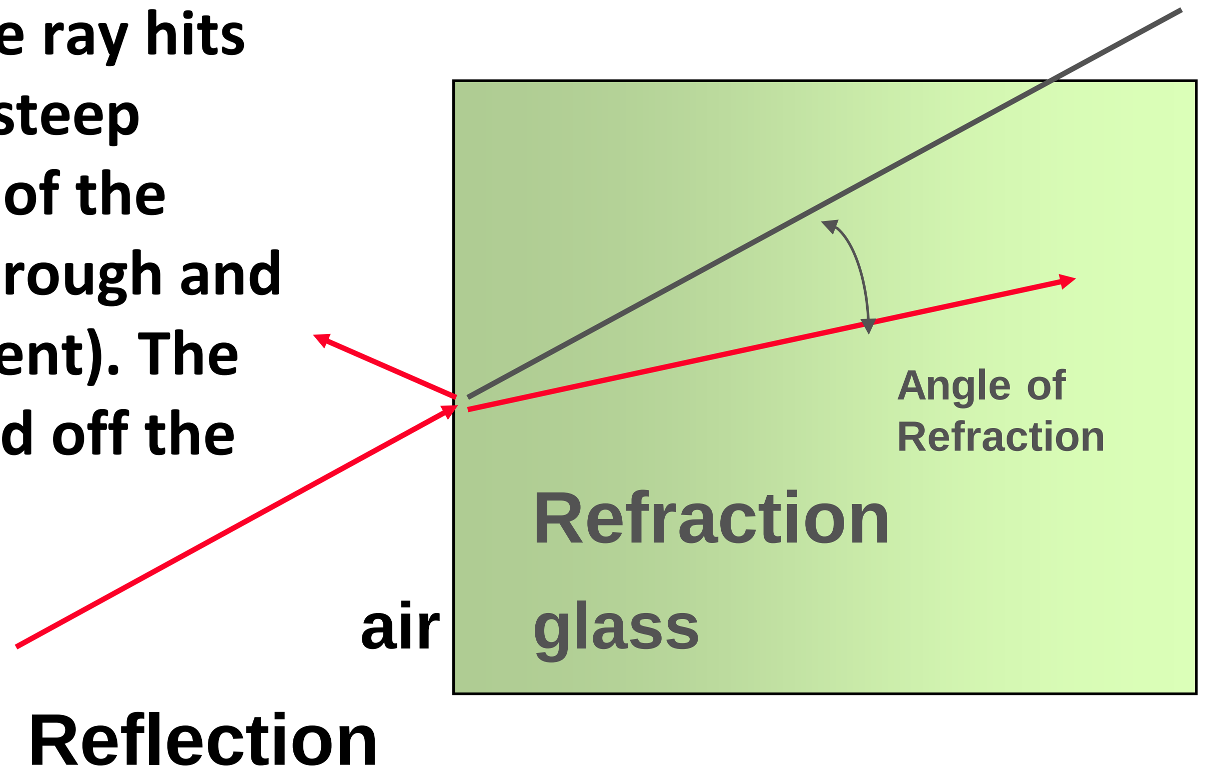
Reflections

Some or all of the light that strikes a surface is reflected off at the *same angle*.



Refraction & Reflection

If the angle the ray hits the surface is steep enough, most of the light passes through and is refracted (bent). The rest is reflected off the surface.

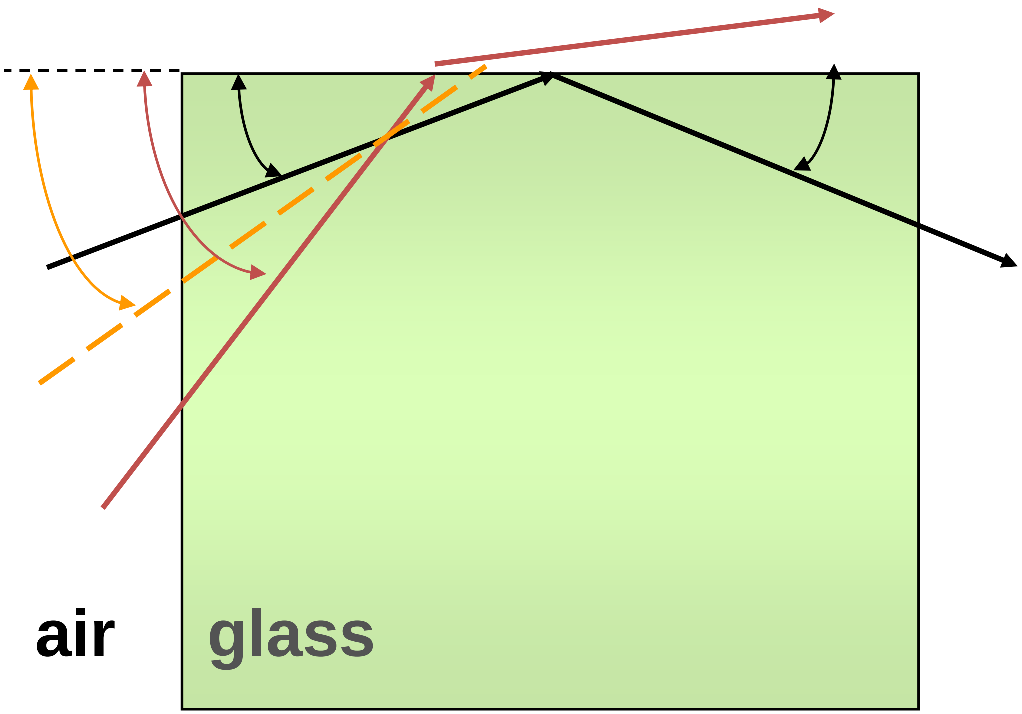


Refraction & Reflection

The Critical Angle

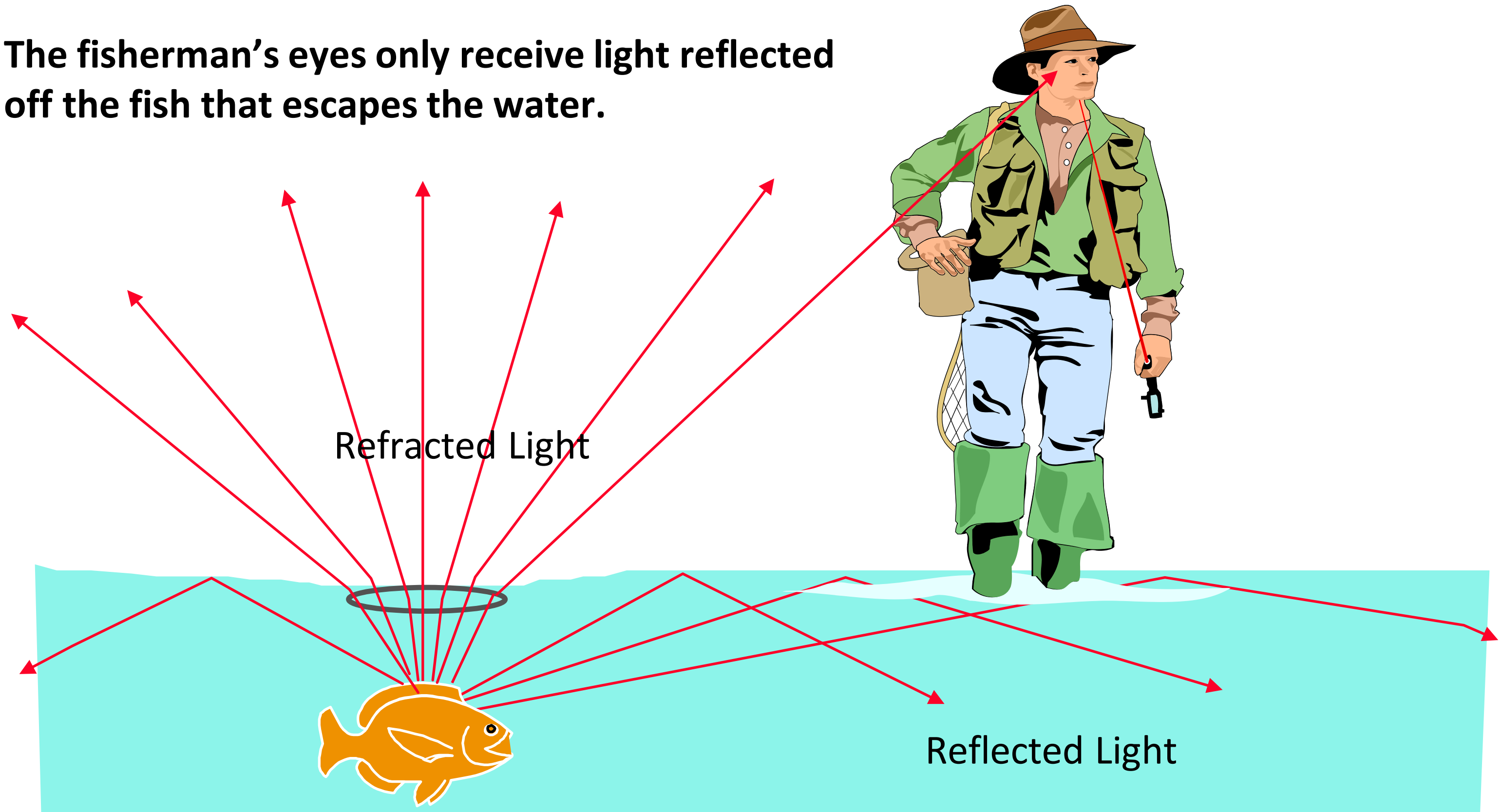
At an angle shallower than the Critical Angle, the light is Reflected back into the fiber. This condition is known as Total Internal Reflection.

At an angle that is steeper than the Critical Angle, the light will penetrate the glass/air boundary and exit the fiber.



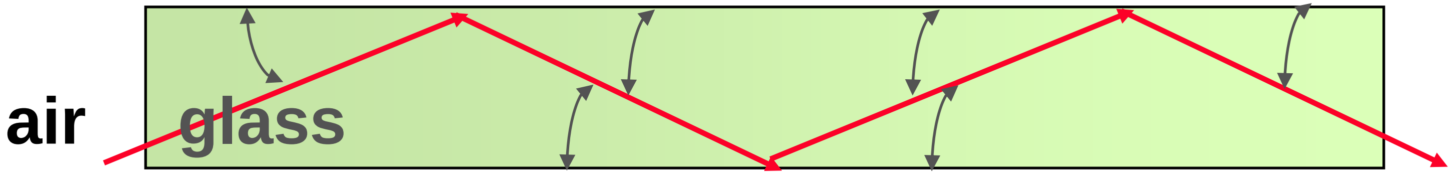
The Critical Angler

The fisherman's eyes only receive light reflected off the fish that escapes the water.



Light rays reflecting off the fish that strike the surface of the water at an angle outside that defined by the circle do not escape but are reflected back into the water.

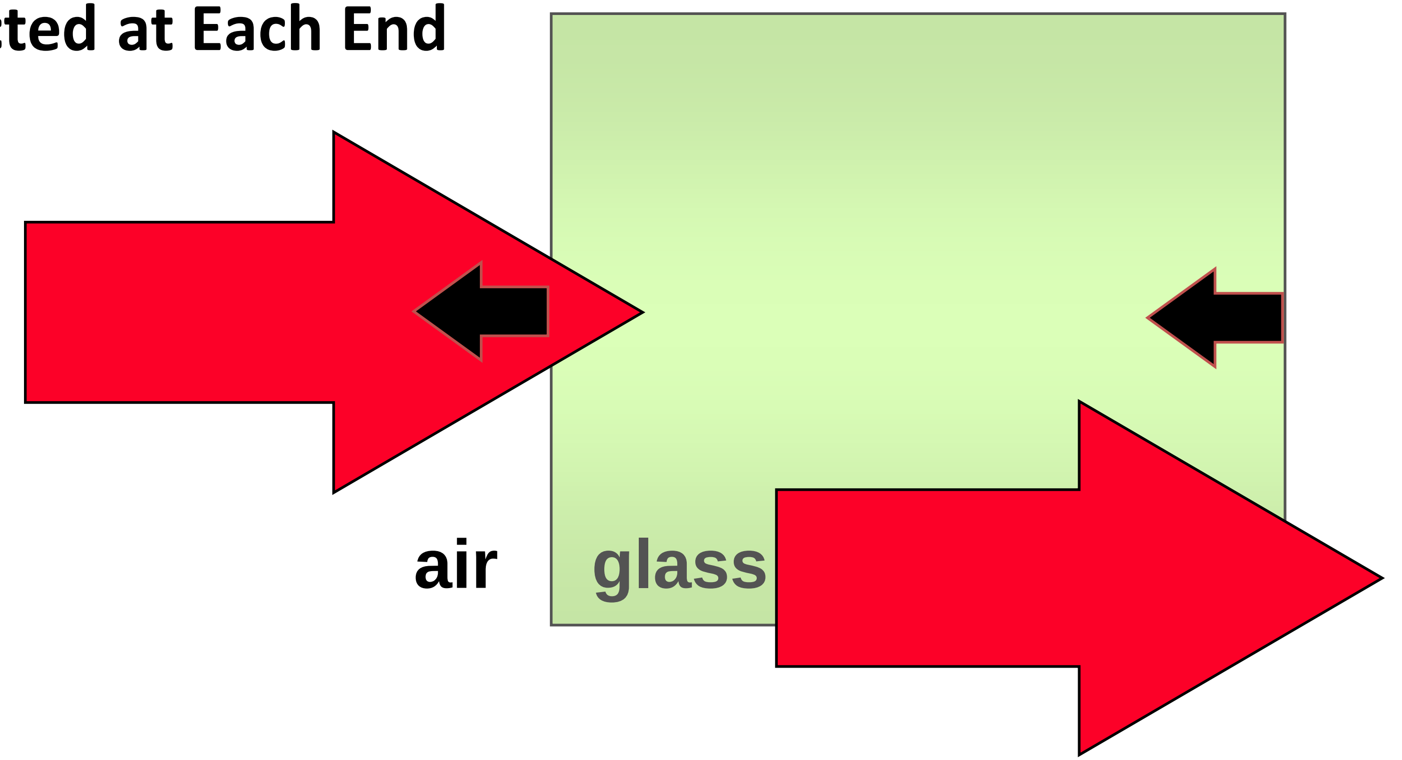
Refraction & Reflection



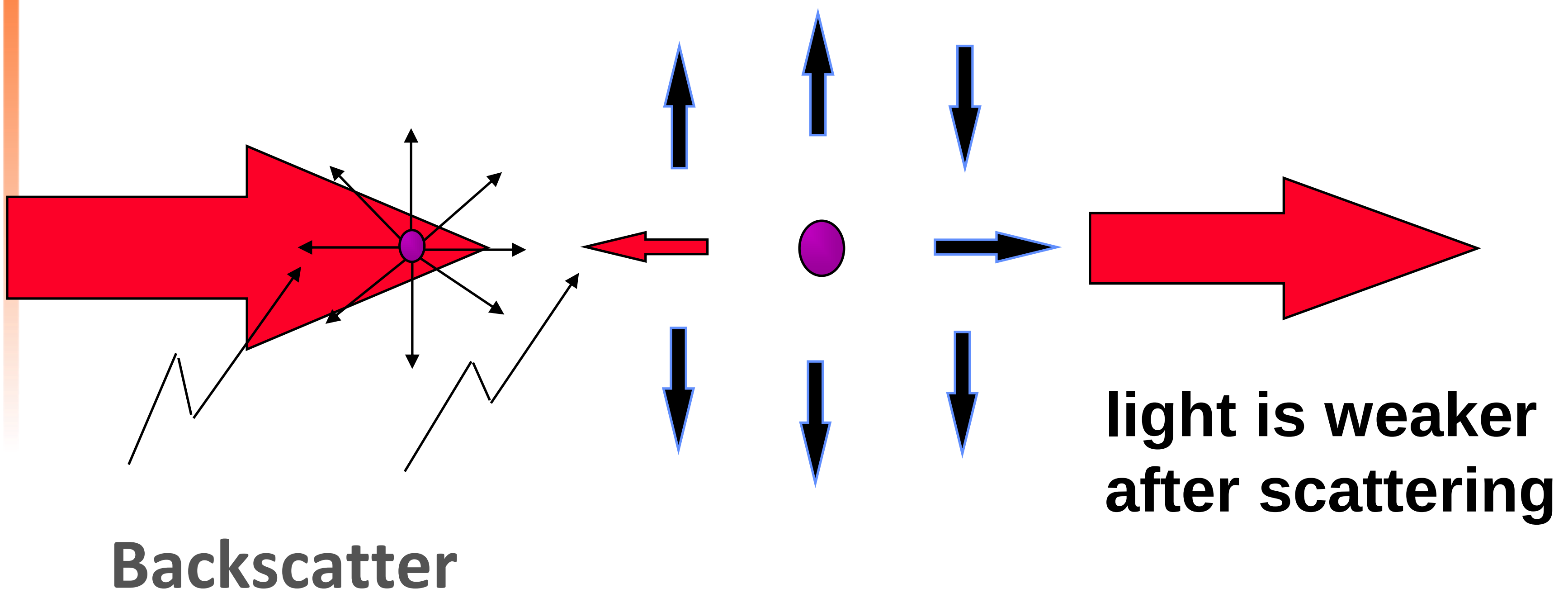
As long as the light ray stays at the Critical Angle or less as it hits the air-glass interface, it will remain in the fiber until it reaches the other end.

Reflections at Ends of Fiber

Up to 4% of Light Is Reflected at Each End Face

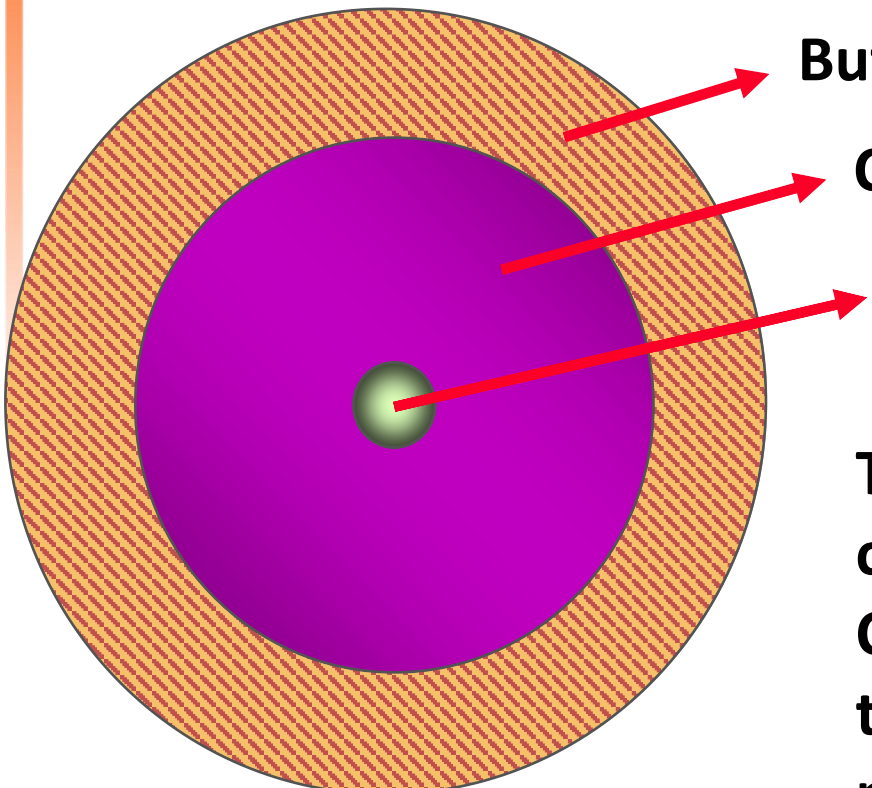


Rayleigh Scattering



As light passes through a particle part of it is *scattered* in all directions. The part that returns to the source (*about 0.0001%*) is called *BACKSCATTER*.

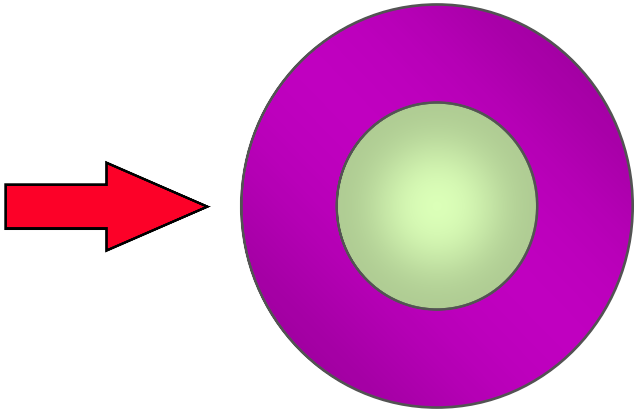
Optical Fiber Parameters

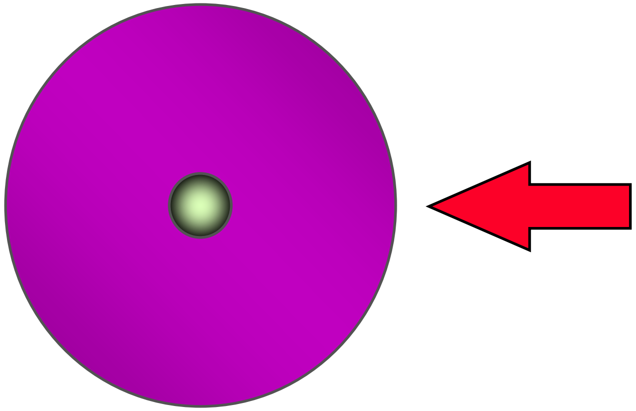


The denser Core is centered within the Cladding. Light travels in the Core only. The Buffer protects the glass fiber.

Optical Fiber Types

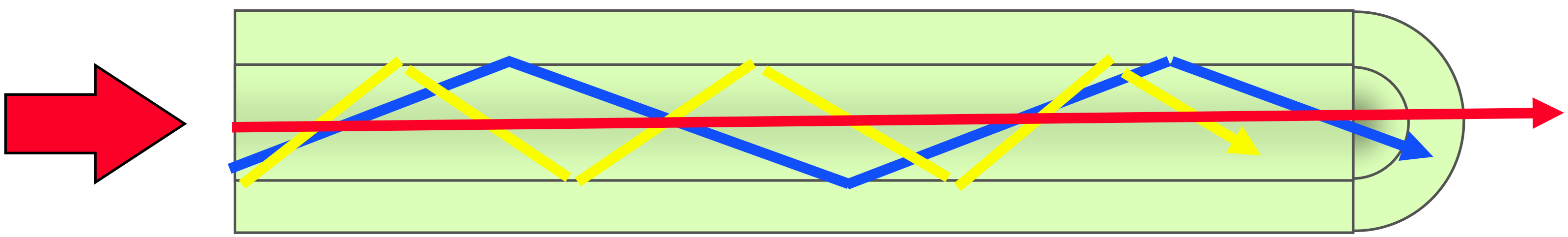
Multimode fiber has a large core relative to the cladding diameter. 50, 62.5, 100 um are typical core sizes centered in a cladding of 125/ 250 um.



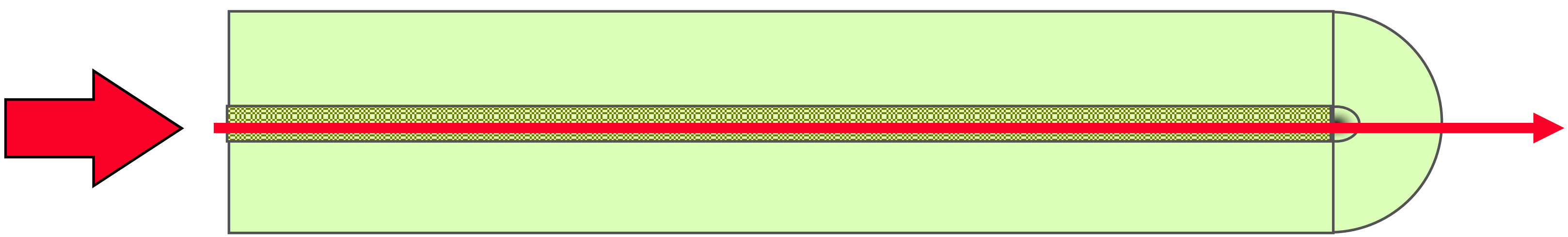


Singlemode fiber has a smaller core relative to the cladding diameter. 8 - 9 um is a typical core size centered in a cladding of 125 um.

Multimode vs. Singlemode Fiber

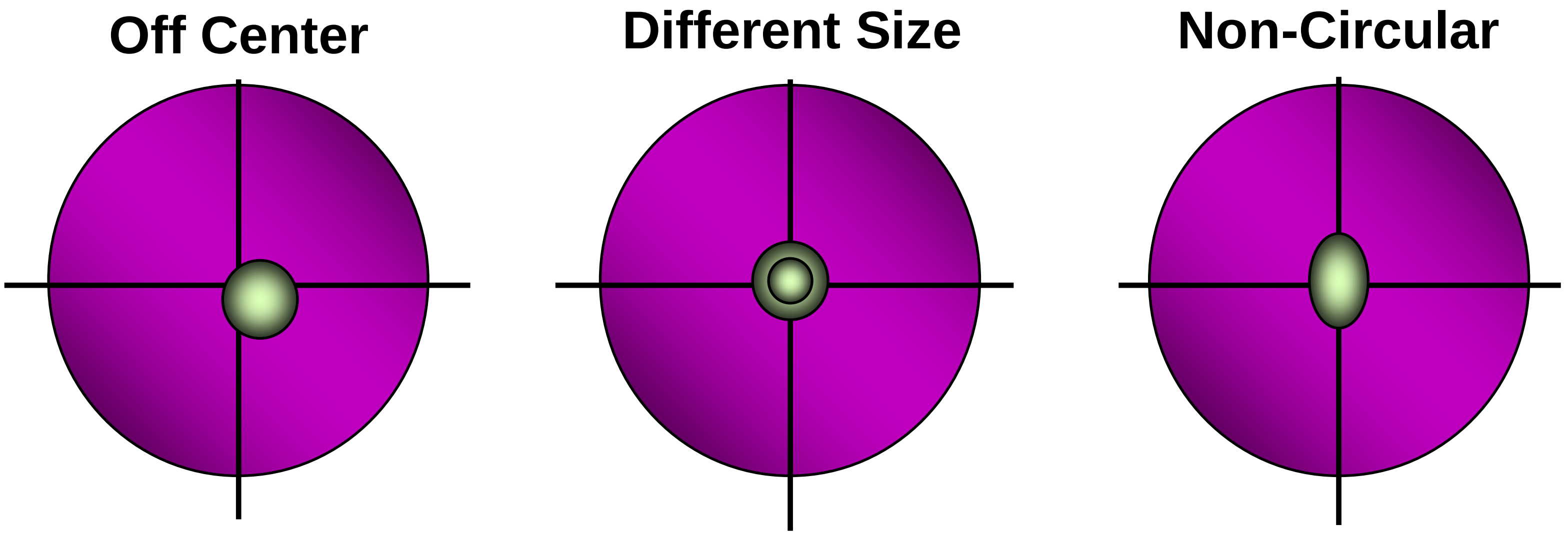


Multimode allows many paths (“modes”) for the light



Singlemode allows only one single path for the light

Fiber Geometry Problems



All fibers are allowed a certain tolerance in the core/cladding geometry. This can cause light loss at joints between fibers.

Index of Refraction (n)

$$n = \frac{C}{V}$$

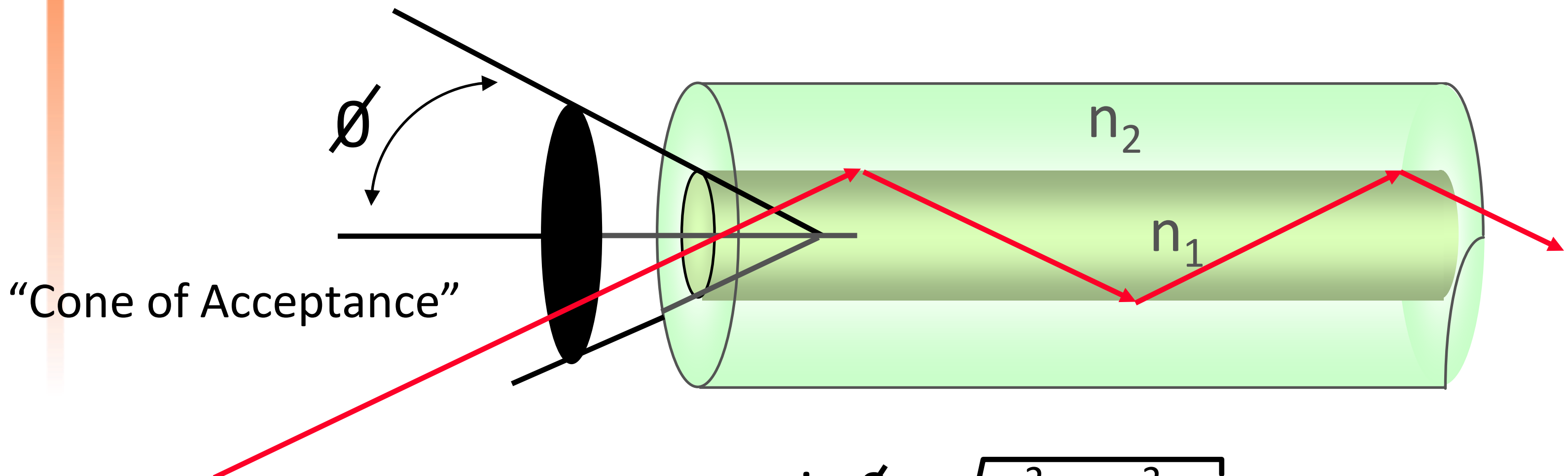
(velocity in a vacuum)

(velocity in glass)

"C" is a constant. "V" depends on the density of the glass. The denser the glass the slower the light travels.

(smaller "V" => larger "n")

How IOR Affects Fiber Characteristics



$$\sin Ø = \sqrt{n_1^2 - n_2^2}$$

"n" affects how wide the acceptance angle can be and what the critical angle will be.

Attenuation in Fiber

Rayleigh Scattering
Macro Bending
Micro Bending
Absorption

Rayleigh Loss

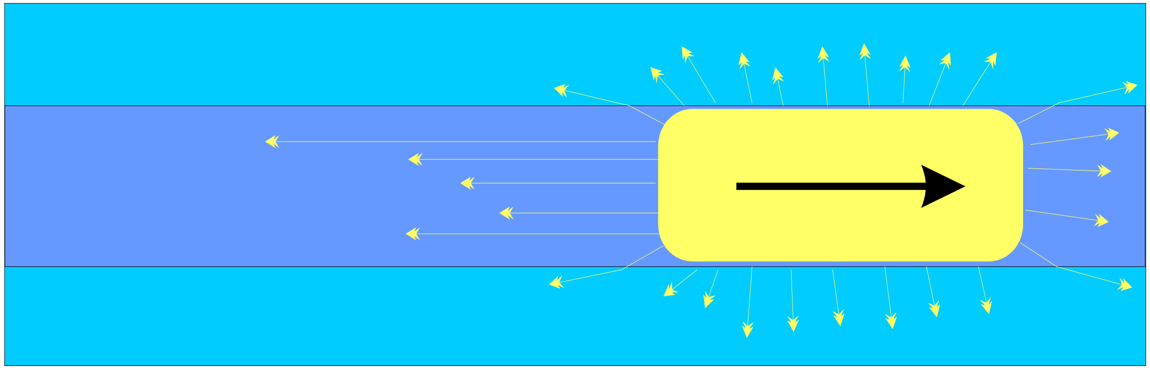
2.50 dB/km at 850 nm Multimode

1.0 dB/km at 1300 nm Multimode

0.35 dB/km at 1310 nm Singlemode

0.20 dB/km at 1550 nm Singlemode

Rayleigh Scattering



Rayleigh scattering is the primary cause of light loss as the pulse of light travels down the fiber.

Bending Losses

Macrobending

Visible Bend
Light Rays Exceed Critical Angle
More Severe at Longer Wavelengths

Bending Losses

Microbending

Microscopic Wrinkle
Caused in Manufacturing
Temperature Fluctuations

Absorption

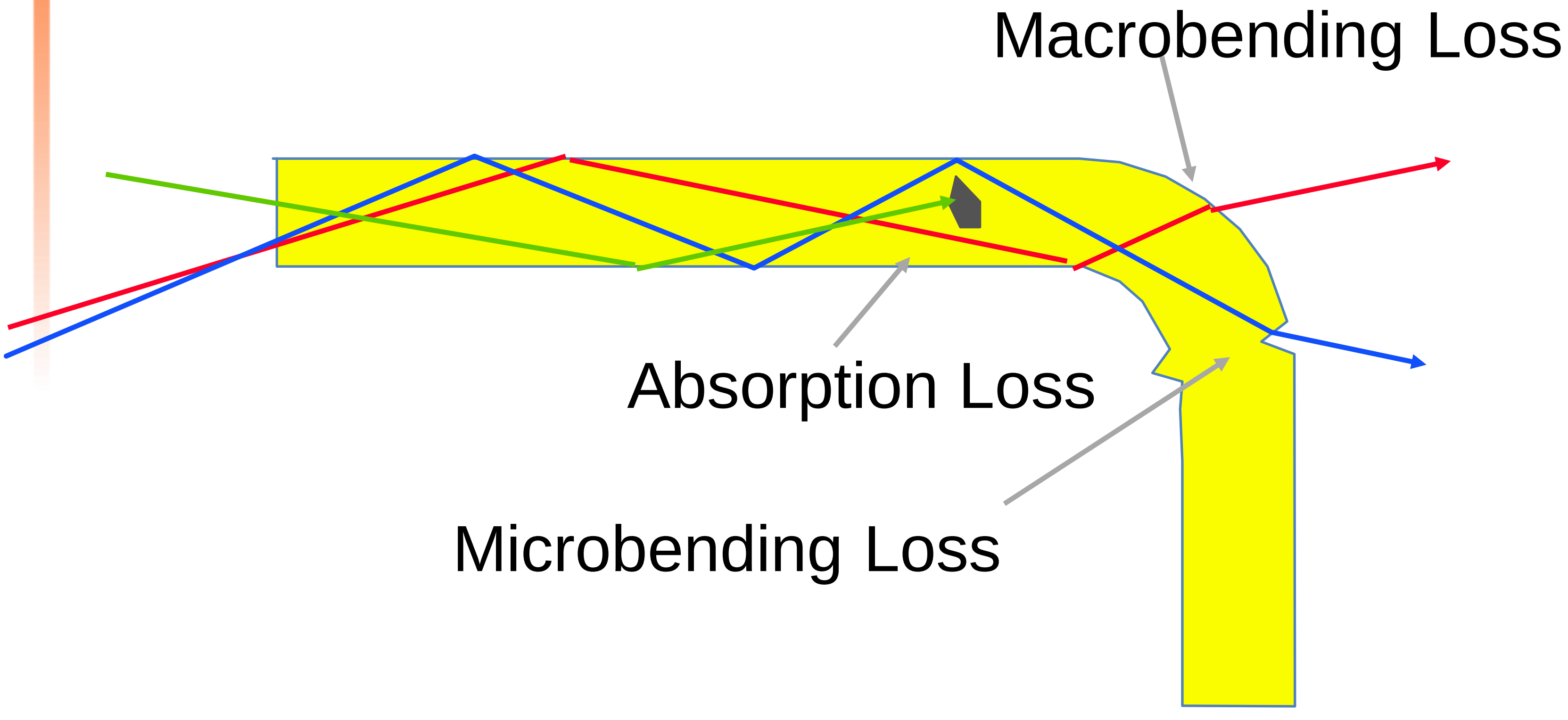
Microbending

Wavelength Dependent

Intrinsic to Fiber

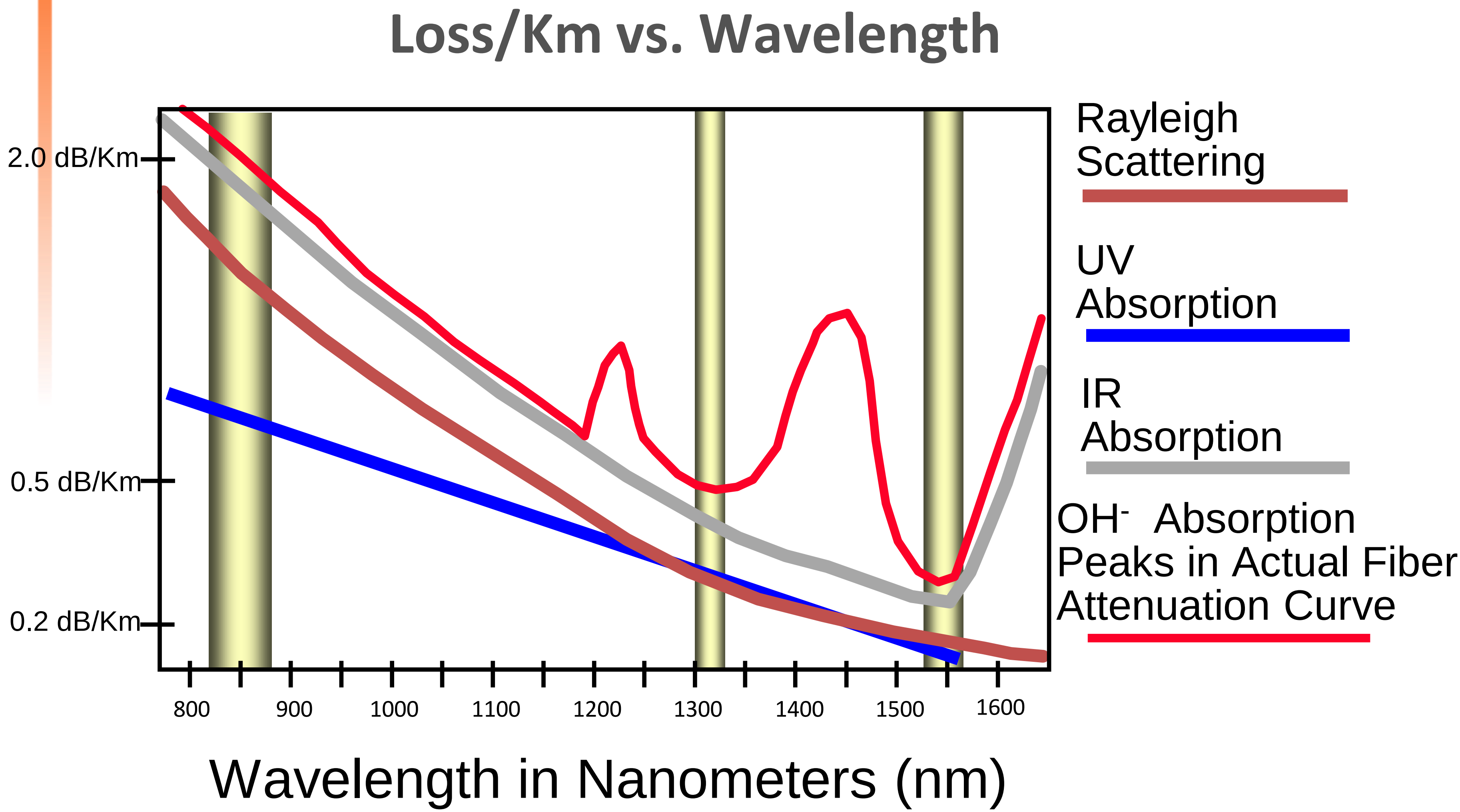
Caused by Molecular Structure

Attenuation in Fiber

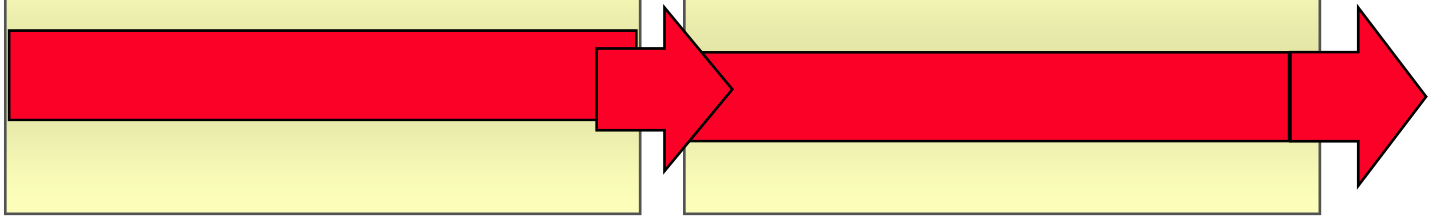


Note: Only the fiber core is shown.

Spectral Attenuation



Splice Loss Due to Core Mismatch



Off-center core in second fiber does not receive all the light from the first fiber. The amount of light lost is the Splice Loss.

Typical Splice Loss Values

Fusion: 0.05 to 0.20 dB

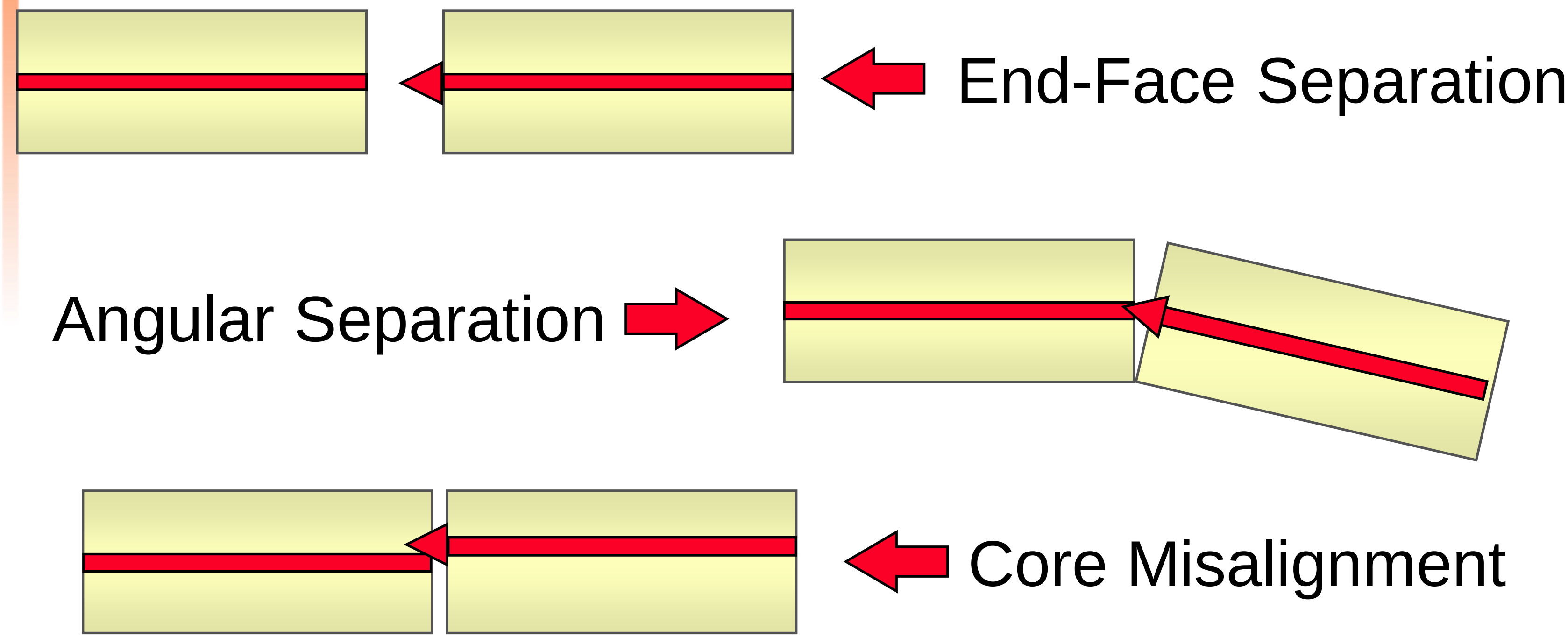
Mechanical: 0.10 to 0.50 dB

Splice Loss Depends on:

- *Quality of Fiber*
- *Craftsmanship*
- *Splicing Device Quality*

Causes of Connector Loss

Typical Loss = 0.5dB



Testing Fiber - Why?

Verify specs

Check handling

Measure work

Record best condition

- **Detect defects**
- **Locate faults**
- **Troubleshoot problems**

Testing Fiber - When?

At Factory

When Received

After Placed

After/During Splicing

- **System Acceptance**
- **Periodic (Annual)**
- **Troubleshooting**

Testing Fiber - What?

Continuity

Average Loss (dB/Km)

Splice Loss & Location

Reflectance / ORL

End-to-End Attenuation

Overall Length

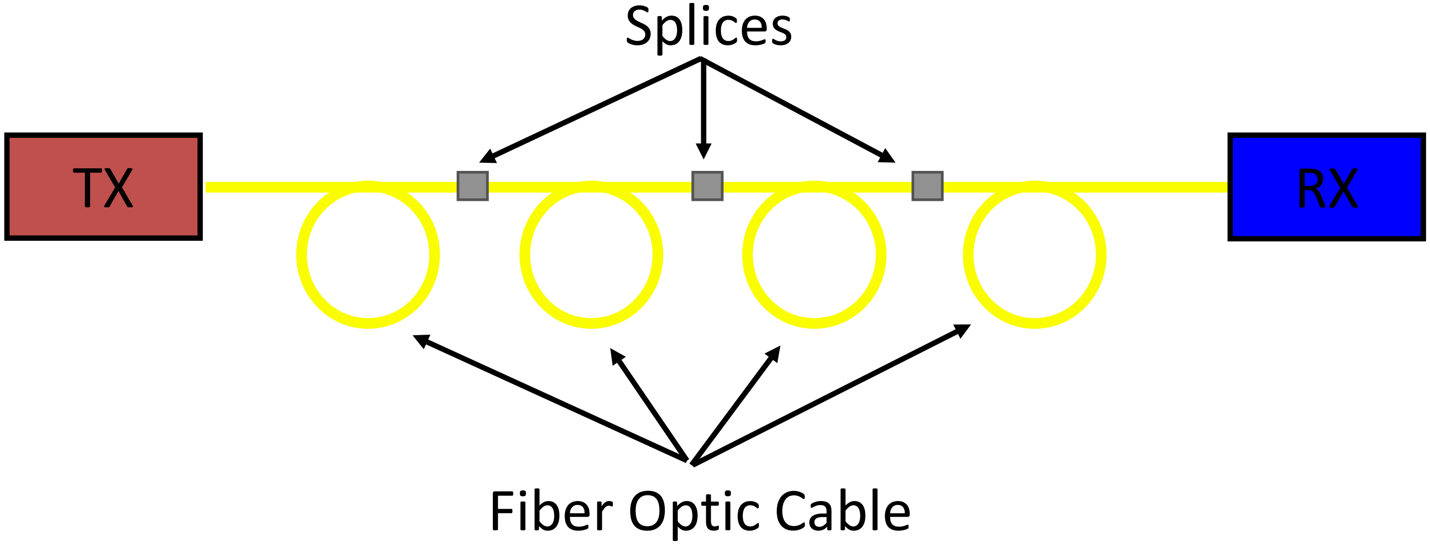
Testing Fiber - How?

Optical Power Meter

Optical Source

OTDR

Basic Fiber Optic Link



Optical Power Meter Applications

Measure TX Output

Measure Fiber Loss

Optimize Splices

ID Active Fibers

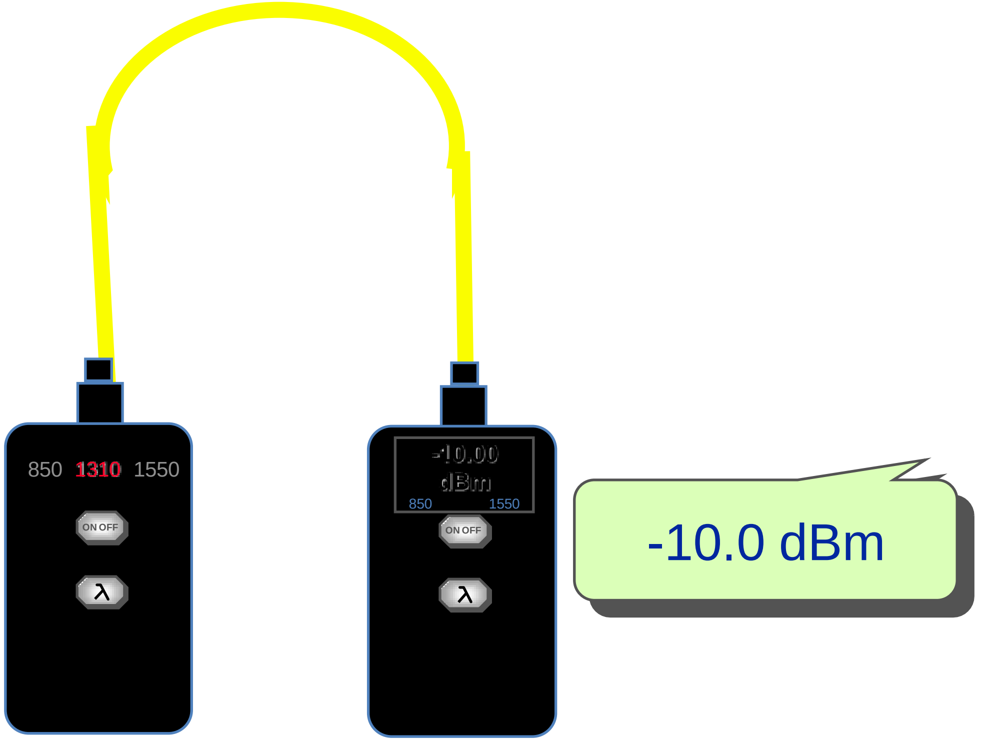
Optical Sources LED & LD

Standard Reference for Continuity

Stable Reference for Fiber & Component Loss

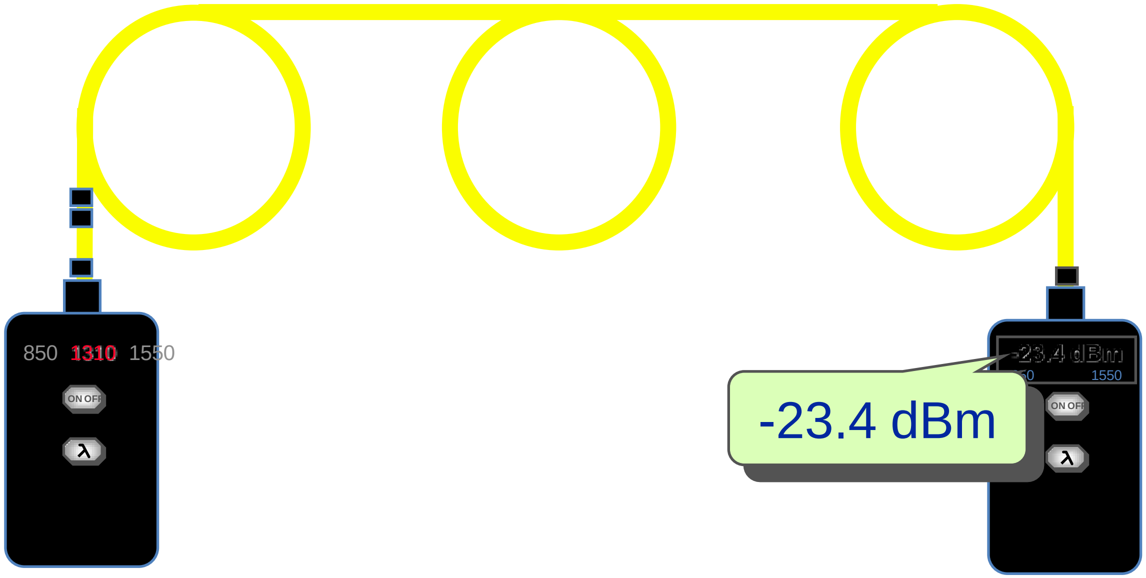
Optical Power Calculations

Step 1 - Take Reference (P1)



Optical Power Calculations

Step 2 - Read Fiber Output (P2)



Optical Power Calculations

Step 3 - Calculate Loss

End-End Loss = $P_1 - P_2$

Loss = -10.0 - (-23.4) = *13.4 dB*

The OTDR

Creates a graph of DISTANCE vs. RETURN SIGNAL LEVEL along fiber

Produces “Trace” or profile of signal level loss throughout the fiber

Uses radar principle to measure distance

OTDR Measurements

Locate End of Fiber (Fault Locate)

Measure End-to-End Loss

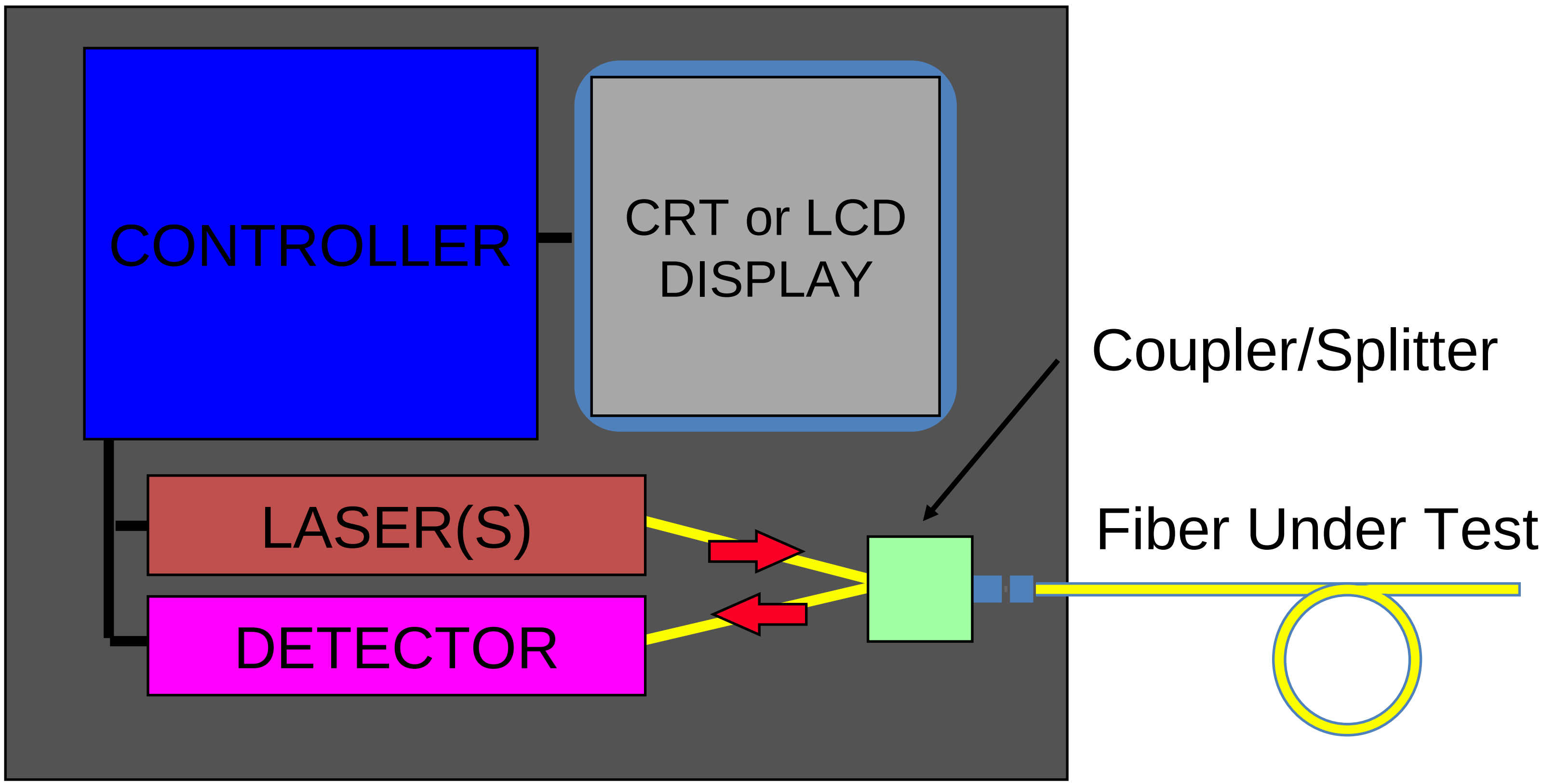
Locate Splices & Defects

Measure Splice & Defect Loss

Measure Splice & Connector Reflectance

Calculate Optical Return Loss

OTDR Block Diagram



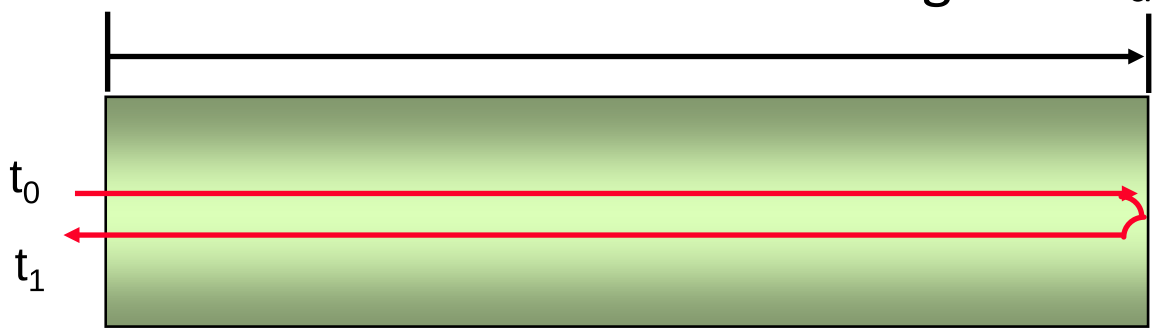
OTDR Distance Measurements

$$d = \frac{t\,C}{2\,n}$$

"C" = speed of light "n" = Index

If "n" is incorrect, then the distance measured will also be wrong!!

"d"



"t" = $t_1 - t_0$

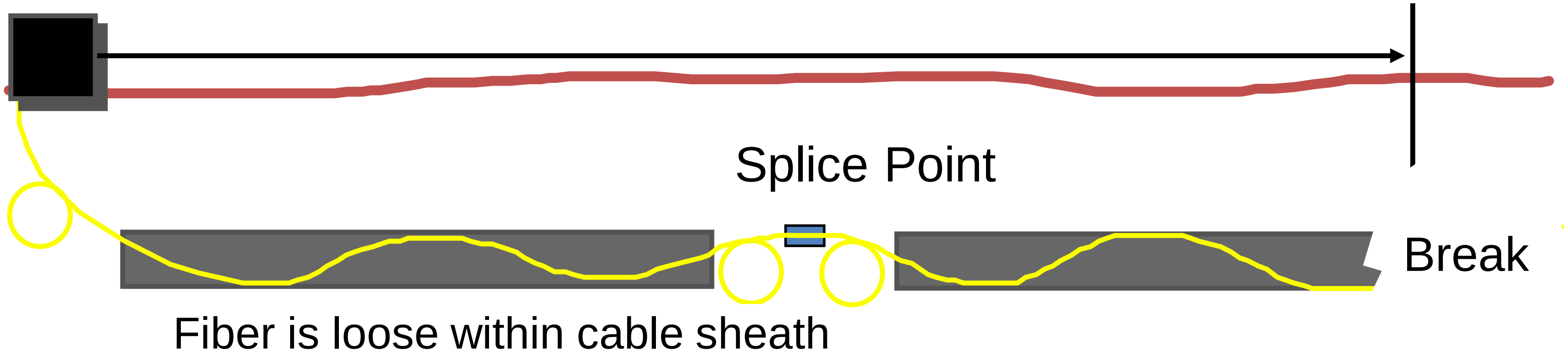
Speed of Light in a Vacuum is: 299,792,460 meters per second.
Speed of Light in a Vacuum is: 186,287.5 miles per second.

Index of Refraction (IOR) Table

Manufacturer		1310nm	1550nm
AT&T	Normal	1.4659	1.4666
	Disp.Shifted	1.4743	1.4750
Corning	SMF-21	1.4640	1.4640
	SMF-28	1.4700	1.4700
	Disp.Shifted	1.4760	1.4760

OTDR Distance Measurements

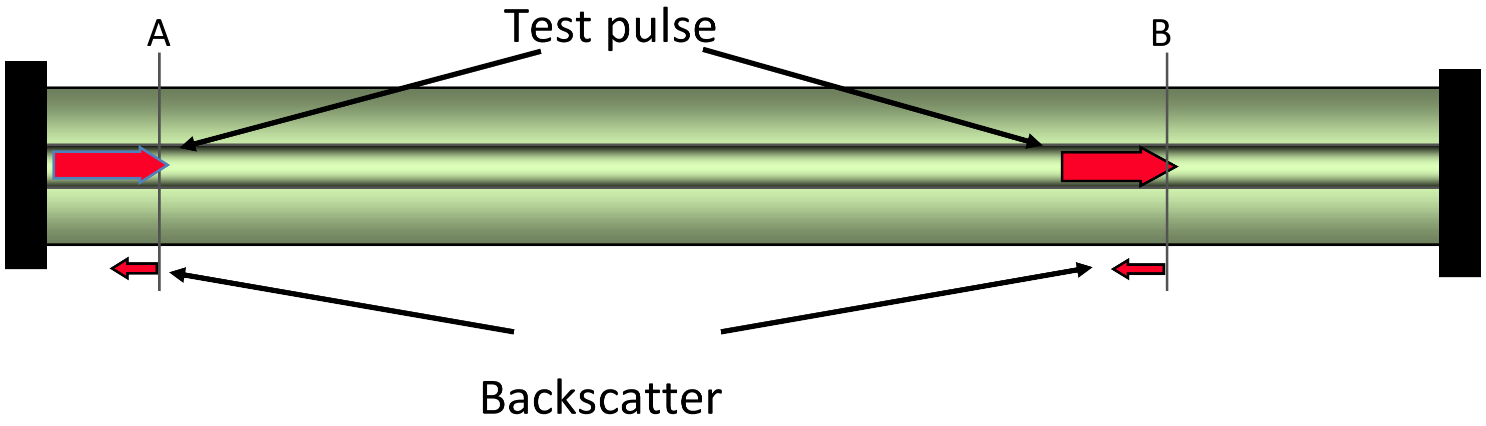
- Index of Refraction set correctly for fiber being tested
- Fiber length versus sheath length (approx. 2%) - Helix factor
- Sheath length versus ground distance need to compensate for loops & slack in fiber & cable
- Measure from closest known event on fiber to break
- Set OTDR's resolution as high as possible



OTDR Loss Measurements

- OTDR measures BACKSCATTER and REFLECTIONS
- Compares BACKSCATTER levels to determine loss between points in fiber
- Splice losses determined by amount of shift in backscatter
- Reflection & ORL measurements determine the reflective quality of link components and connectors.

OTDR Loss Measurements



Backscatter is directly related to the level of light in the test pulse. As the level of light in the pulse width decreases with distance, so does the backscatter it produces.

Using an OTDR

Setup Measurement Parameters

Gather Data (Scan Fiber)

Analyze Data (Interpret Trace)

Document Results (Print or Store)

OTDR Setup

Select Wavelength

850nm or 1300nm (MM),

1310nm or 1550nm (SM)

Select Pulse Width*

10ns to 20,000ns

Select Range*

Must be longer than fiber length by 25%

Select Resolution*

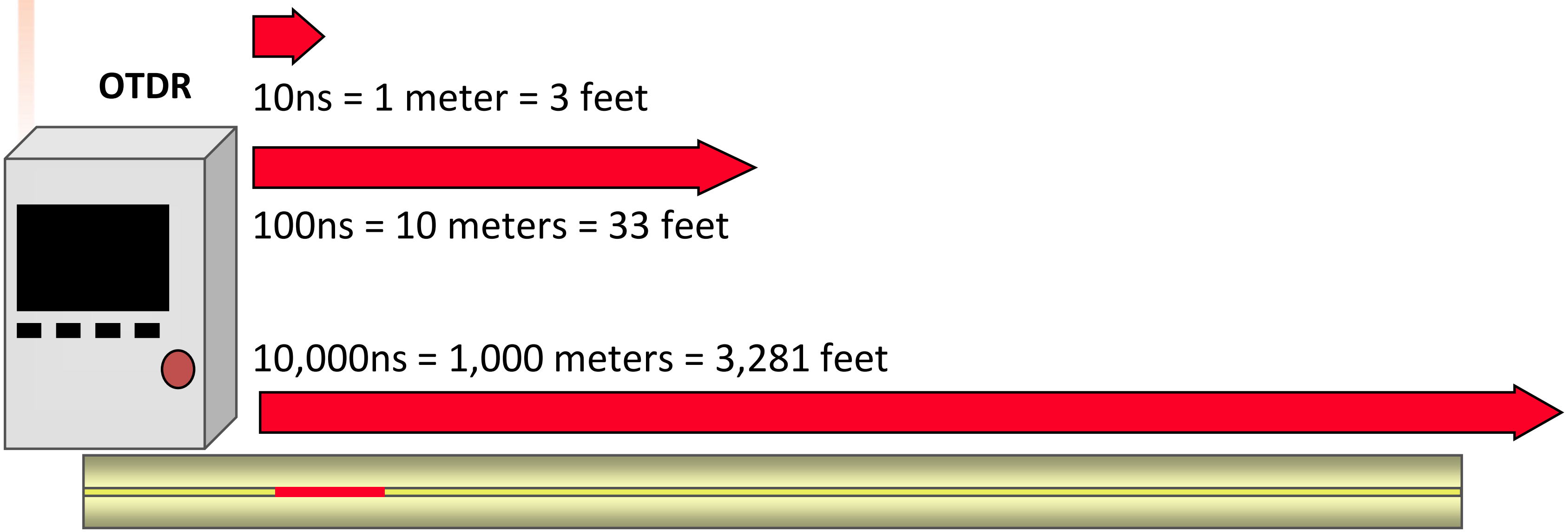
From 0.25 to 16 meters (1 to 50 feet)

Select Amount of Averaging

Timed, Fast, Medium or Slow

Pulse Width

The laser in the OTDR is pulsed. The laser is turned on for a precise length of time. Time is distance. Turning the laser on for 10 ns, will fill up 1 meter or 3 feet of fiber with light. The longer the laser is turned on, the longer the pulse of light traveling through the fiber. Longer pulses occupy longer physical distances in the fiber.



Only one test pulse is allowed in the fiber at any time.

Gathering Data

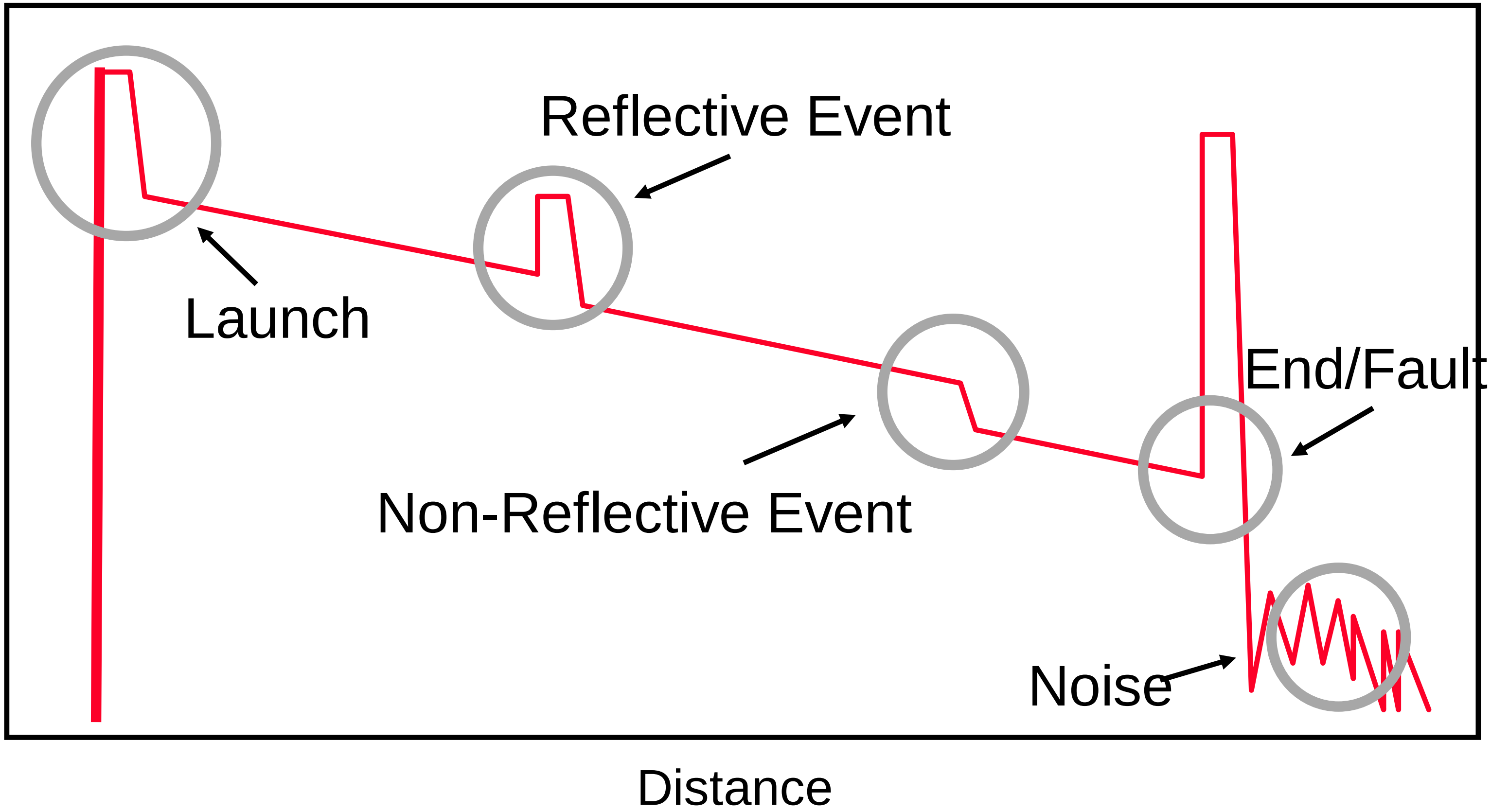
Connect Fiber to Test Port

Press TEST or REAL TIME Key

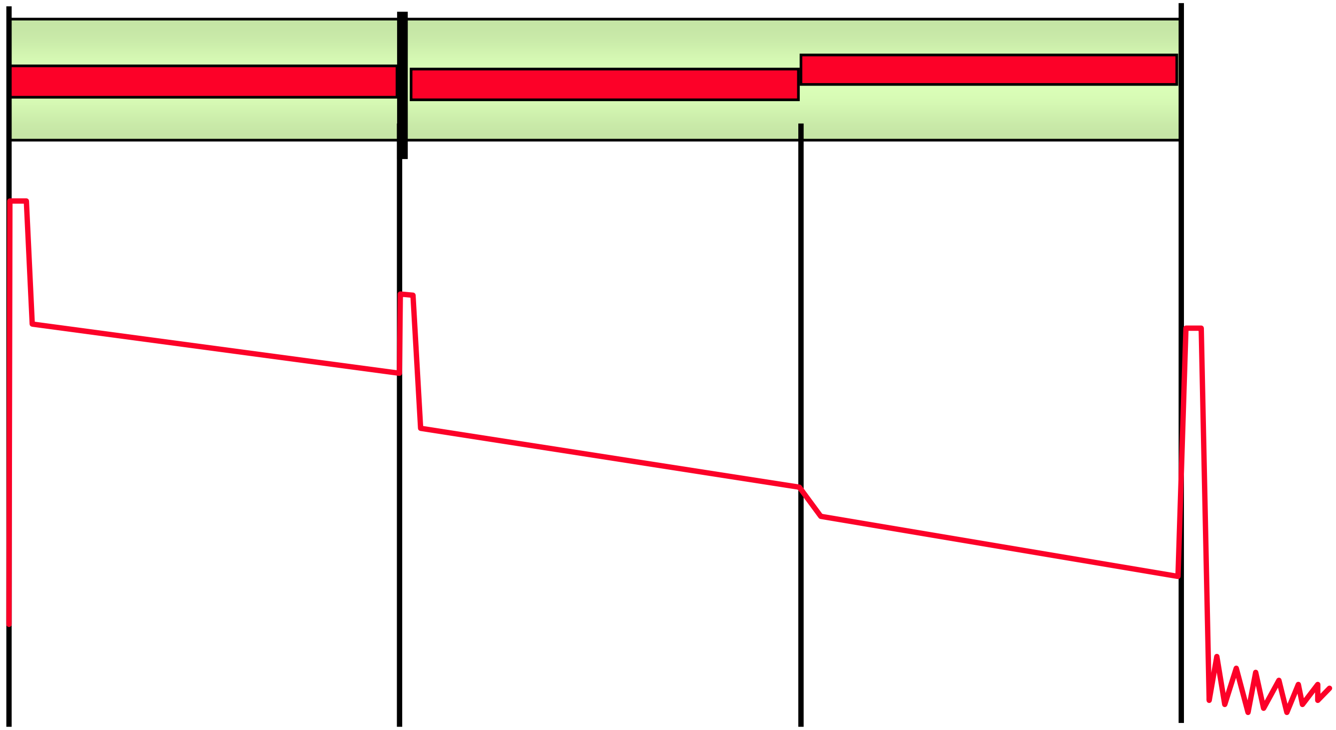
or

Press FAULT LOCATE Key

OTDR Trace Basics



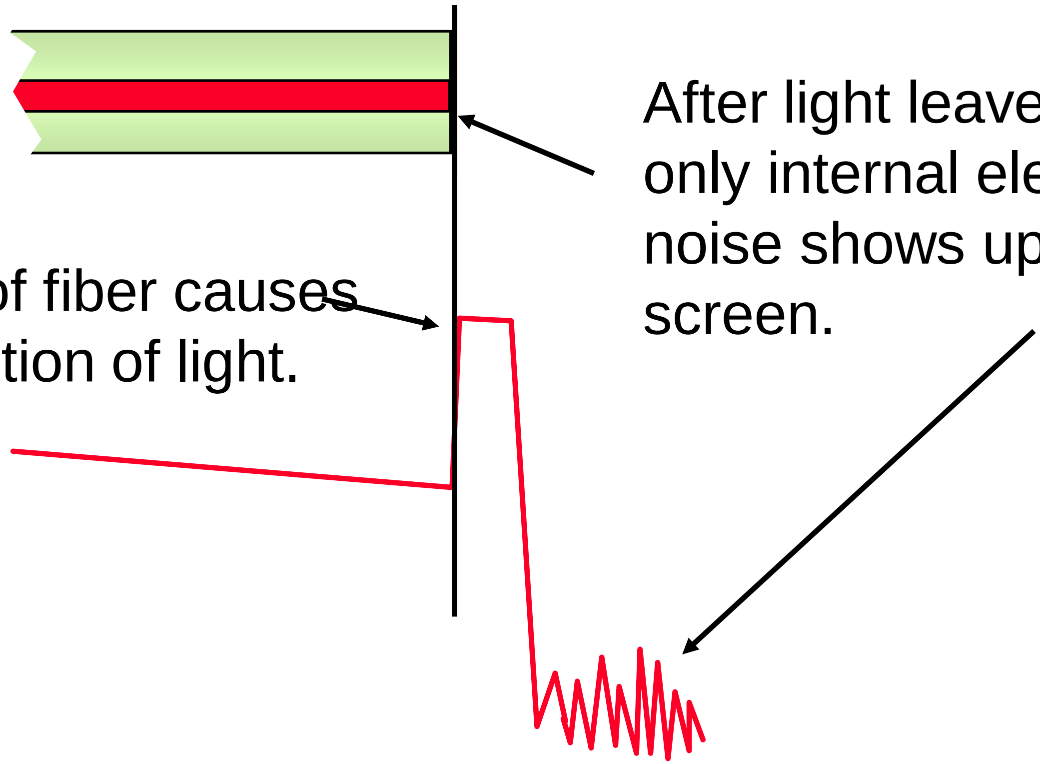
OTDR Trace Features



Interpreting Results

- Locate Fiber End
- Locate Splices & Defects ("Events")
- Measure Overall Loss
- Measure Event Loss
- Measure Reflections & ORL

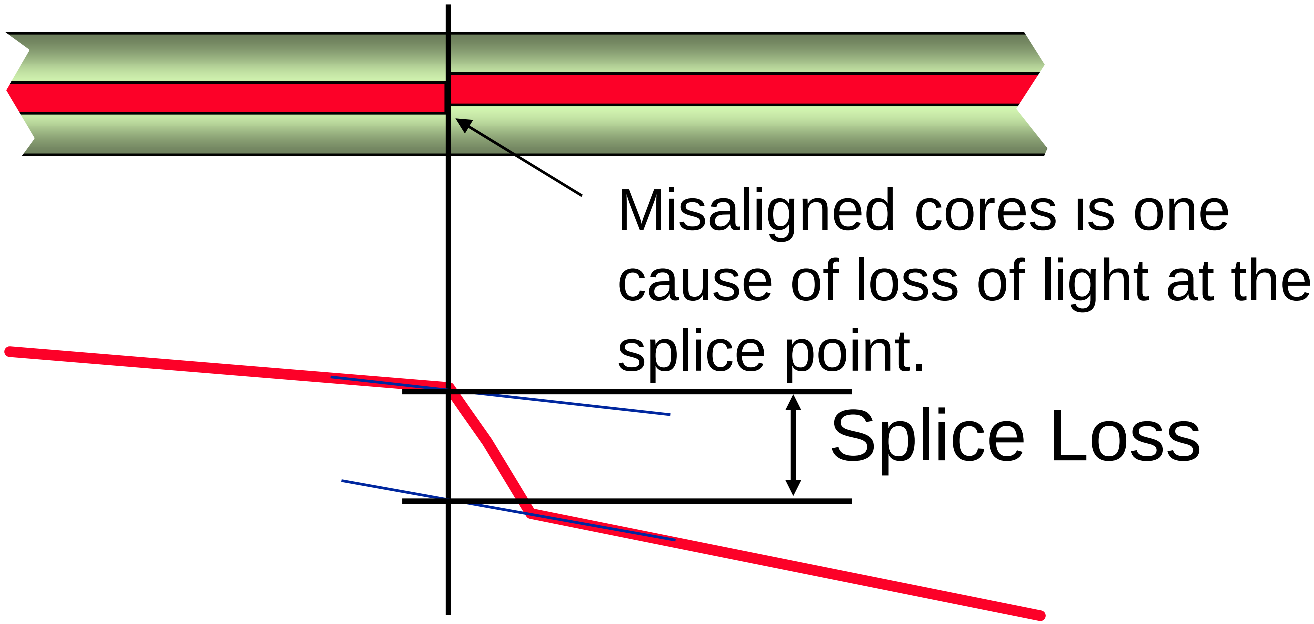
Locating End of Fiber



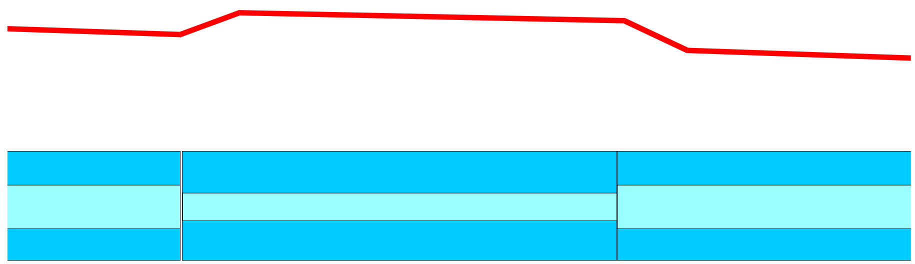
After light leaves fiber end, only internal electronic noise shows up on OTDR screen.

End of fiber causes reflection of light.

Locating & Measuring Non-Reflective Event



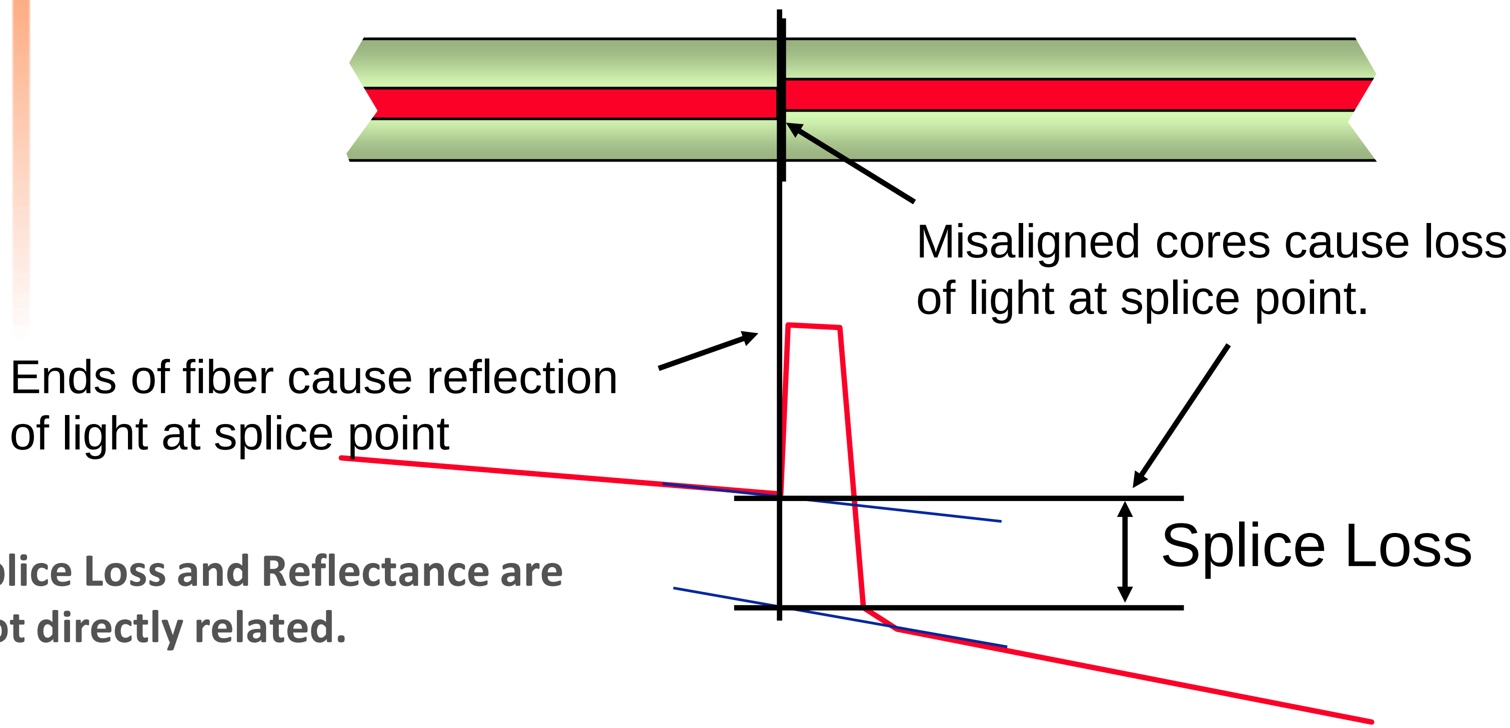
Gainers and Losers



$$\text{Total Backscatter} = -10 \log \left(\frac{W1}{W2} \right)^2 \text{dB}$$

W1 - field radii of initial fiber
W2 - field radii of following fiber

Locating & Measuring Reflective Event



Splice Loss and Reflectance are not directly related.

Reflection Magnitude Factors

What Creates A Big Reflection?

90º or Angled End Face

cleaved or crushed

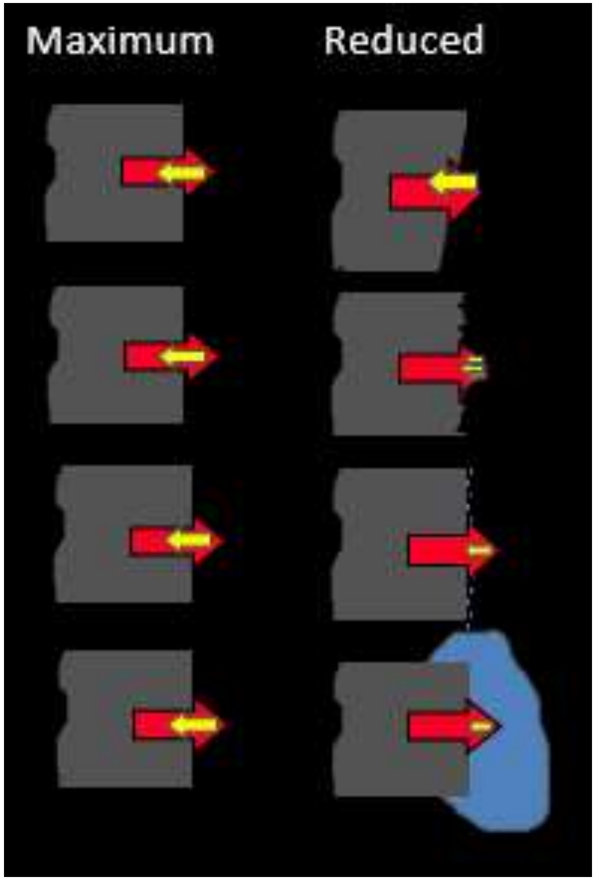
Smooth or Rough Surface

polished or scratched

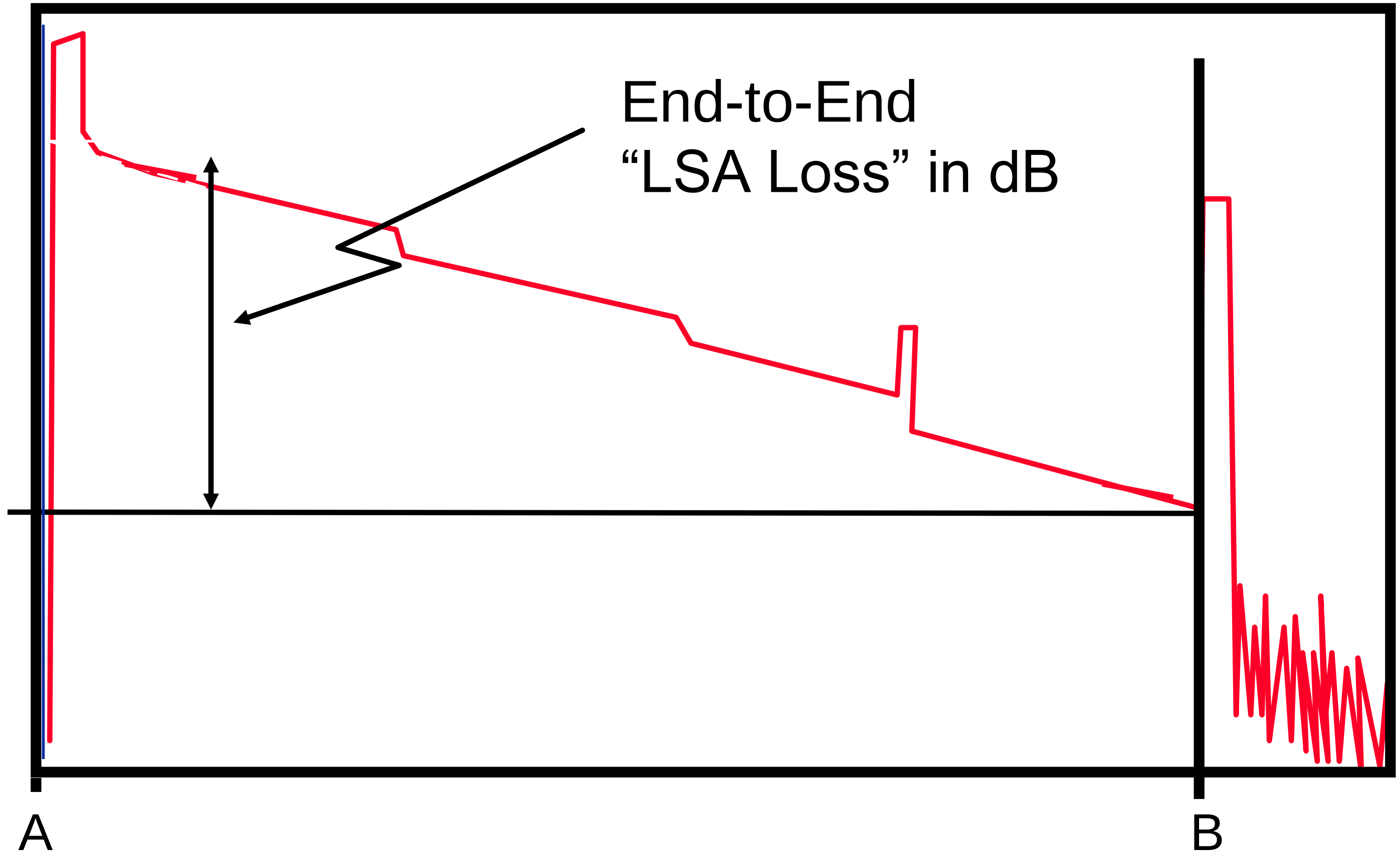
Clean or Dirty End Face

Glass-Air or Glass-xxx

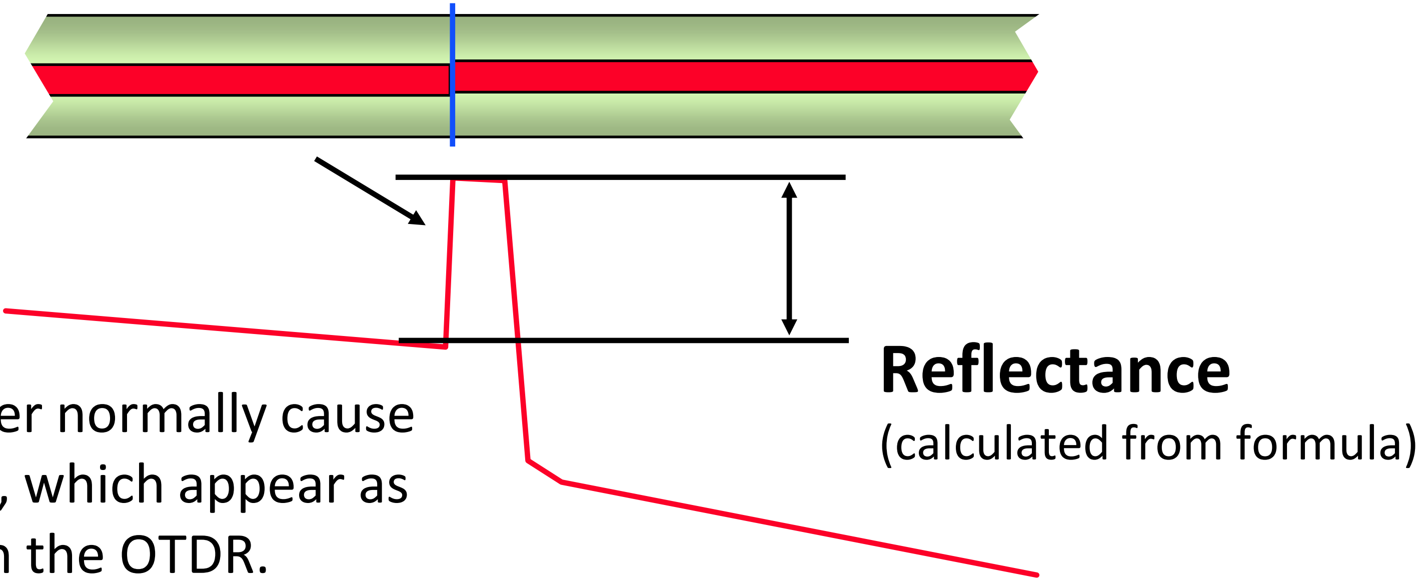
connectorized or in water/oil



Measuring Overall Loss

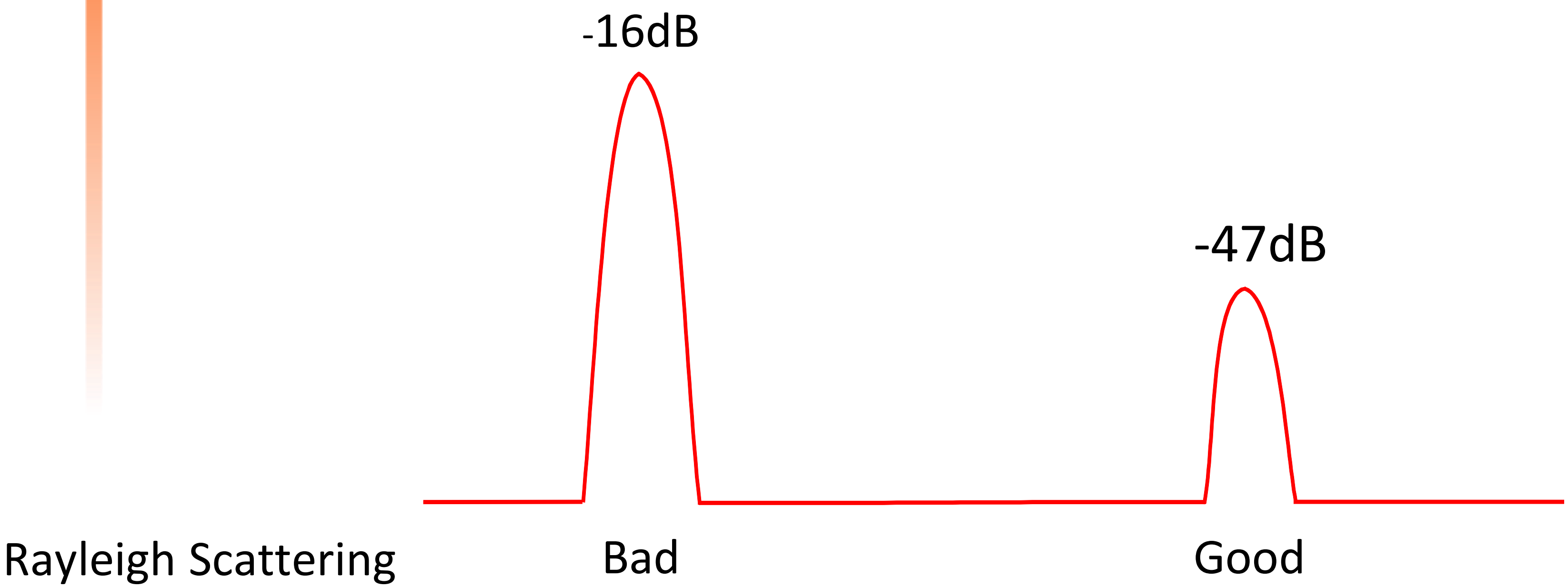


Measuring Reflectance



Ends of fiber normally cause reflections, which appear as “spikes” on the OTDR.

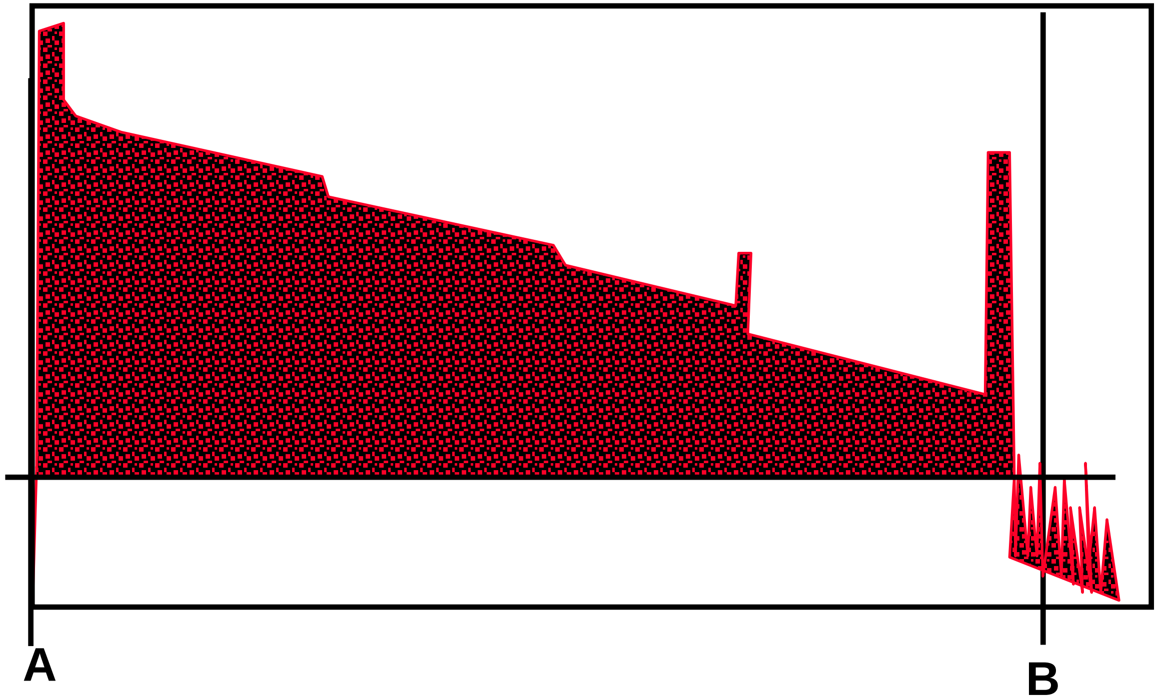
Reflections Are Negative



Reflections are measured from the receiver's point of view. Reflected light is power lost to the receiver and is therefore a negative number.

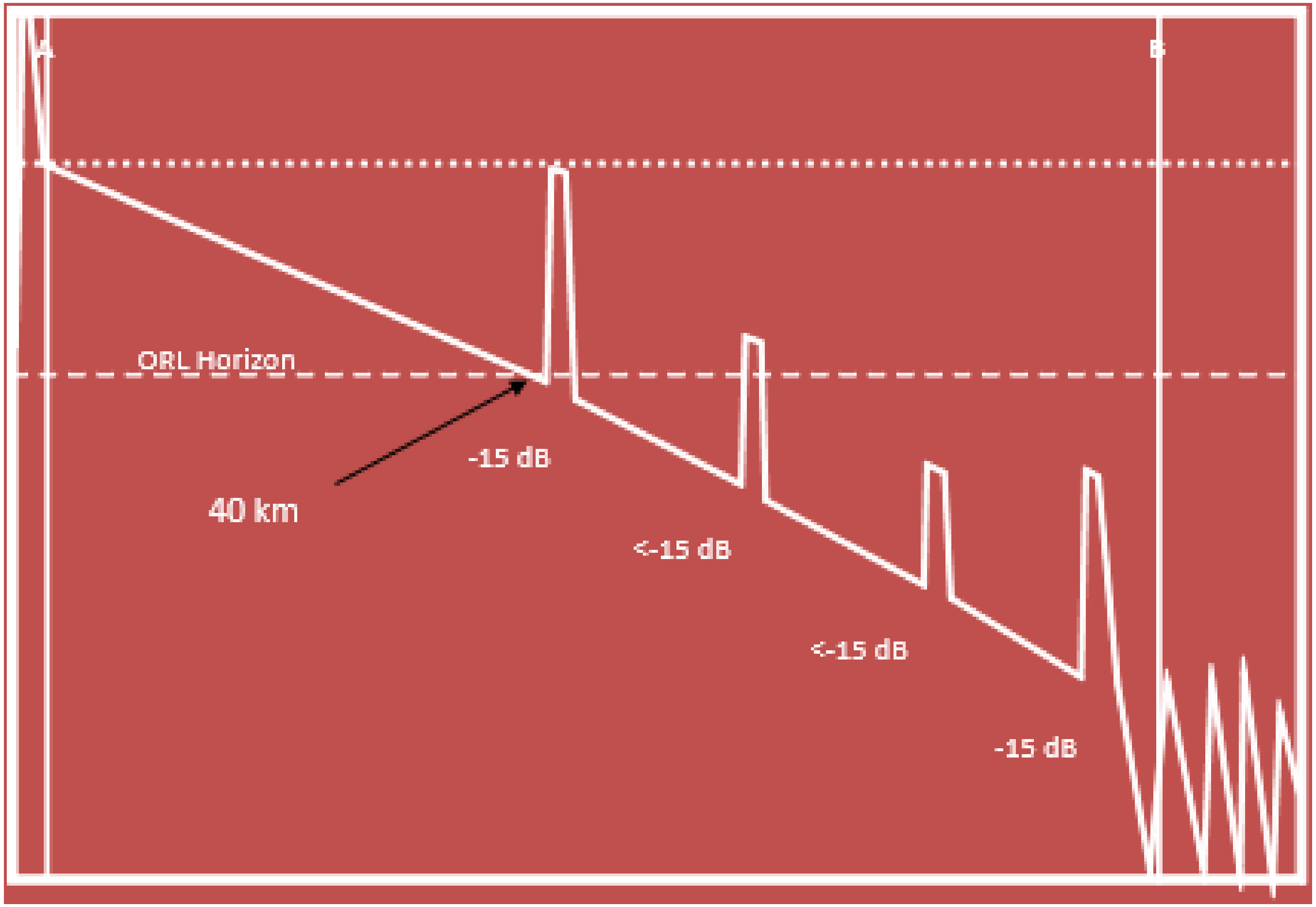
Measuring "ORL"

Optical Return Loss



ORL is looked at from the transmitter's point of view. It is the total power returned to the transmitter from the fiber link and is typically expressed in dB. It includes the total Backscatter and all Reflections.

ORL Measurement Horizon



Reflections returning from farther than 40km will have not effect on the stability of the transmitter. Accurate ORL measurements do not require measuring to the end of a 150 km link. Only the first 40 km matter.

OTDR Choices & Tradeoffs

Wavelength:
Distance & Stress Detection

Pulse Width:
Dead Zones vs. Dynamic Range

Data Point Spacing:
Testing Times vs. Resolution

Cost:
Price vs. Performance

Wavelength

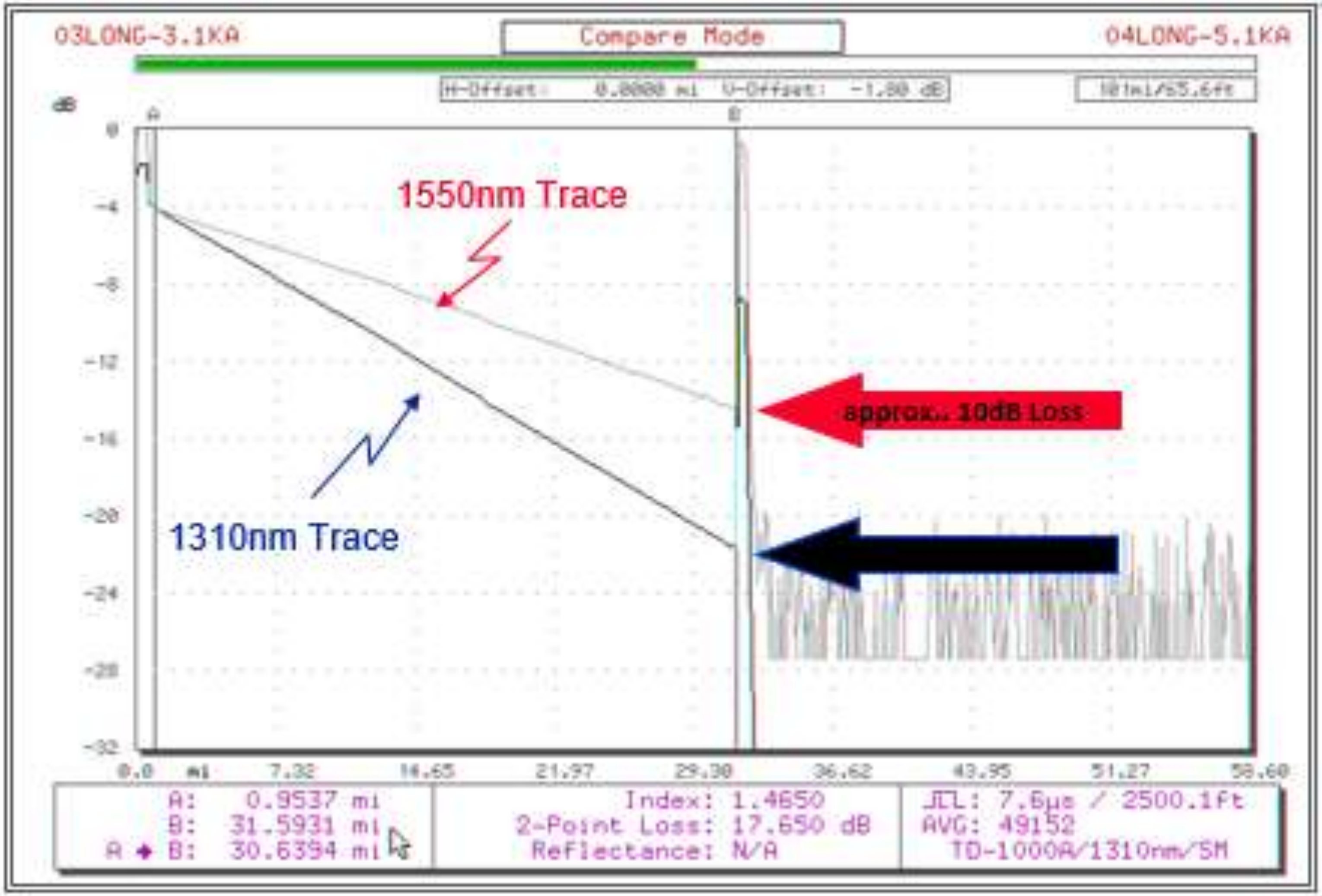
Longer Wavelengths Have Lower Loss
Scattering loss is lower

Longer Wavelengths Have Higher Loss
Bending loss is higher

Compare Tests At Two Wavelengths
To determine differences

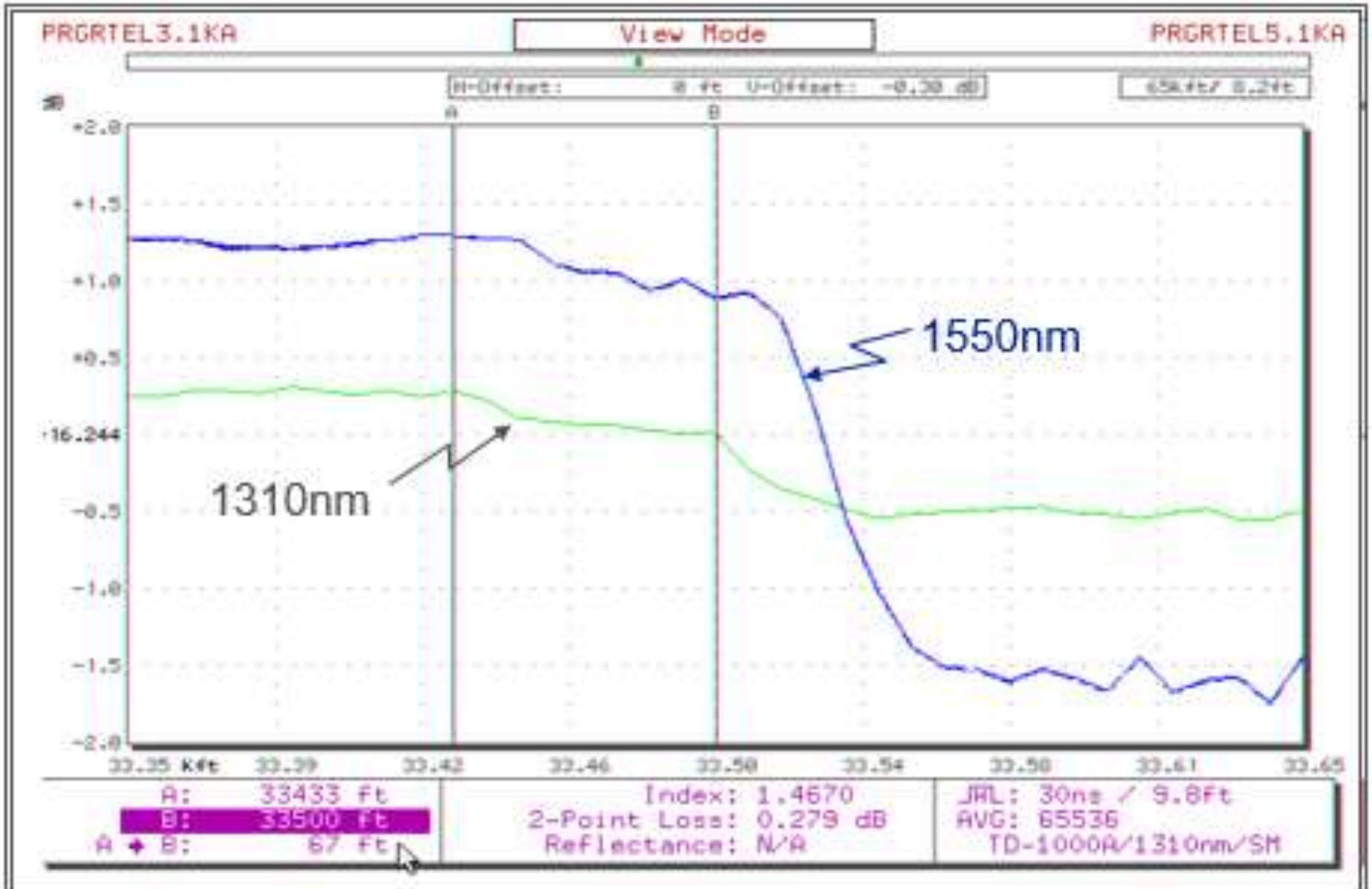
Wavelength

Scattering Loss Difference



Wavelength

Bending Loss Difference



Dead Zones

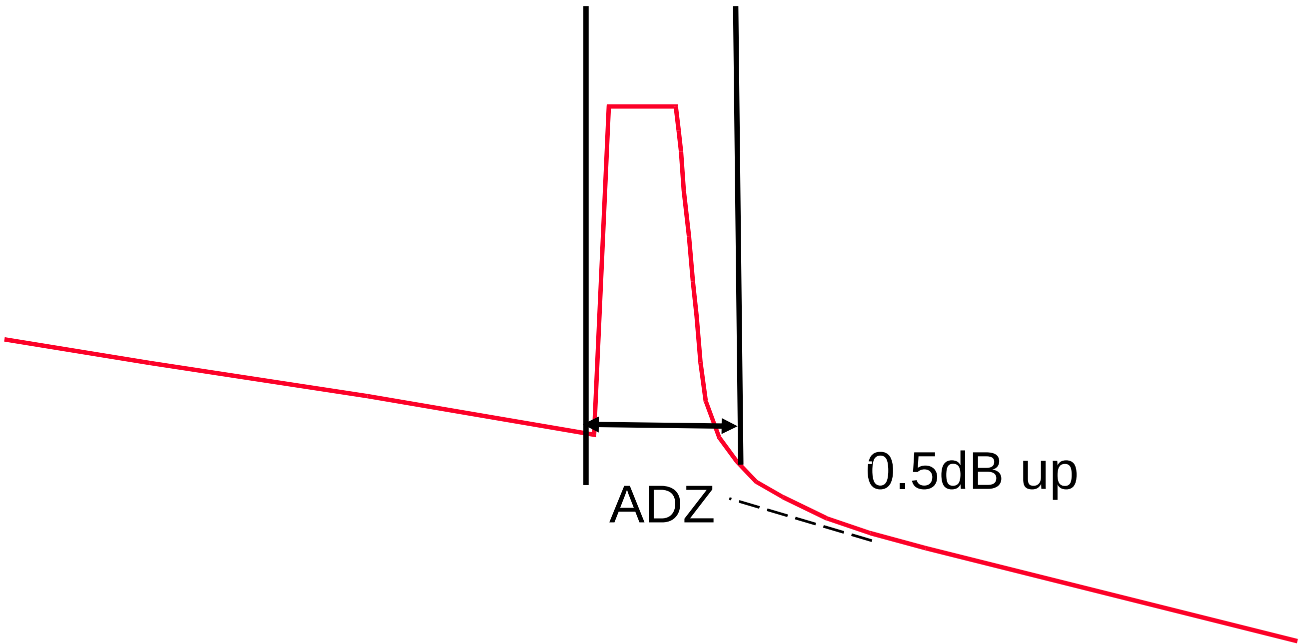
Specified as a DISTANCE

Determines how CLOSE to OTDR you can detect and measure a splice loss

Determines how CLOSE TOGETHER two events (splices) can be measured

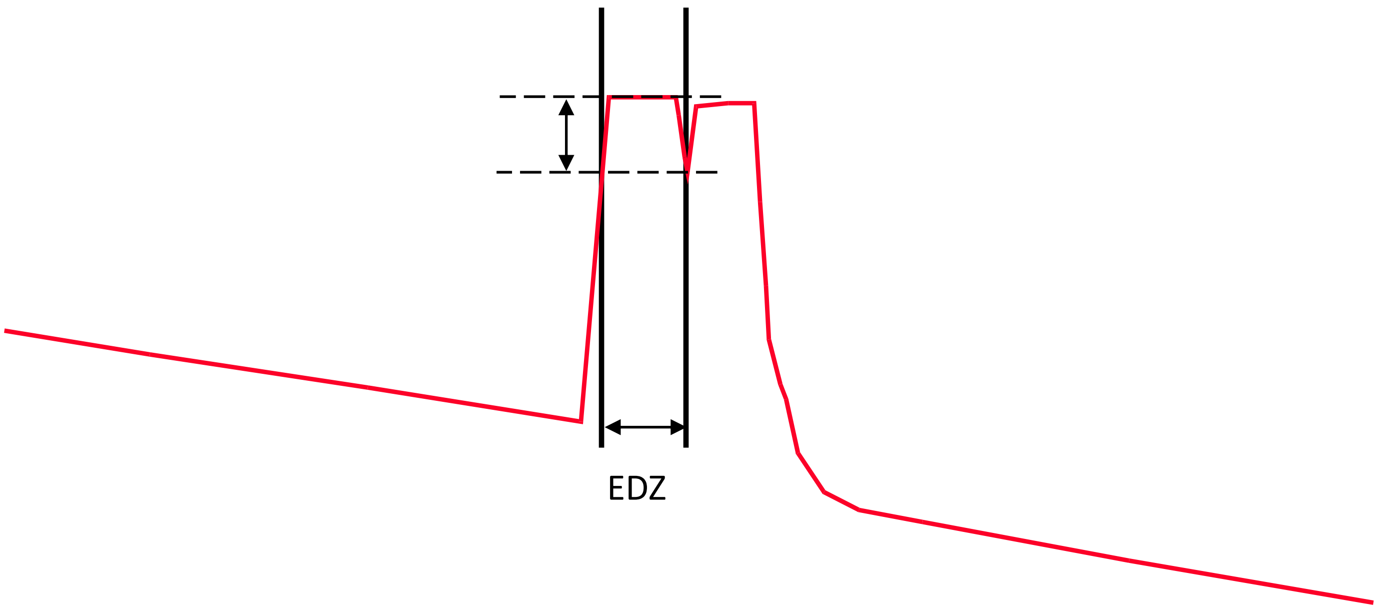
Directly related to PULSE WIDTH: larger pulse widths produce larger dead zones

Attenuation Dead Zone



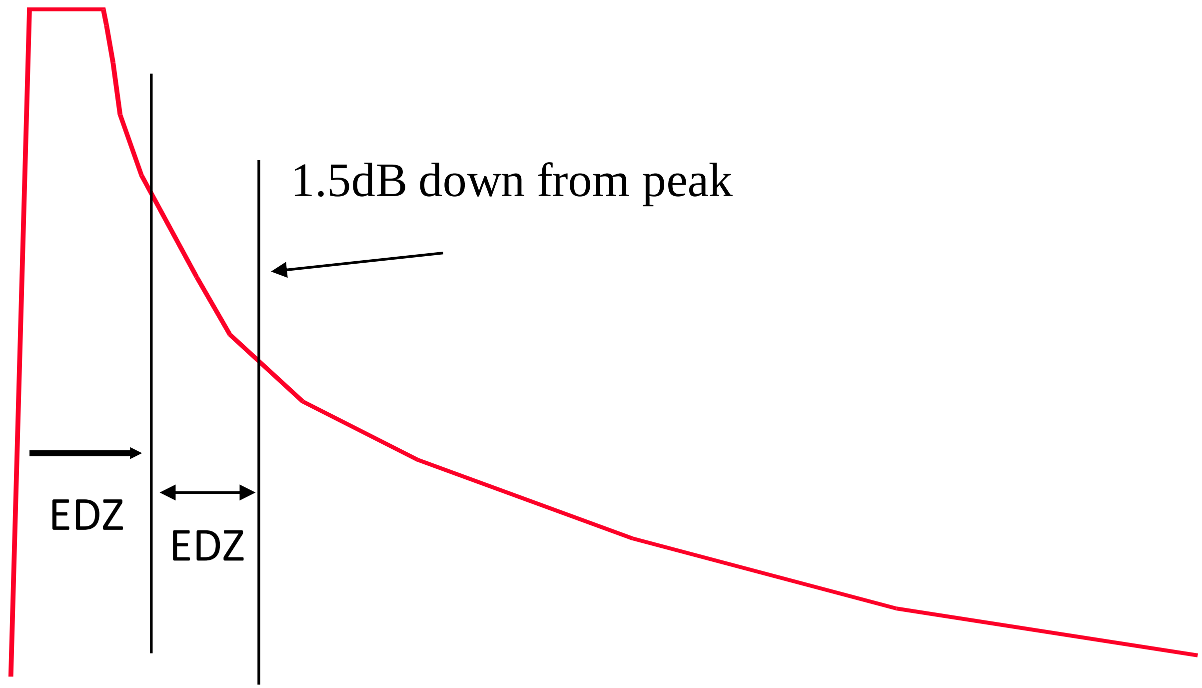
The distance of the Attenuation Deadzone is from the start of a reflective event until <u>0.5dB up from the backscatter level</u> after the reflection.

Event Deadzone



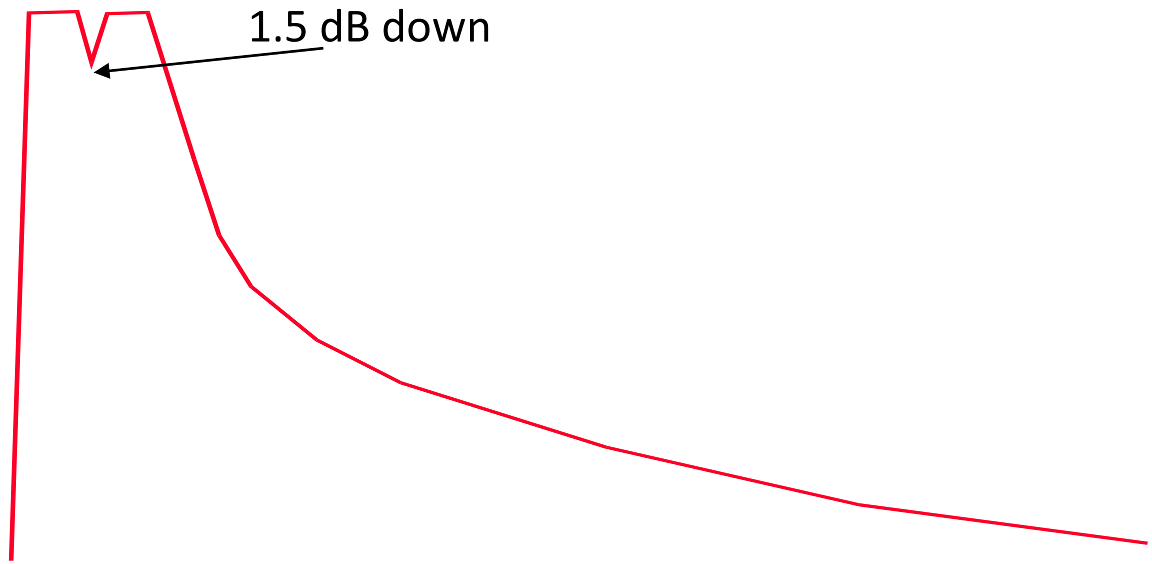
An Event Deadzone is the distance between two points 1.5 dB below the peak of a reflective event.

Initial Event Deadzone



An OTDR's Initial Event Deadzone will have this appearance without a fiber connected to the OTDR.
When the OTDR is connected to a fiber at the patch panel and this trace is displayed, what then?

Initial Event Deadzone



However, should the OTDR display the trace above when connected to a fiber at the patch panel, it can easily be seen that there are two events. The first is at the OTDR, the second is where the fiber is broken.

Dynamic Range

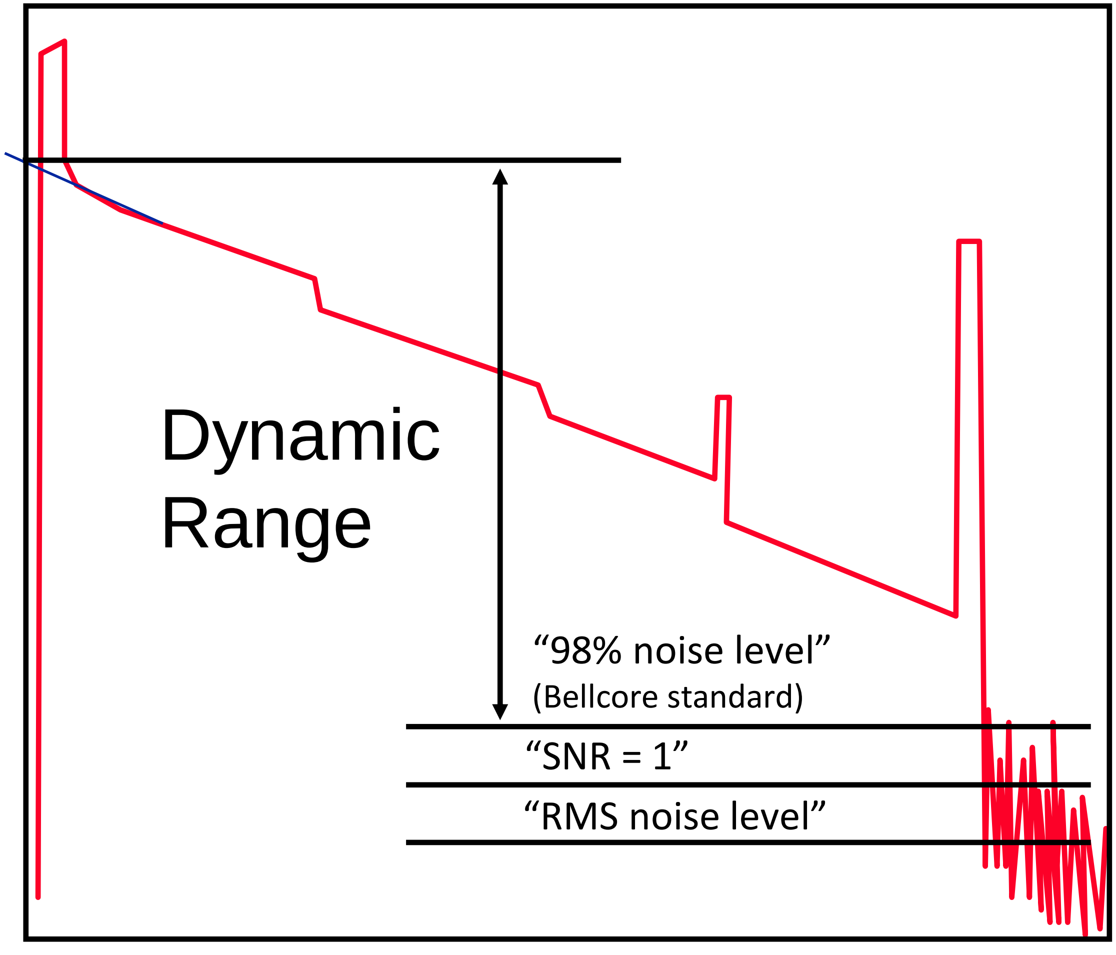
Measured in dB. Typical range is 30-40dB

Describes how much loss an OTDR can measure in a fiber, which in turn describes how long of a fiber can be measured

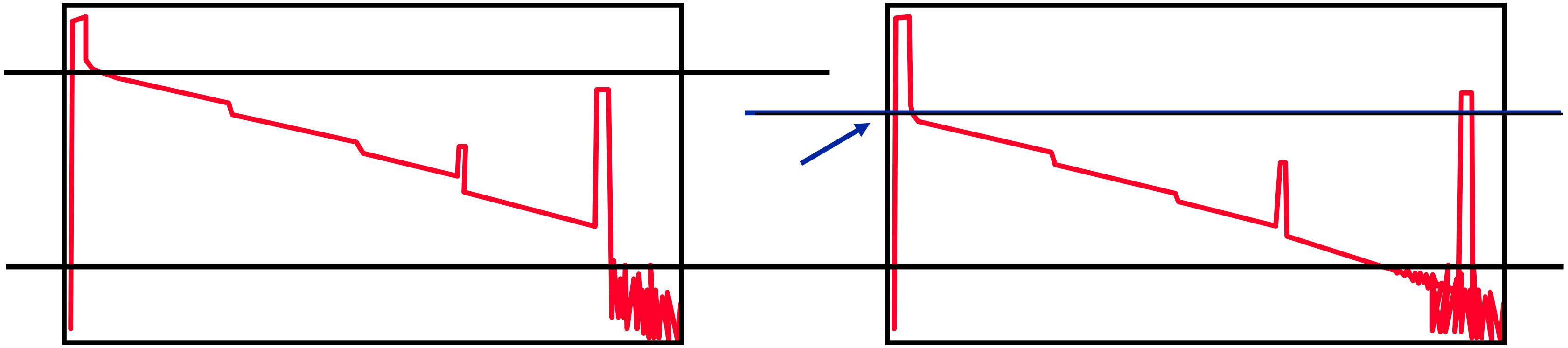
Directly related to Pulse Width: larger pulse widths provide larger dynamic range

Increase by using longer PW and by decreasing noise through averaging

Dynamic Range



Dynamic Range Effects



Dynamic Range OK to measure entire fiber.

Insufficient Dynamic Range due to low launch level at start of fiber.

Resolution

Described as a DISTANCES

Two Types:

(1) Data Point Spacing ("DPS")

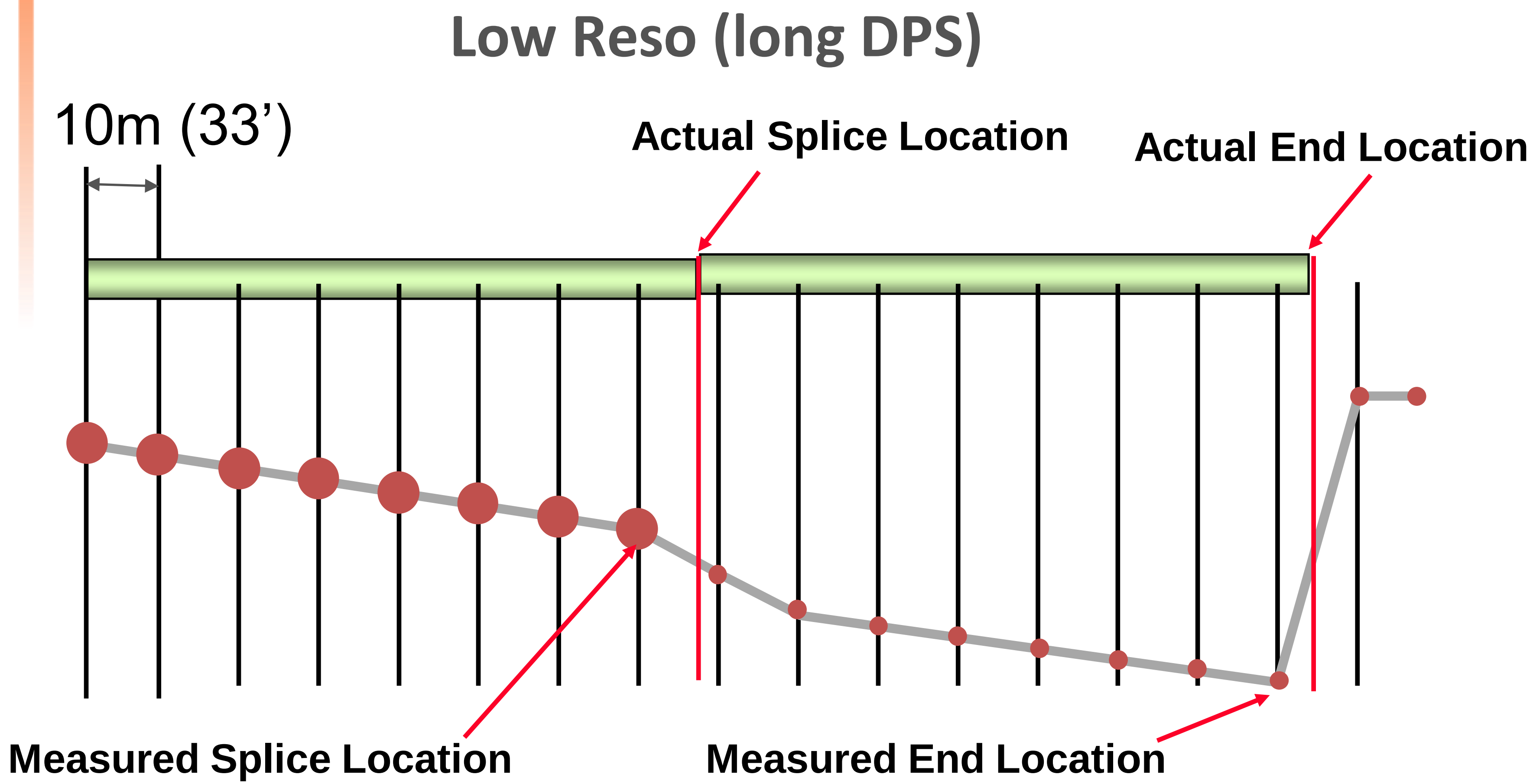
(2) Spatial Resolution (from Dead Zones)

Determines:

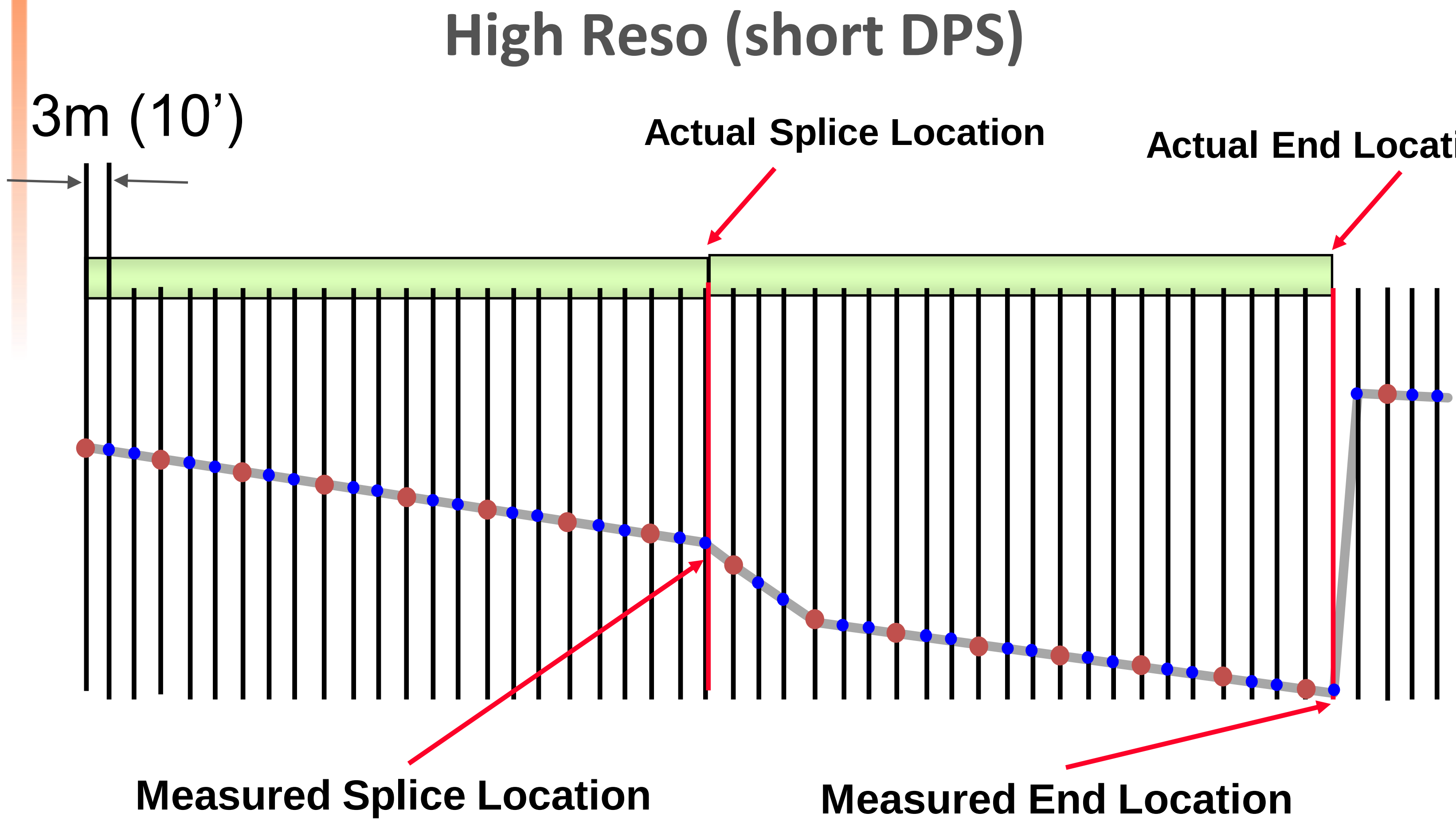
(1) accuracy of event location

(2) if you can measure two closely-spaced splices in the fiber

Data Point Resolution

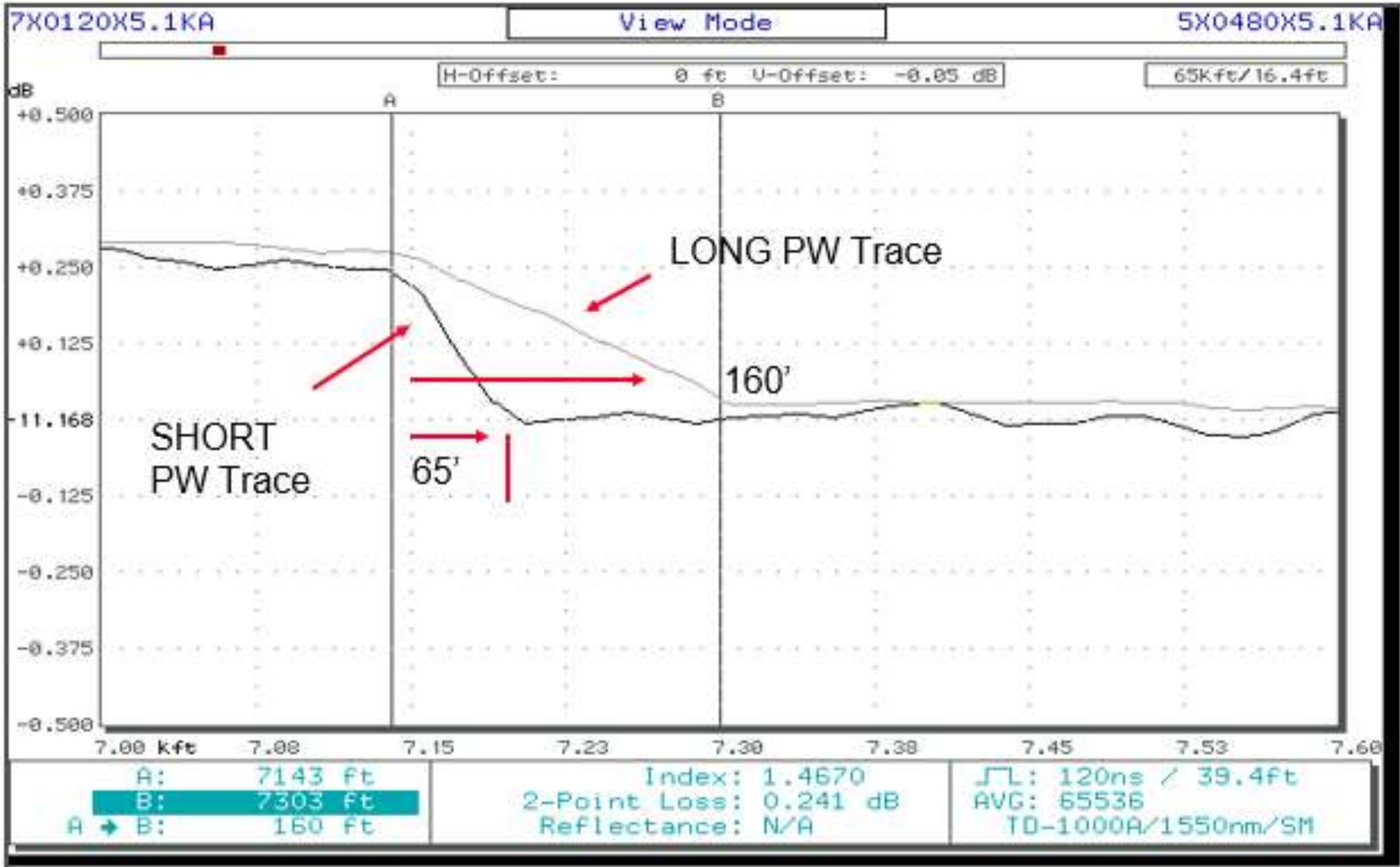


Data Point Resolution



Spatial Resolution

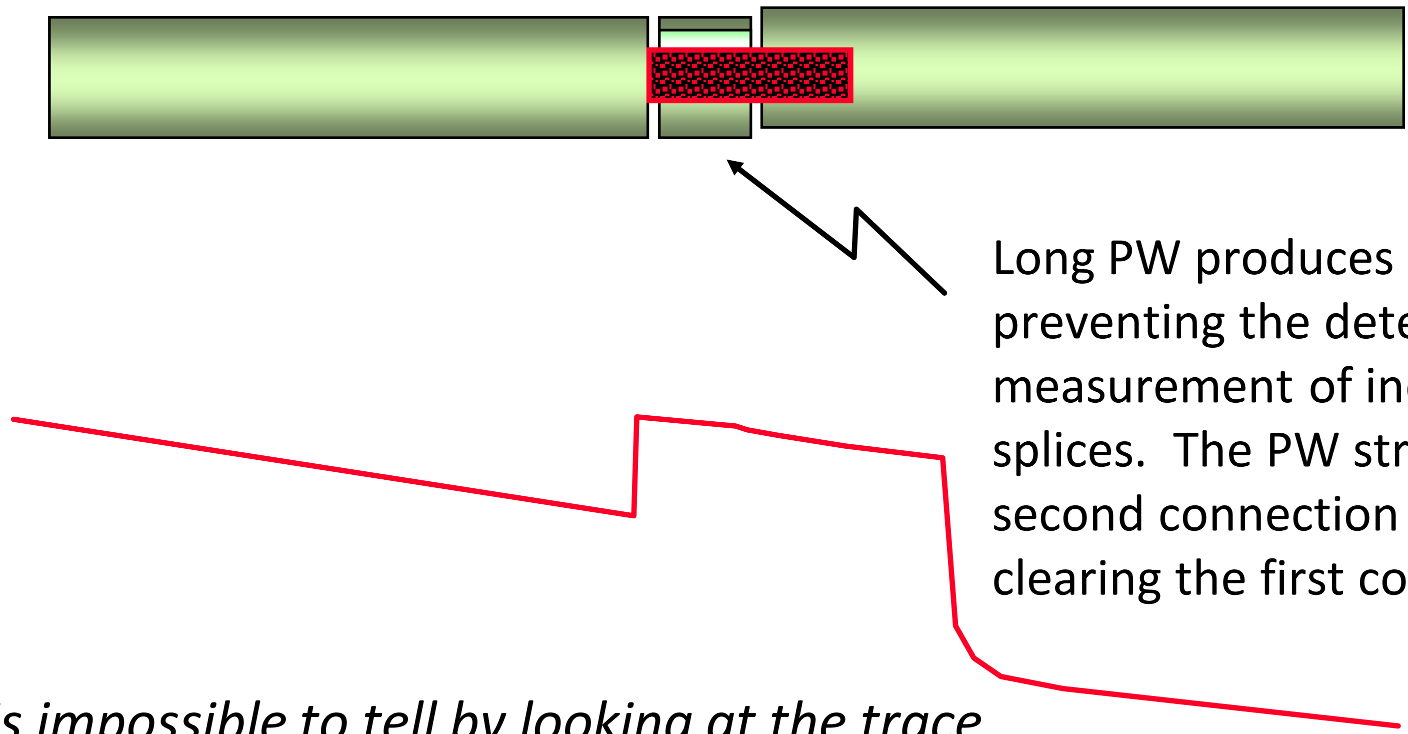
Long vs. Short Pulse Widths



Long Pulse Width takes longer to make the transition from backscatter of first fiber to backscatter of second fiber. Short Pulse Width makes a sharper transition.

Spatial Resolution

Dead Zone Effects From Using *Long* Pulse Width

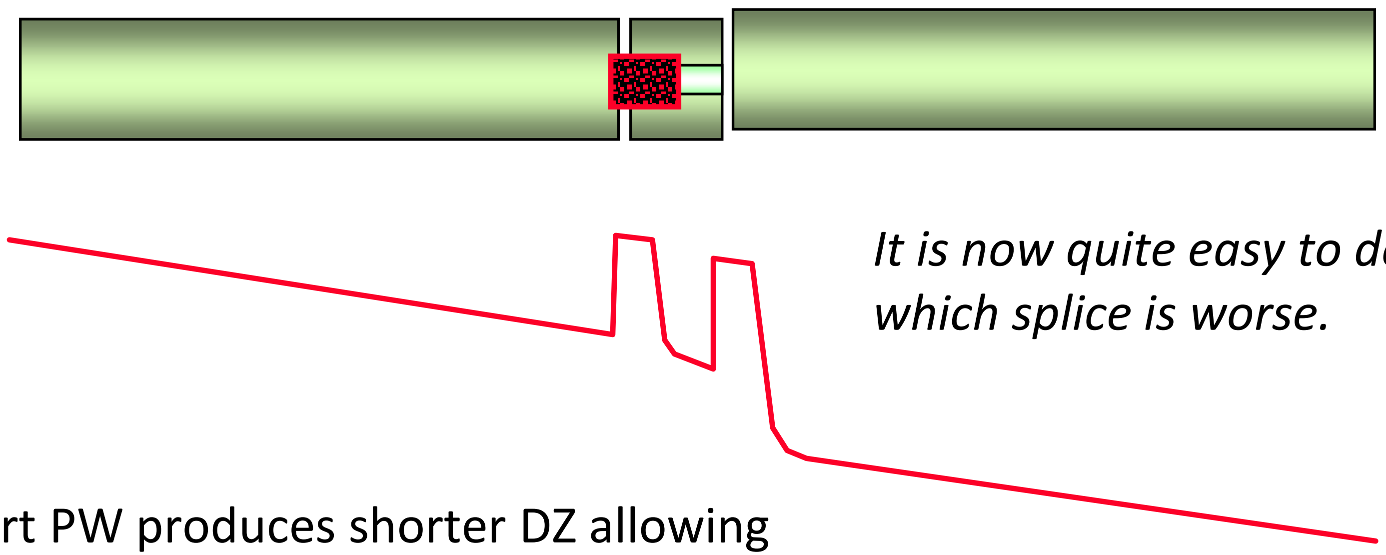


Long PW produces longer DZ, preventing the detection & measurement of individual splices. The PW strikes the second connection before clearing the first connection.

It is impossible to tell by looking at the trace which splice is causing the high loss.

Spatial Resolution

Dead Zone Effects From Using *Short* Pulse Width



It is now quite easy to determine which splice is worse.

A short PW produces shorter DZ allowing each splice to be measured individually. The PW clears the first connection before striking the second. This produces Rayleigh scattering between them allowing individual measurement.

Fiber Analysis Software

(FAS)

Automatic Trace Interpretation

Locates Fiber End

Locates Splices, Bends & Defects

(known as “events”)

Measures Event Loss

Measures End-to-End Loss

Measures Reflectance

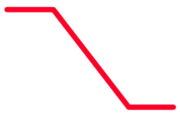
FAS Operations - General

Requires at least 7 data points per pulse length (certain Pulse Width - Resolution settings cannot be analyzed completely)

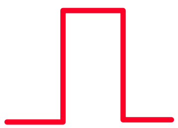
Flags events based on user-defined thresholds for Event Loss (*down to 0.00dB*), Event Reflectance (to -60dB), and Break Detect

Can be set to run automatically after a test or manually by pressing a button

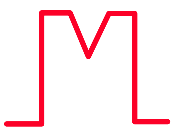
FAS Operations - General



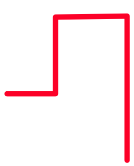
Non-Reflective = fusion splice, defect, or macrobend in fiber



Reflective = mechanical splice



Grouped = two or more NR or R events very close together



Cable End = point in fiber where signal level drops off. Means “Out of Range” or “Out of Distance”.

FAS Operations

Grouped Event

Two or more events flagged as Group

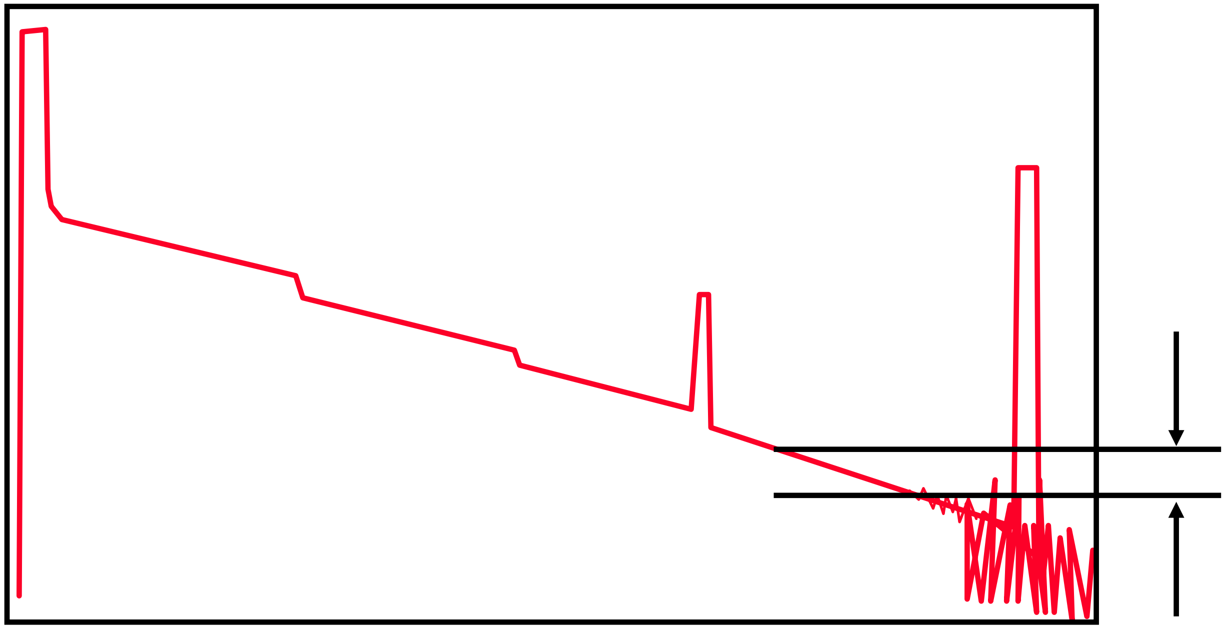
Too close together to make individual measurements

Dead Zone longer than for single event

Clue to look closer, or change OTDR settings and re-test

FAS Operations

“Out of Range”



FAS needs 3dB between backscatter and noise level to find fiber end, or else gives “Out of Range” warning.

REMEDY: Select larger Pulse Width to increase Dynamic Range and/or set “End Detect Threshold” in FAS Setup to lower value.

SUMMARY

Pulse Width *is THE most critical setting*

- Dynamic Range: How far you can test
- Dead Zone: How close in you can see
- Resolution in Fiber: How close together splices can be

Set Range & Reso to Automatic
Adjust Pulse Width to see *more detail*

Wavelength *comparison* shows problems

- *Longer* wavelength can test longer fiber
& detect bending loss

Fiber Analysis Software makes it <u>*EASY*</u>

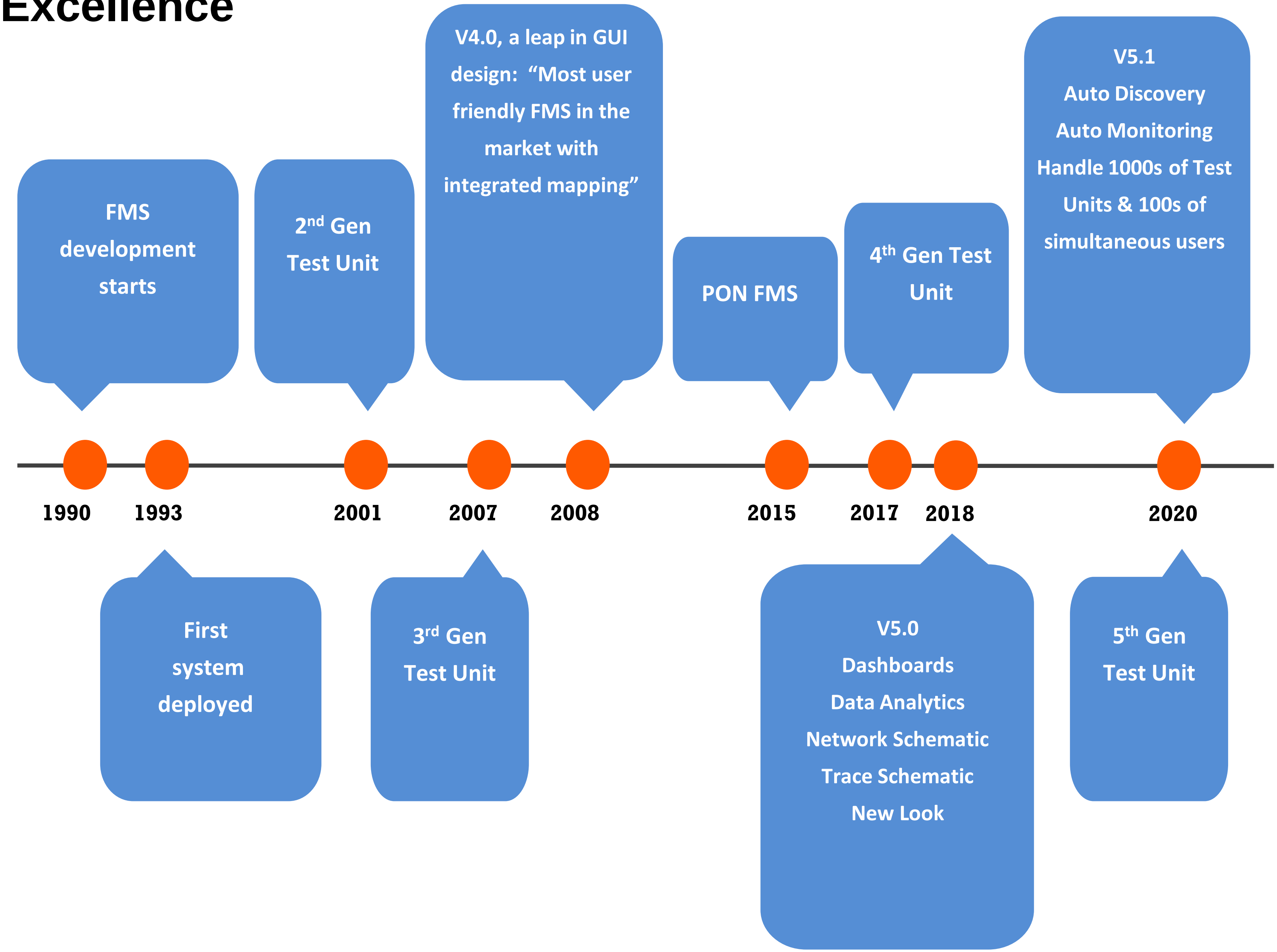
FiberWatch™

Remote Fiber Test System (RFTS)
Fiber Monitoring System (FMS)

Optikai kábel / Fényvezető kábel
Felügyelet / Monitorozás

History

More Than 25 Years of Technology and Product Excellence

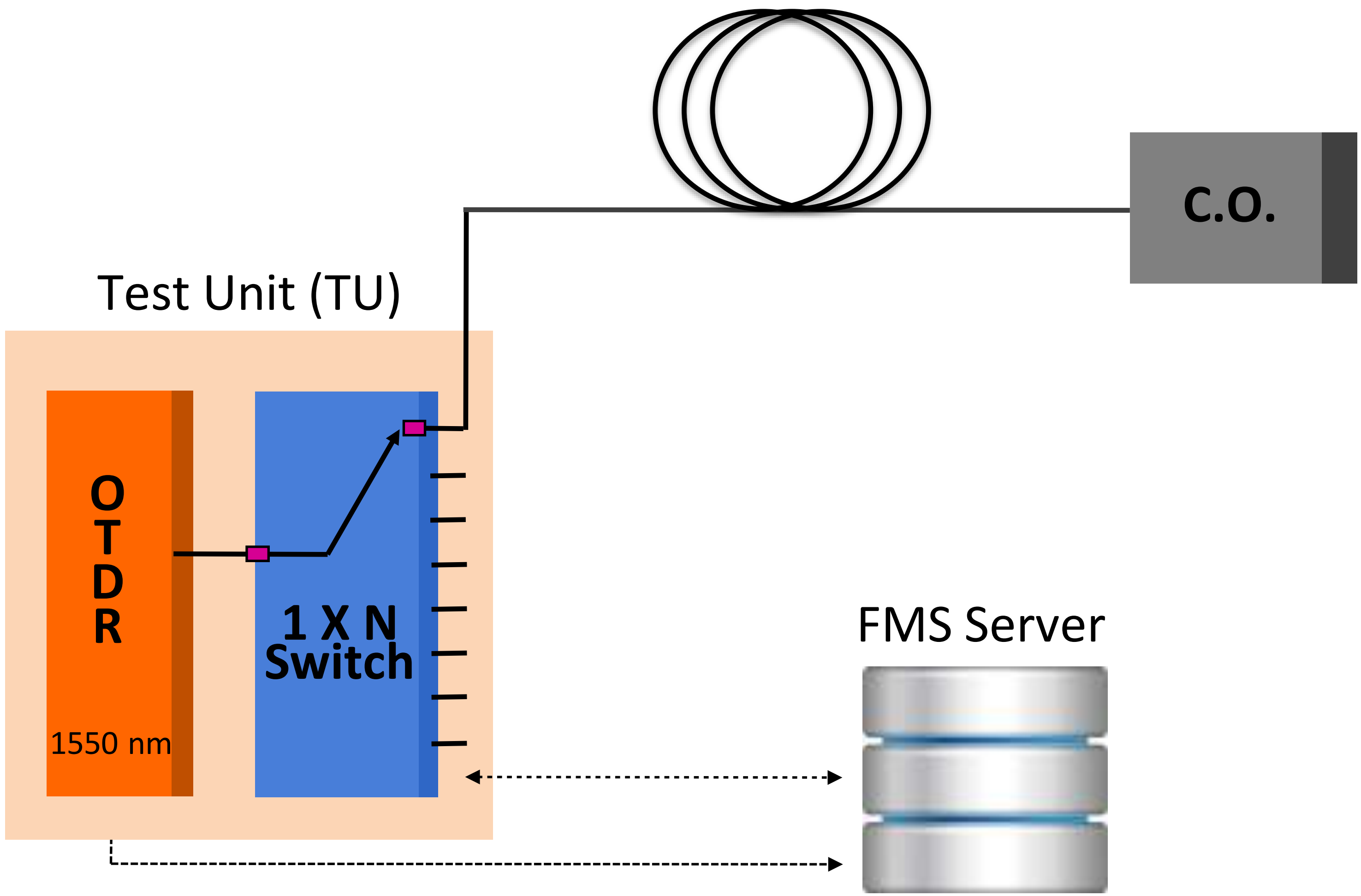


What is Fiber Monitoring?

- 24x7 monitoring of optical fibers
- OTDR trace comparison
- Automatic alarming
- Network/GIS documentation
- System: Server / Test Units / Clients
- Reporting & trend analysis

Dark Fiber Configuration

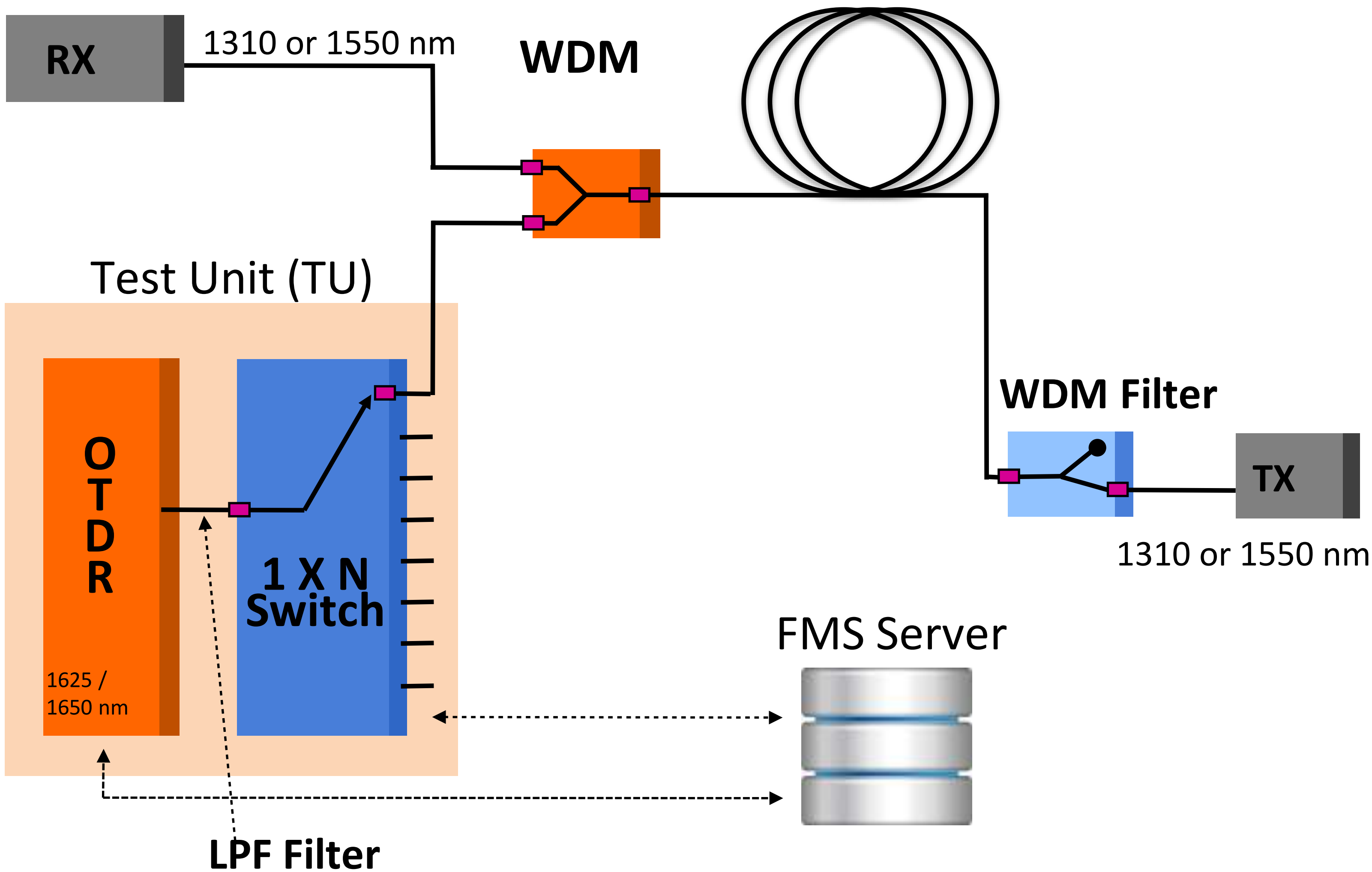
Dark Fiber Monitoring



Active Fiber Configuration

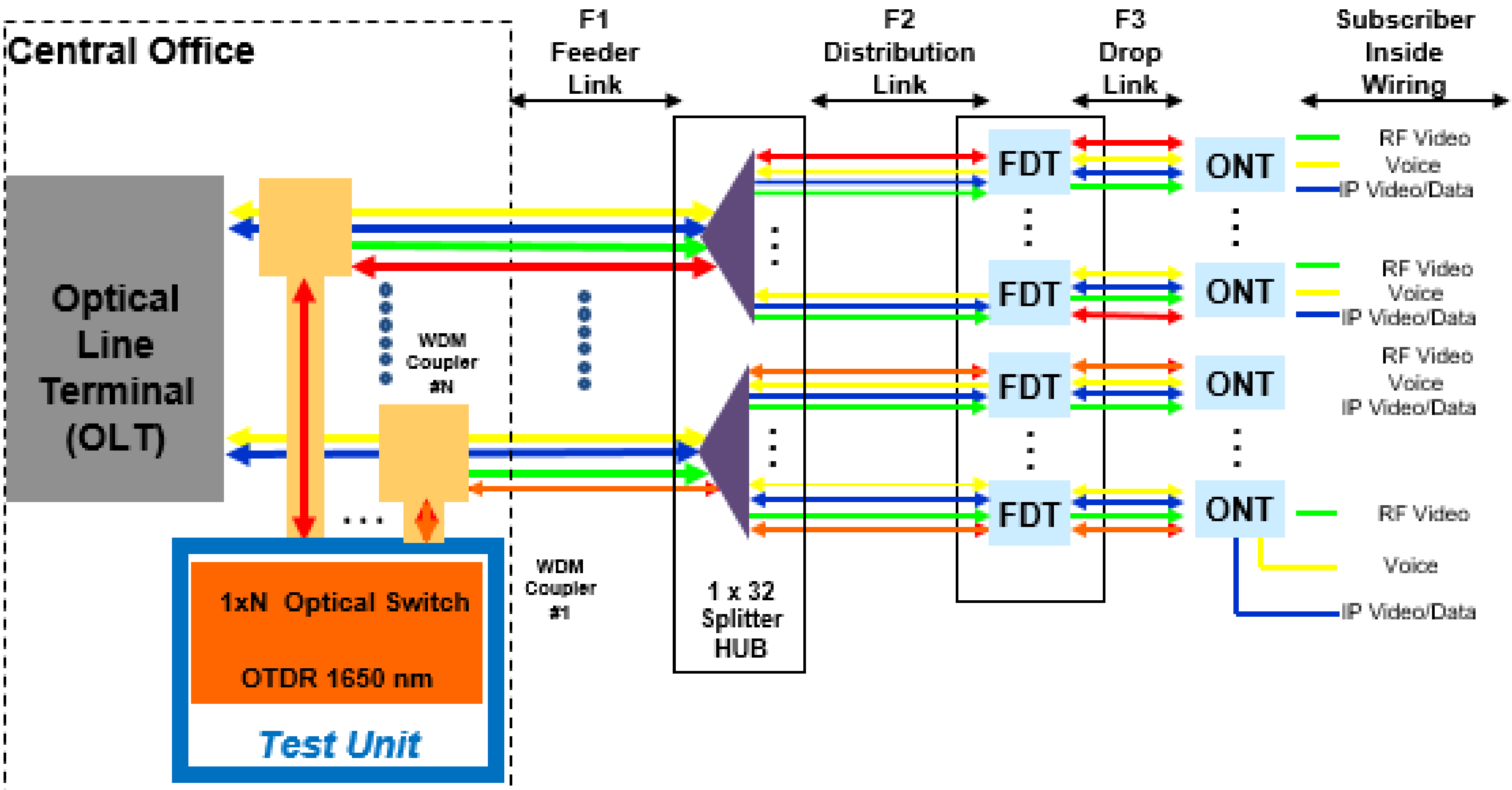
NTEST

Active Fiber Monitoring



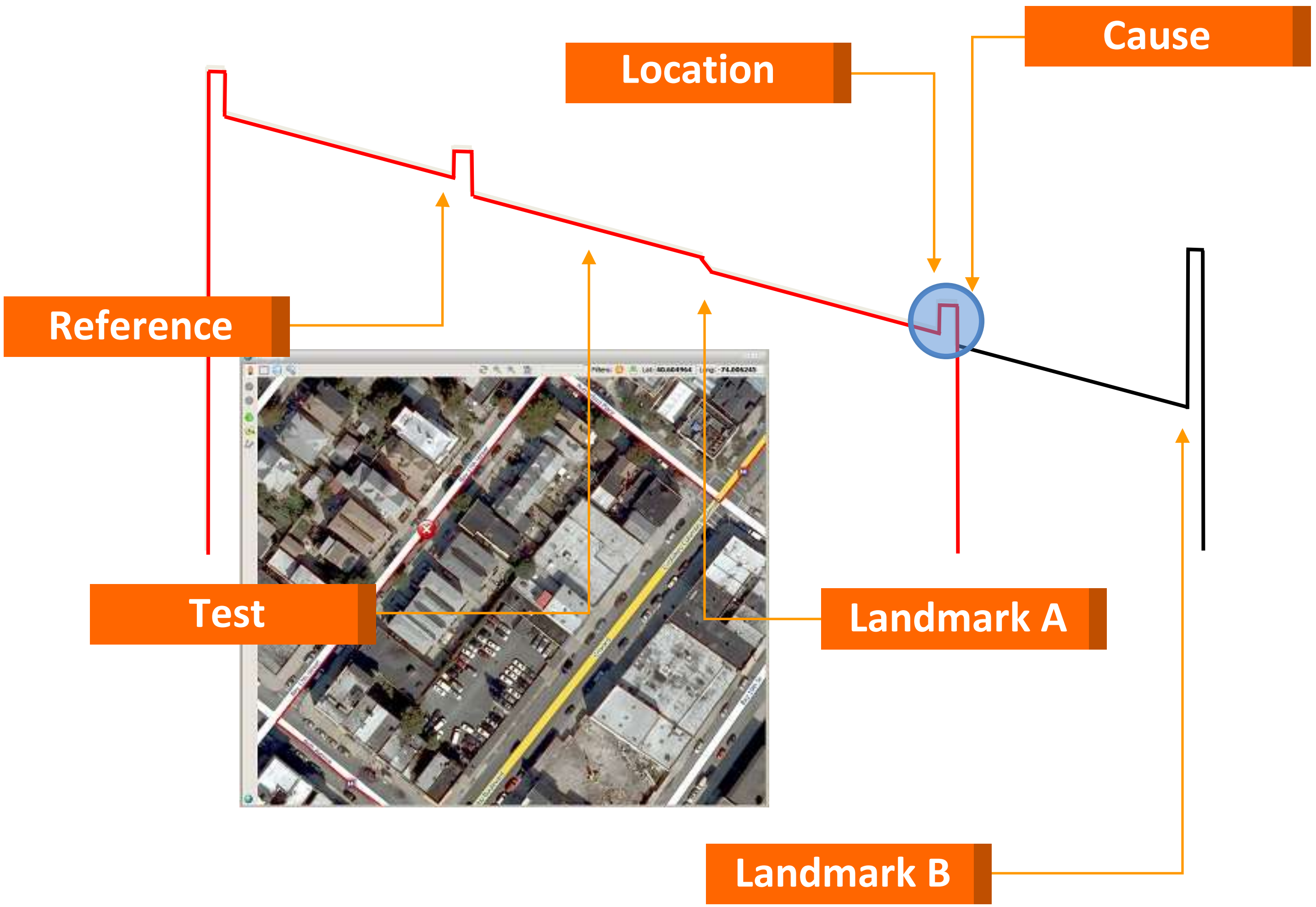
PON Fiber Configuration

PON Fiber Monitoring



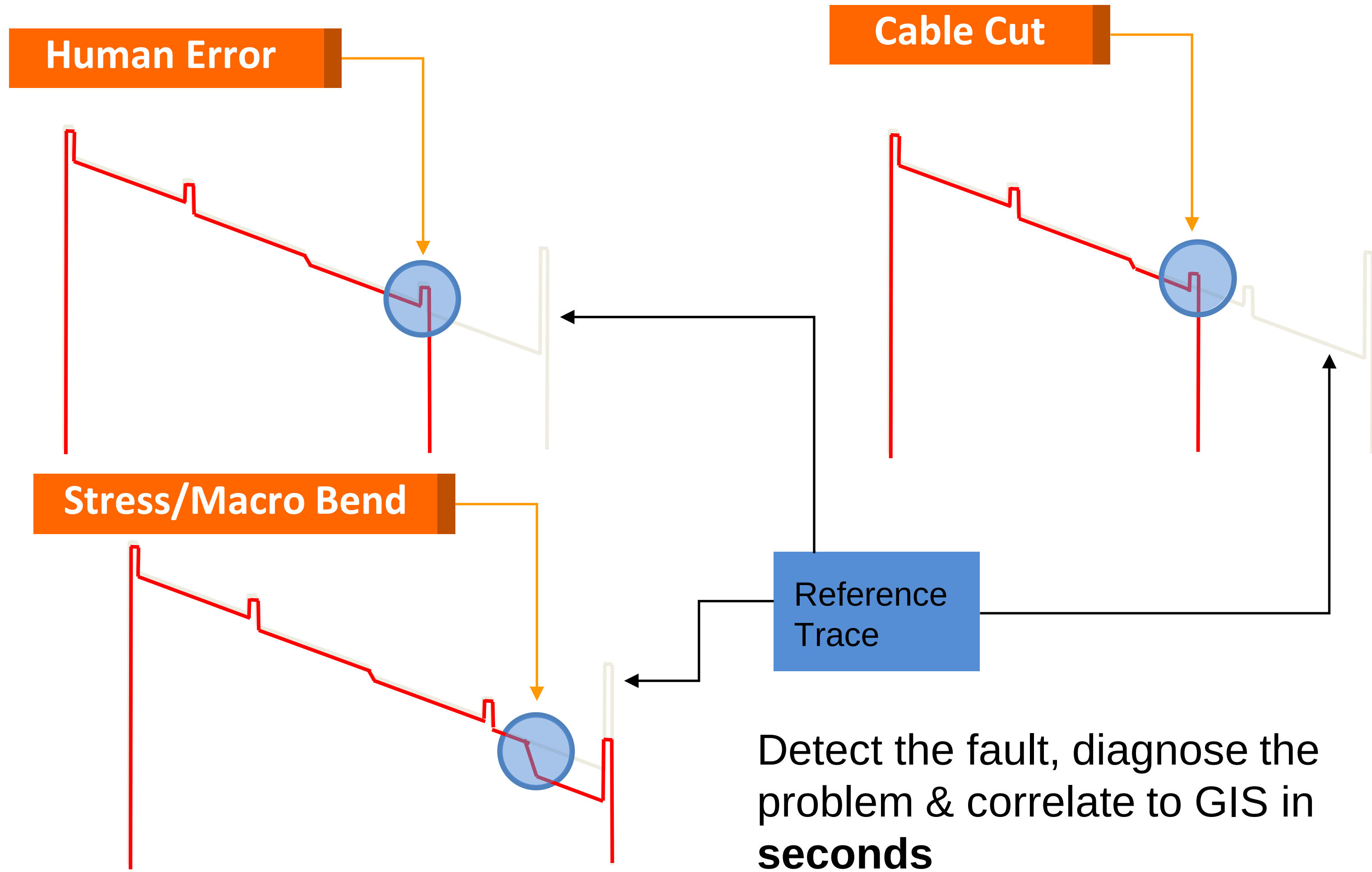
How FiberWatch™ Works

Optical Correlation



Trace Analysis

Alarm Probable Causes



Detect the fault, diagnose the problem & correlate to GIS in **seconds**

FMS Benefits

Why customers deploy a Fiber Monitoring System?

Fast Fault Location - Reduce MTTR

Data Analytics - Proactive Network Maintenance

Network Mapping & Schematic - Efficient operation

Installation Verification - Eliminates contractor fraud

Trace Analysis - Efficient Troubleshooting

Dashboards - Real-time Visualization of key parameters

Sensors & Power Monitors - Enhanced Security

Fast Fault Location

Reduce MTTR

Alarm Report

Fiber Circuit Alarm for XZ-23H
Possible Break Detected

Fiber Circuit: XZ-23H

Severity: Critical

Date: 15 January 2020

Time: 09:43:57 EST

Affected Domains: Northern, HSBC

Probe: Bloomington RTU

Specific Problem: Bad Fiber Scan Analysis

Probable Cause: Possible Break Detected

Optical Distance: 40.2km

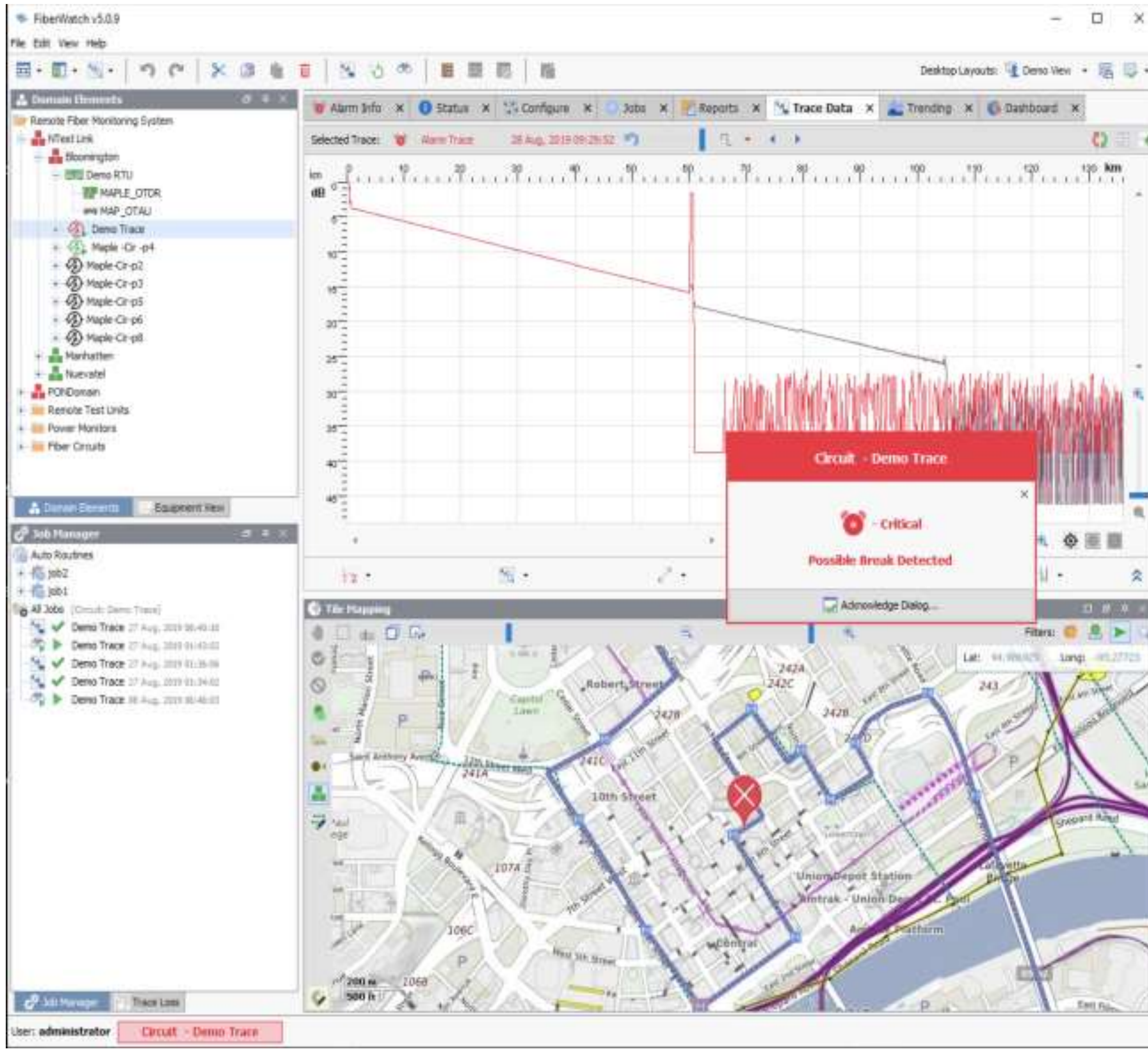
Sheath Distance: 38.1km

0.4km after “MH63”

0.2km before “MH64”

Latitude: 34 23’ 43”

Longitude: -105 42’ 01”



Carrier Case Study

Reduce MTTR

With Monitoring

Breaks located
in less than 2 min

Crew on their way
in less than 14 min

Average outage
less than 3 hours!

Without Monitoring

Locate Break:
Can take hours

Dispatch Crew:
Further delay

Average outage
9.7 hours!

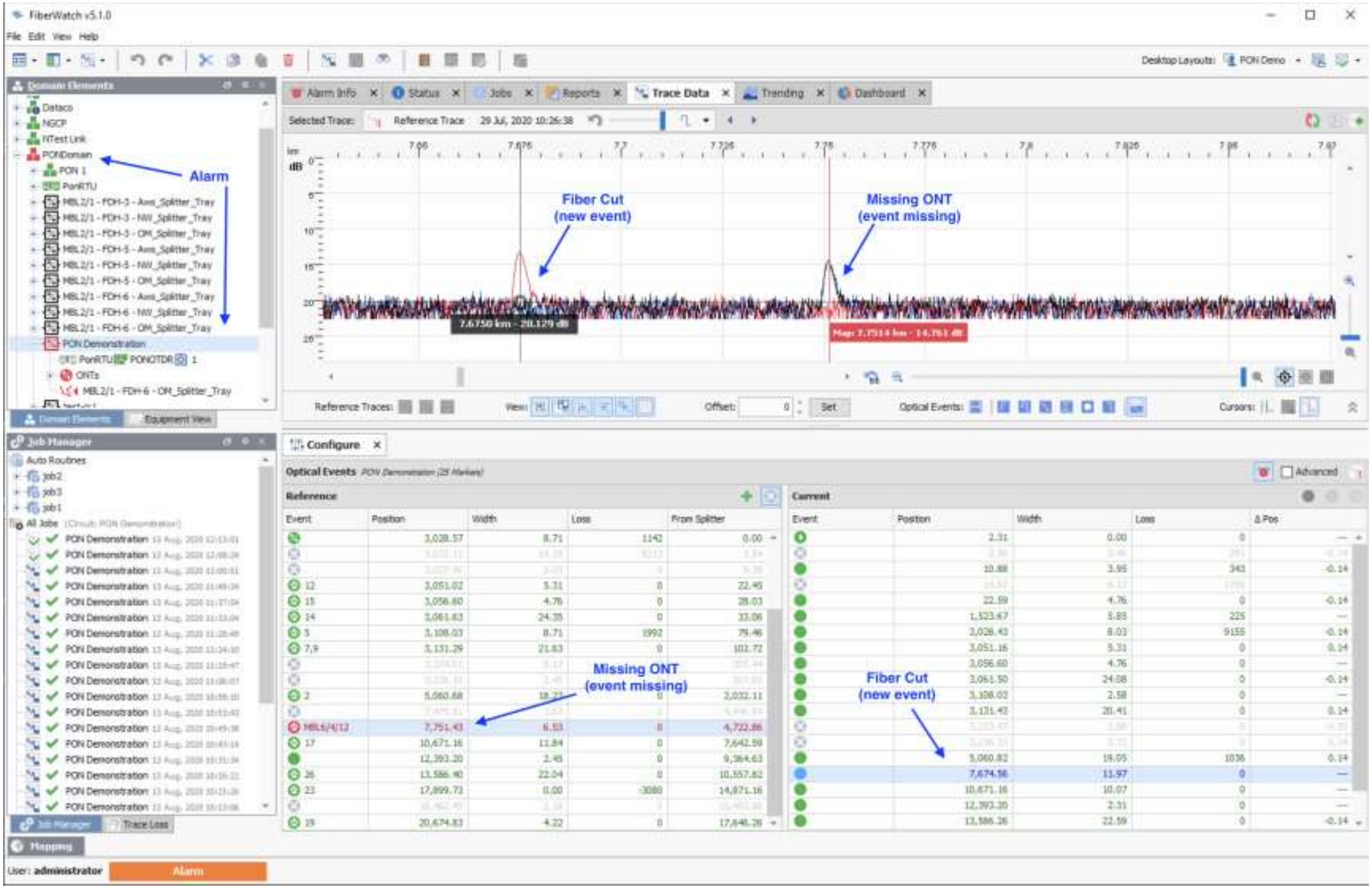
FiberWatch™
Reduces
fault location and
dispatch time
minimizing
TOTAL
Outage Time

C&W Networks

Reduce MTTR

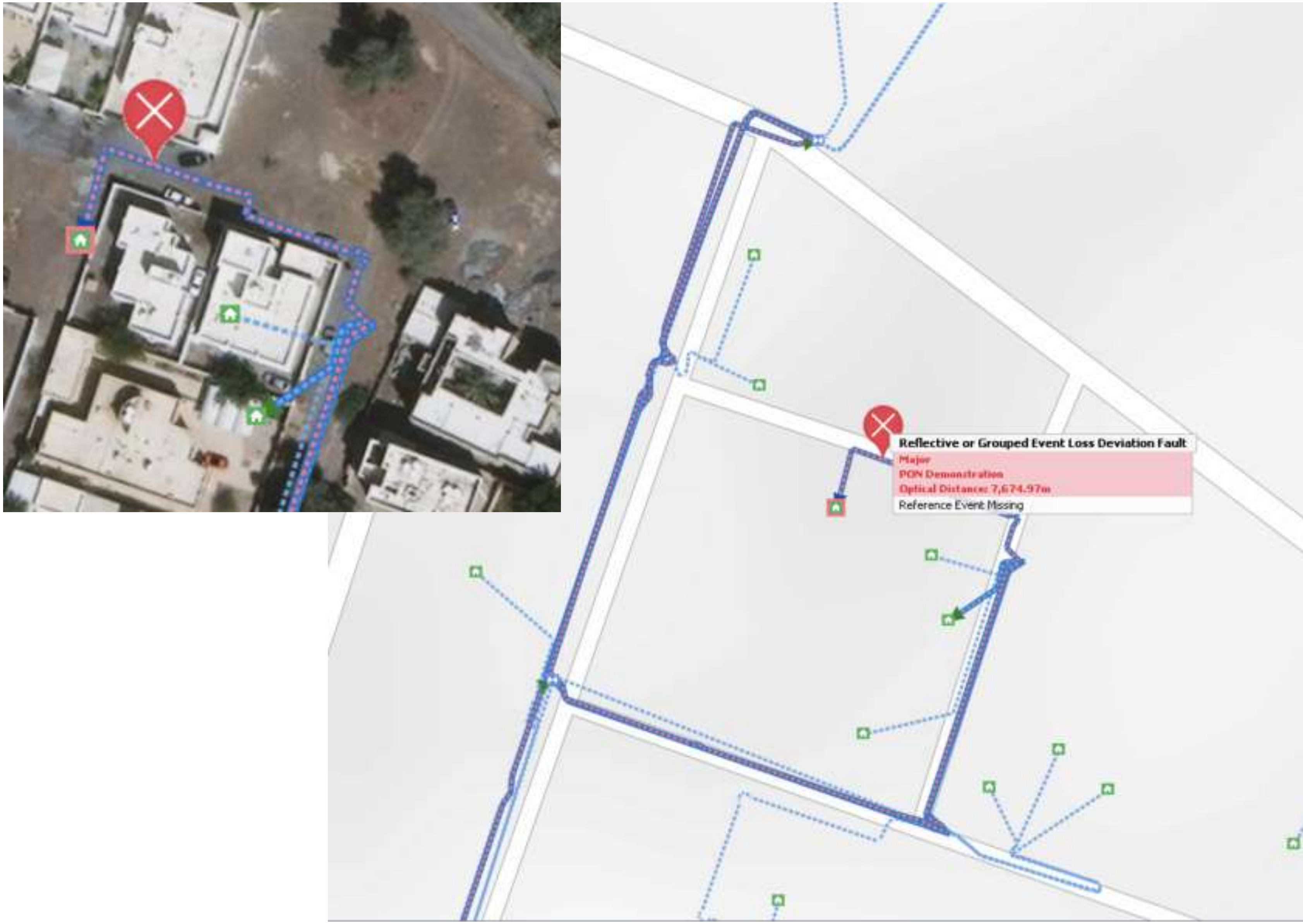
PON Fault Location

Reduce MTTR



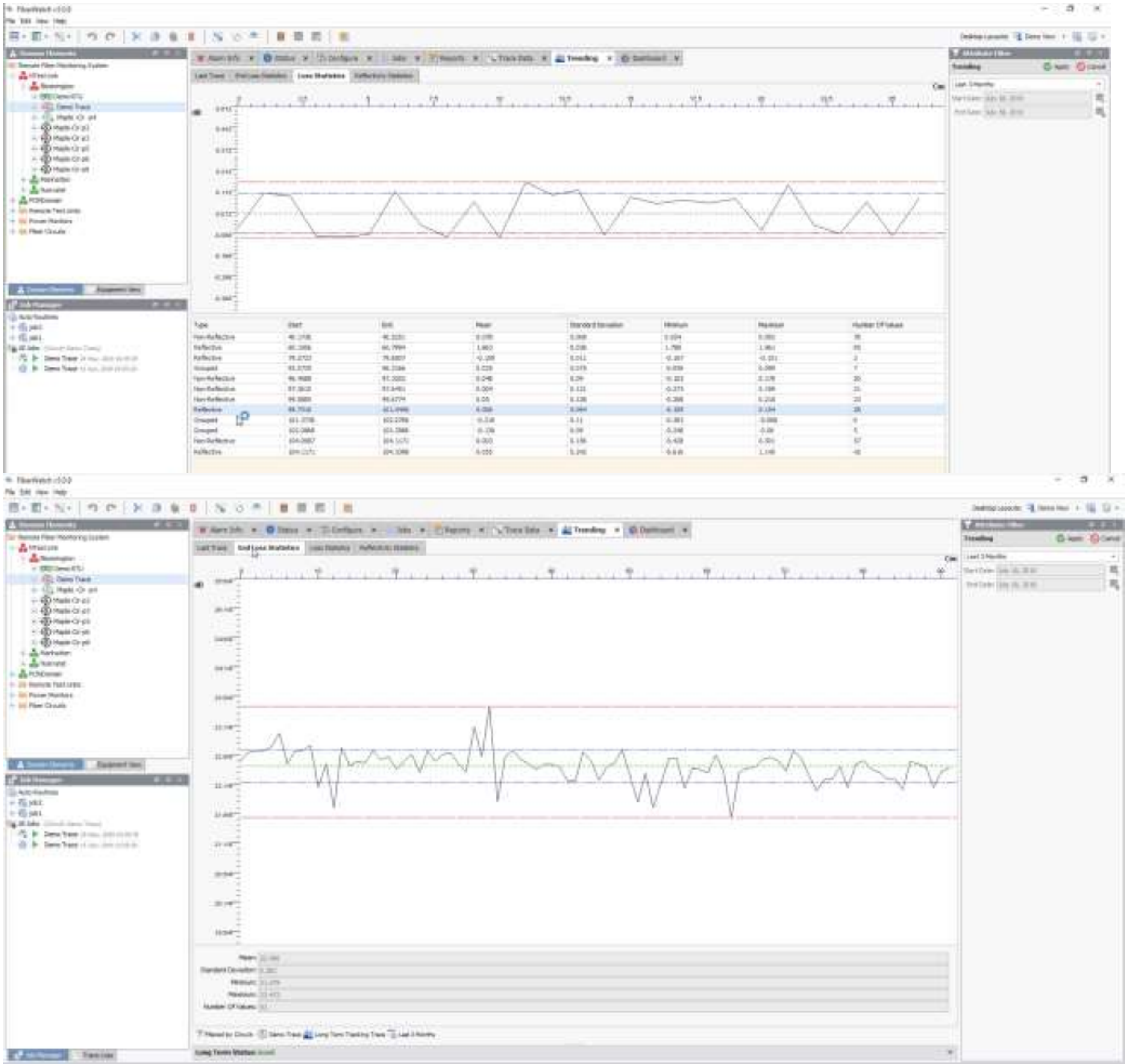
PON Fault Location

Reduce MTTR



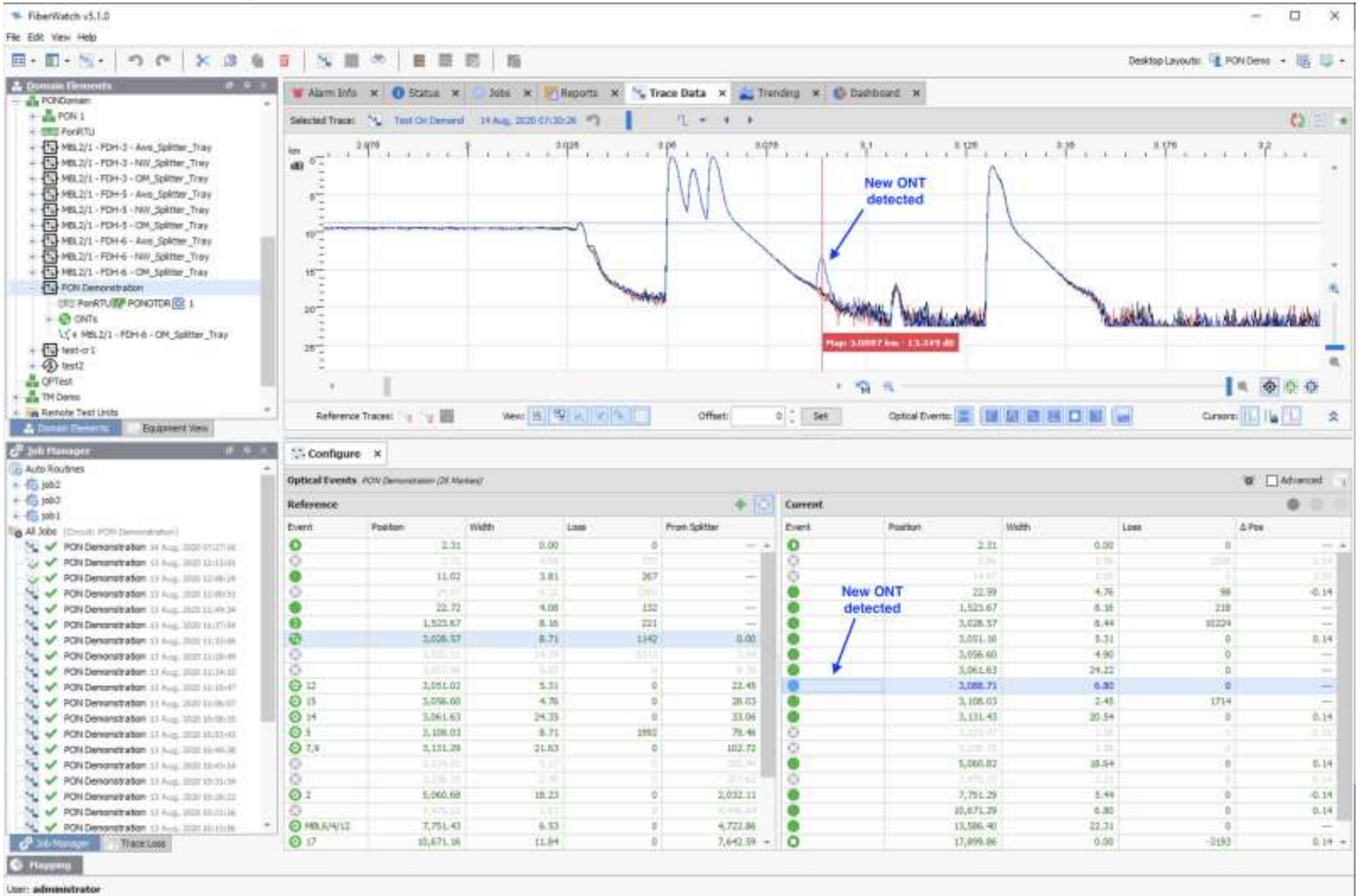
Data Analytics

Proactive Network Maintenance



Installation Verification

Installing a new ONT

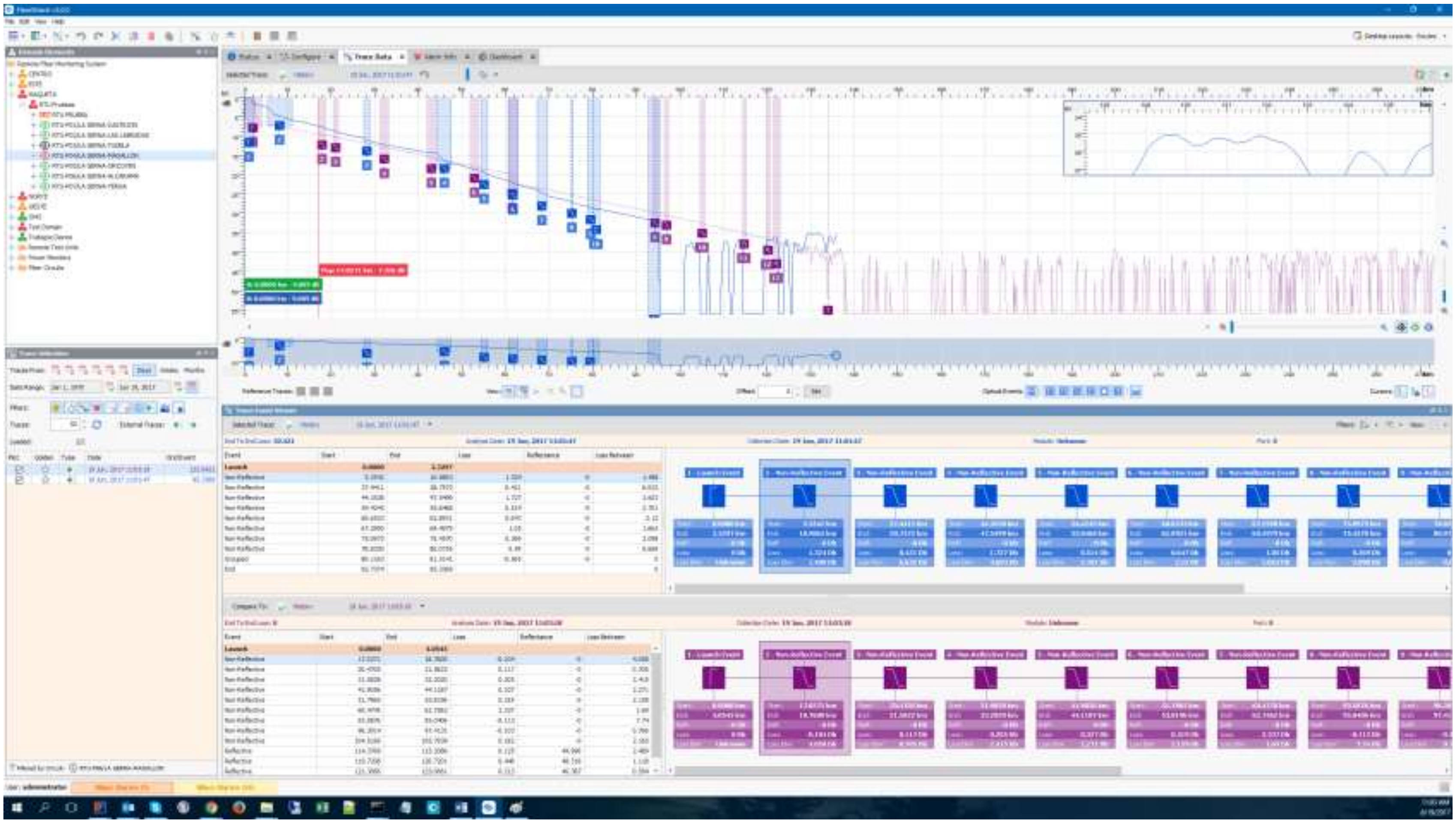


Mobile Application:

- Verification Test
- Add GPS location
- Add address, photos, & other relevant data

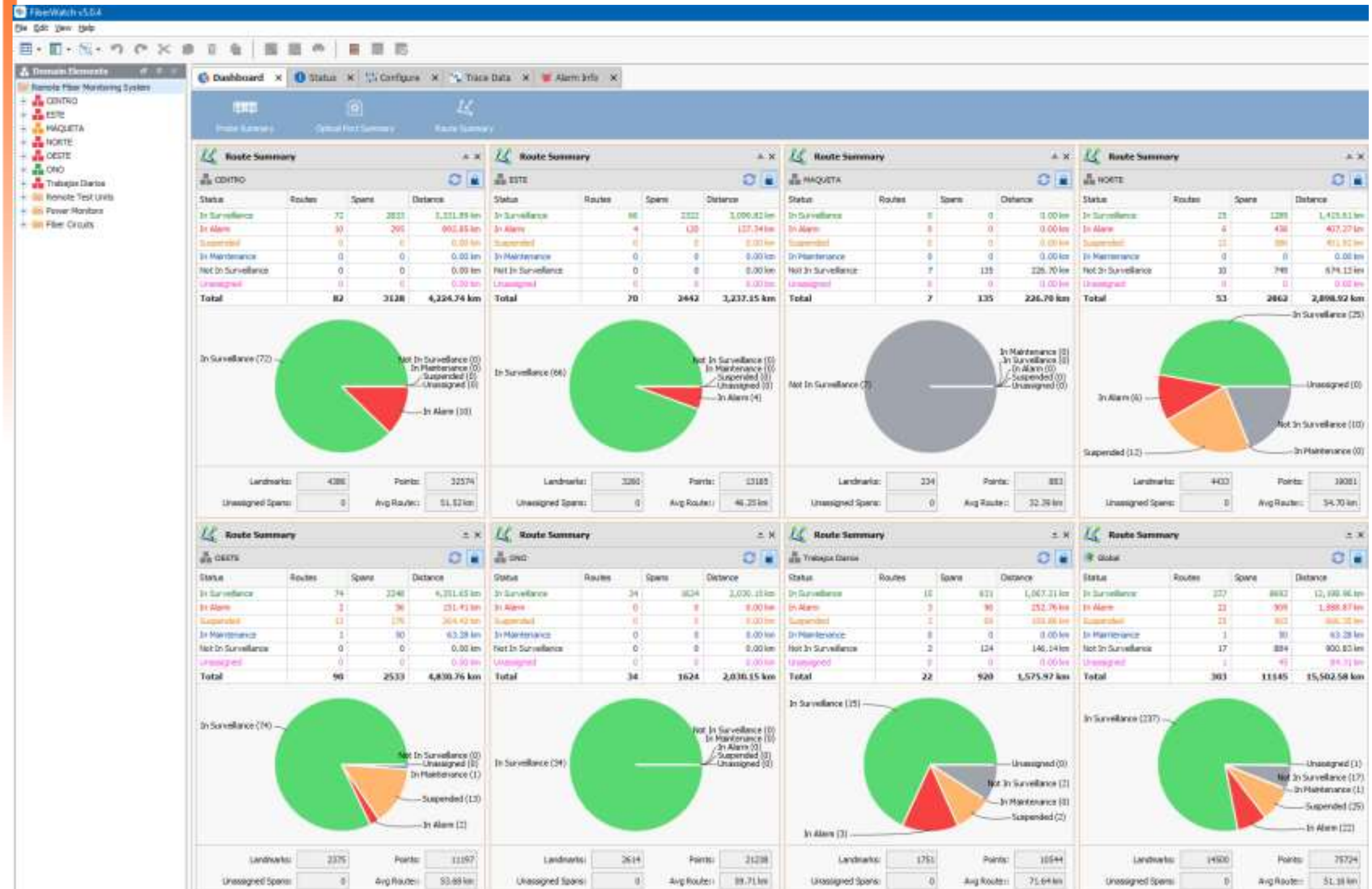
Trace Analysis

Efficient Troubleshooting



Dashboards

Real-time Visualization of key network parameters

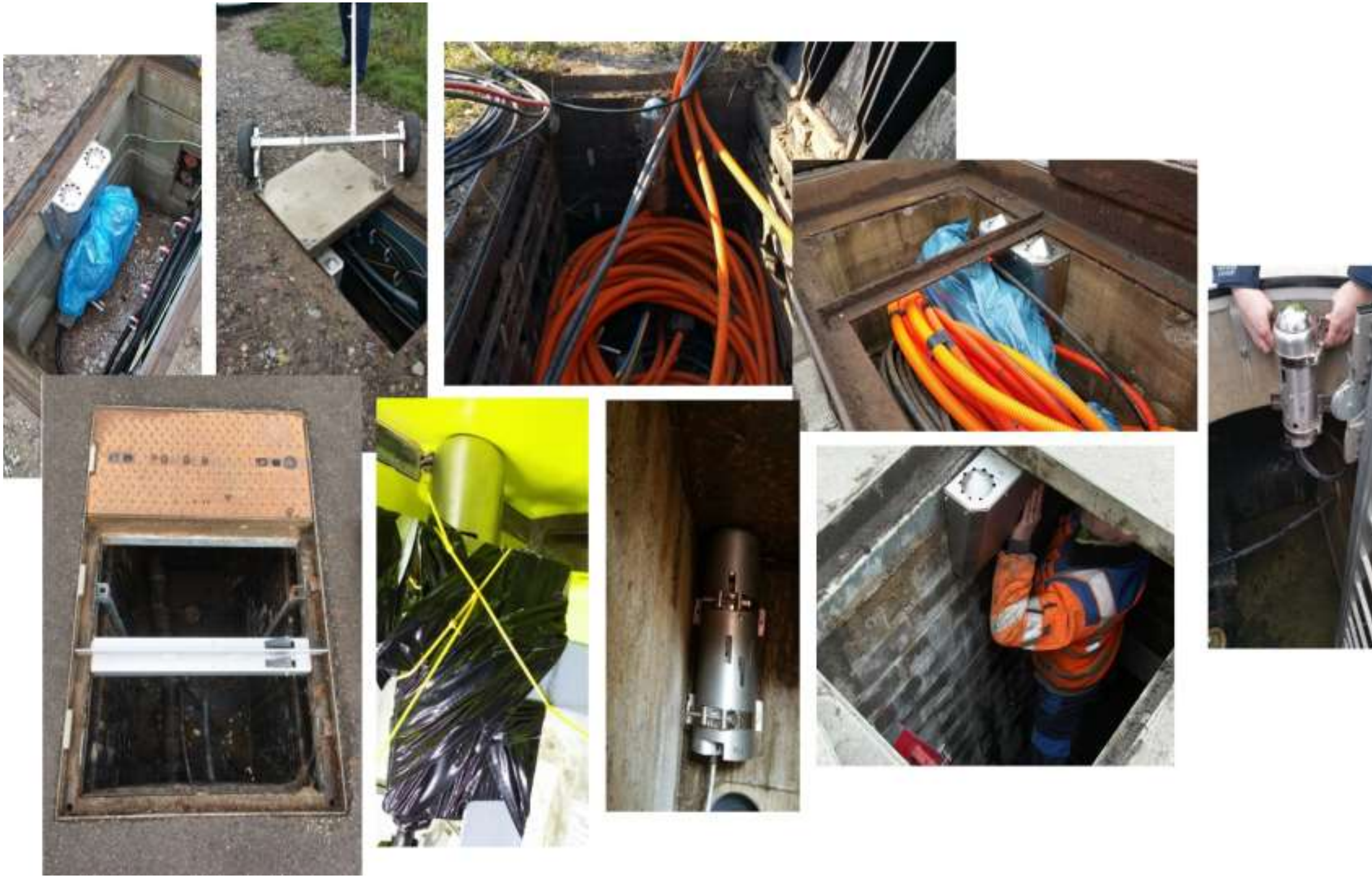


Sensors & Power Monitors

- Sensors
  - Manhole & Cabinet Intrusion Sensors
  - Flooding Sensors
- Power Monitors for real time monitoring
  - Detect changes in < 1 second
  - Accuracy +/- 0.2 dB, Resolution 0.02 dB

Sensors

Network & Critical Infrastructure Security

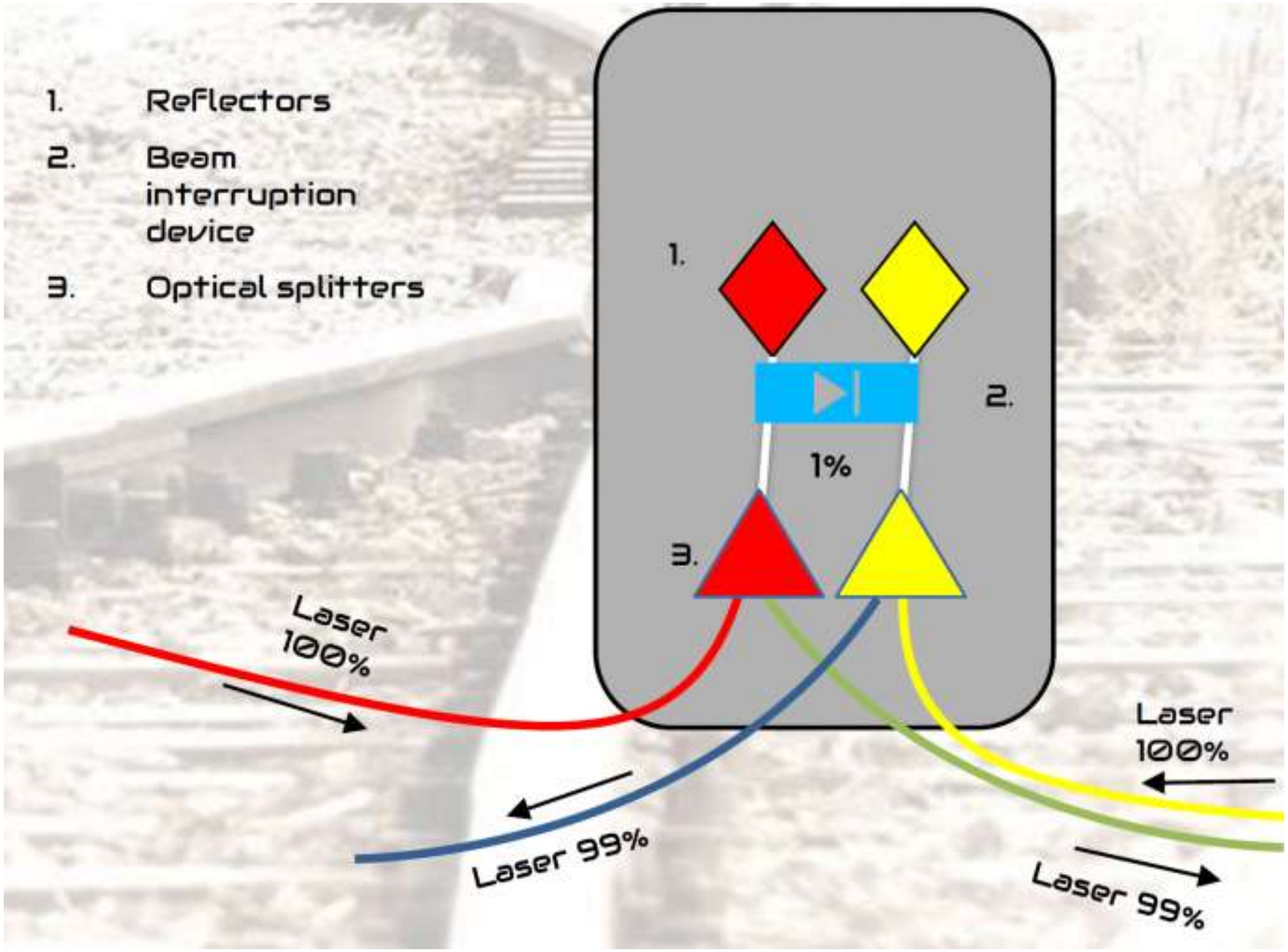


Hardware

Network & Critical Infrastructure Security

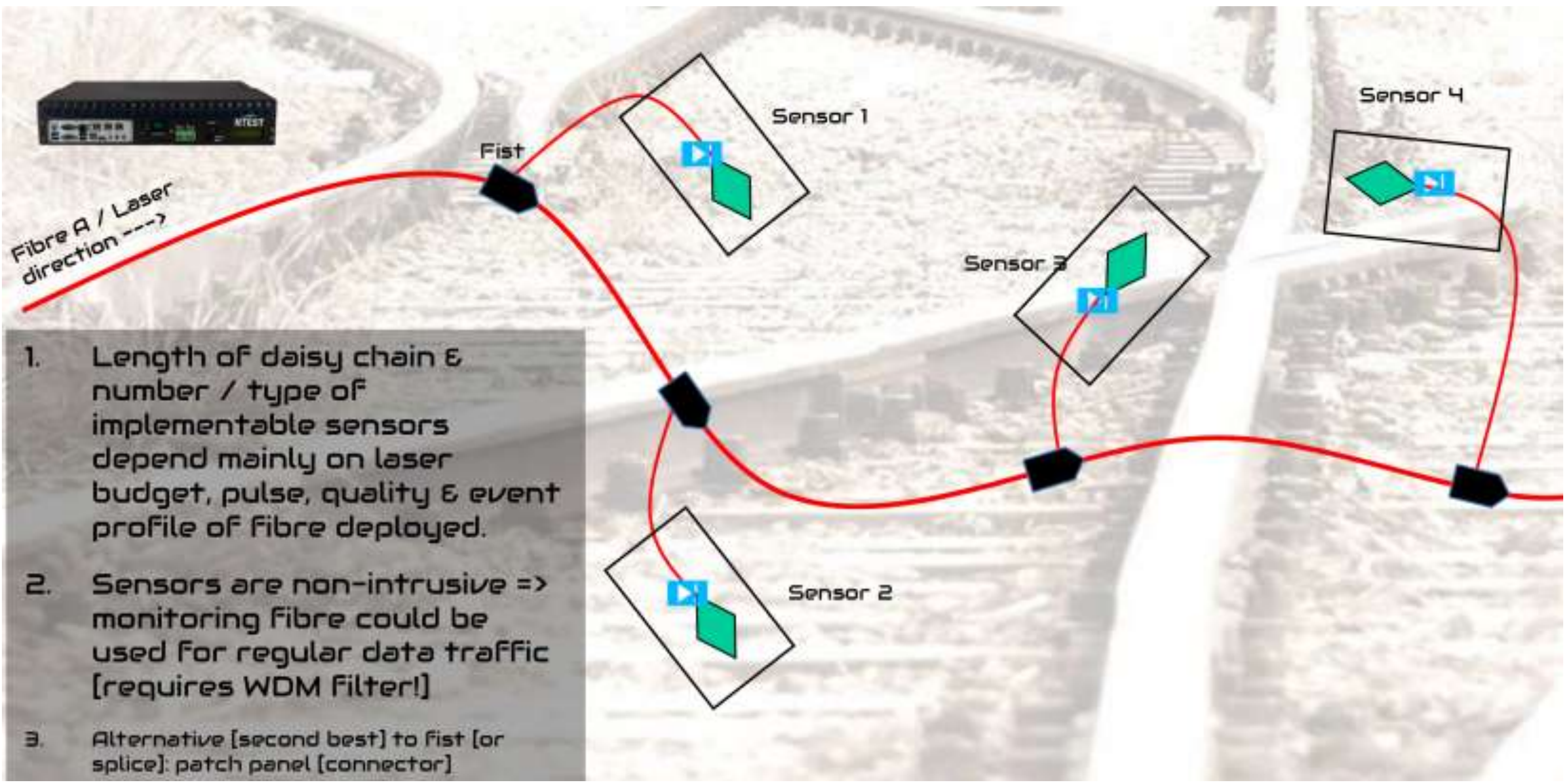
Hardware

Network & Critical Infrastructure Security



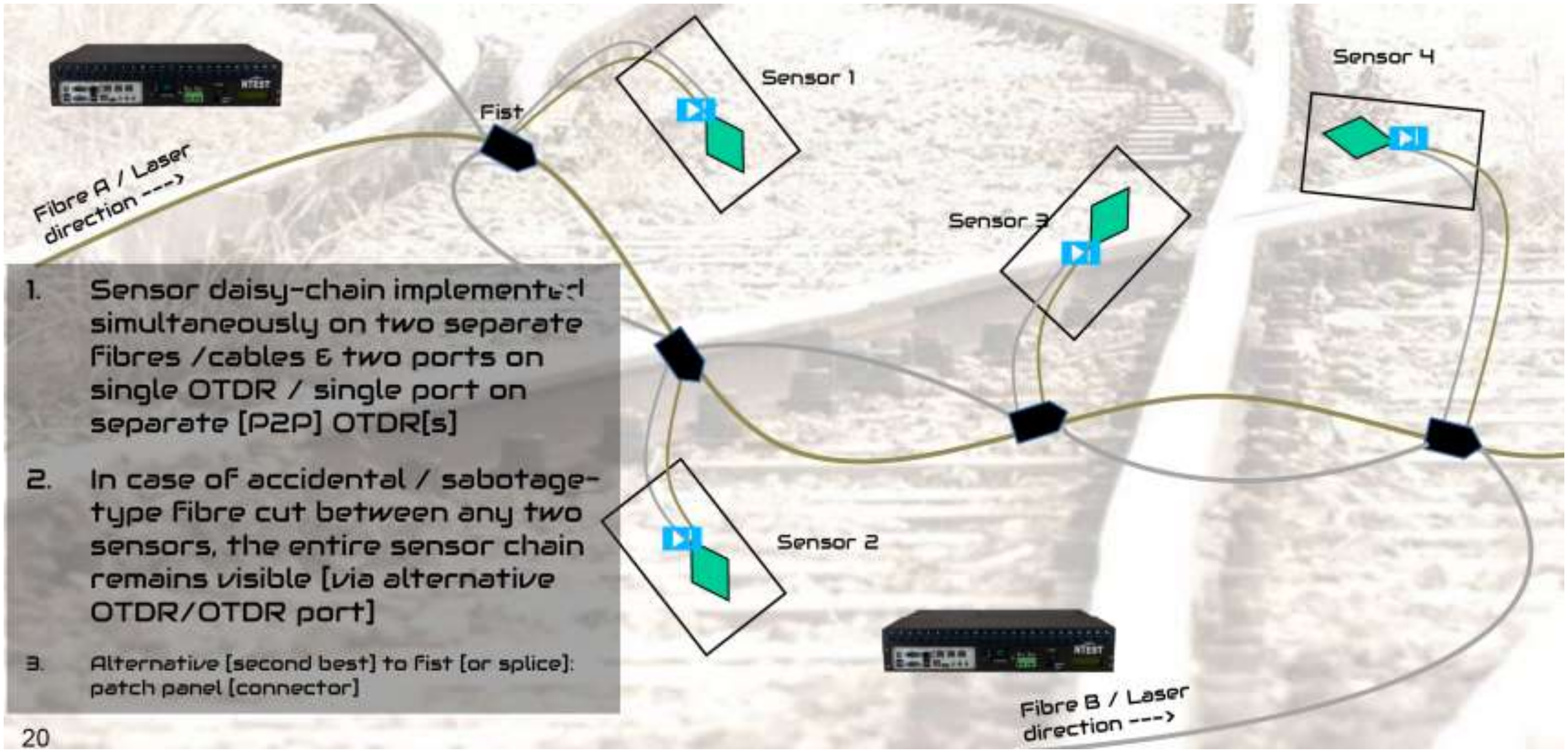
Hardware

Network & Critical Infrastructure Security



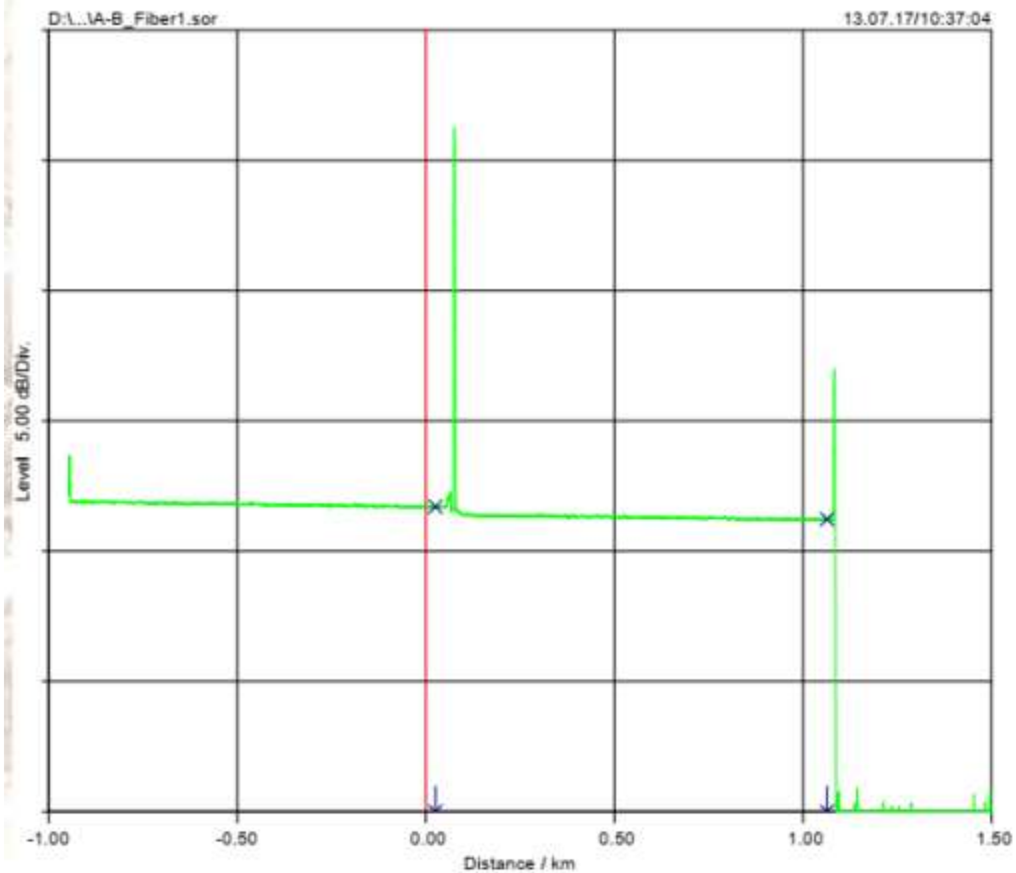
Hardware

Network & Critical Infrastructure Security



Hardware

Network & Critical Infrastructure Security

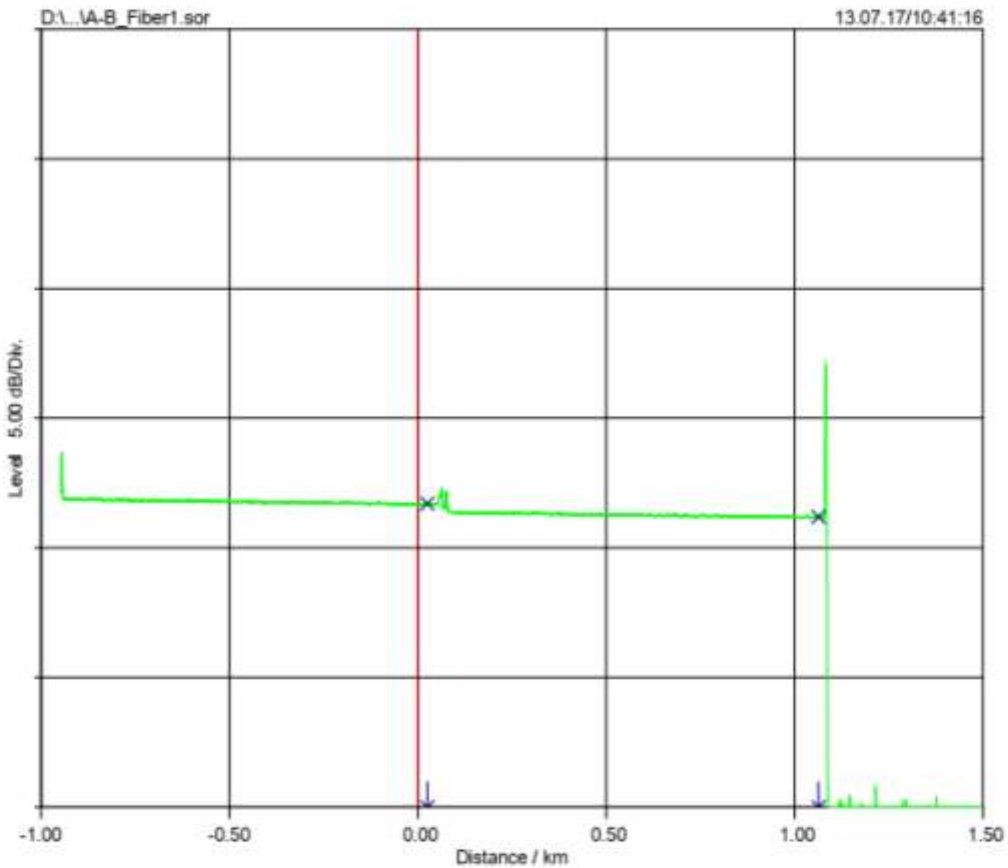


Fiber No.	: 1			
Location	: Schalter 1			
Device	: FTB-730-234B			
Rel. level	: -20,98 dB	Wavelength	:	1627 nm
Evaluation	: 2PA	Distance range	:	2,45 km
IOR	: 1,46873	Hor. resolution	:	0,16 m
Cursor C1	: 0,0257 km	Pulse width	:	30 ns
Cursor C2	: 1,0636 km	Attenuator	:	0,00 dB
Diff. C2-C1	: 1,0379 km	Average counts	:	975
Loss	: 0,48 dB	Smoothing	:	0
Attenuation	: 0,46 dB/km			
Total loss (extrapolated)	: 0.49 dB			

Intrusion sensor in "OK"/"non-alarm" mode – positive return signal [peak] generated by the sensor evidencing the sensor's presence and operatonal condition

Hardware

Network & Critical Infrastructure Security



Fiber No. : 1
Location : Schalter 1
Device : FTB-730-234B

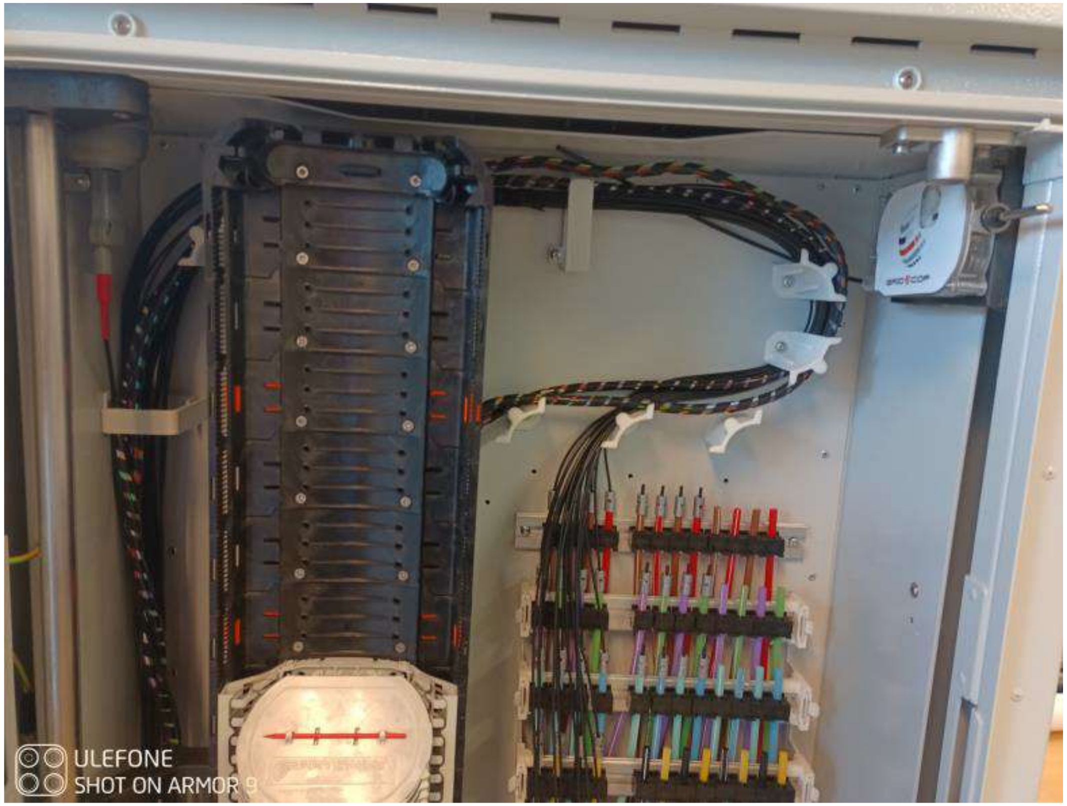
Rel. level	: -10,91 dB	Wavelength	: 1627 nm
Evaluation	: 2PA	Distance range	: 2,45 km
IOR	: 1,46873	Hor. resolution	: 0,16 m
Cursor C1	: 0,0257 km	Pulse width	: 30 ns
Cursor C2	: 1,0636 km	Attenuator	: 0,00 dB
Diff. C2-C1	: 1,0379 km	Average counts	: 975
Loss	: 0,51 dB	Smoothing	: 0
Attenuation	: 0,49 dB/km		

Total loss (extrapolated) : 0.52 dB

Intrusion sensor in "alarm-mode": peak disappears, OTDR trace remains stable [no additional attenuation generated by alarming sensor]; with multiple sensors on identical fibre, all non-alarming sensors remain visible & unaffected by alarm situation of one or several companion sensors

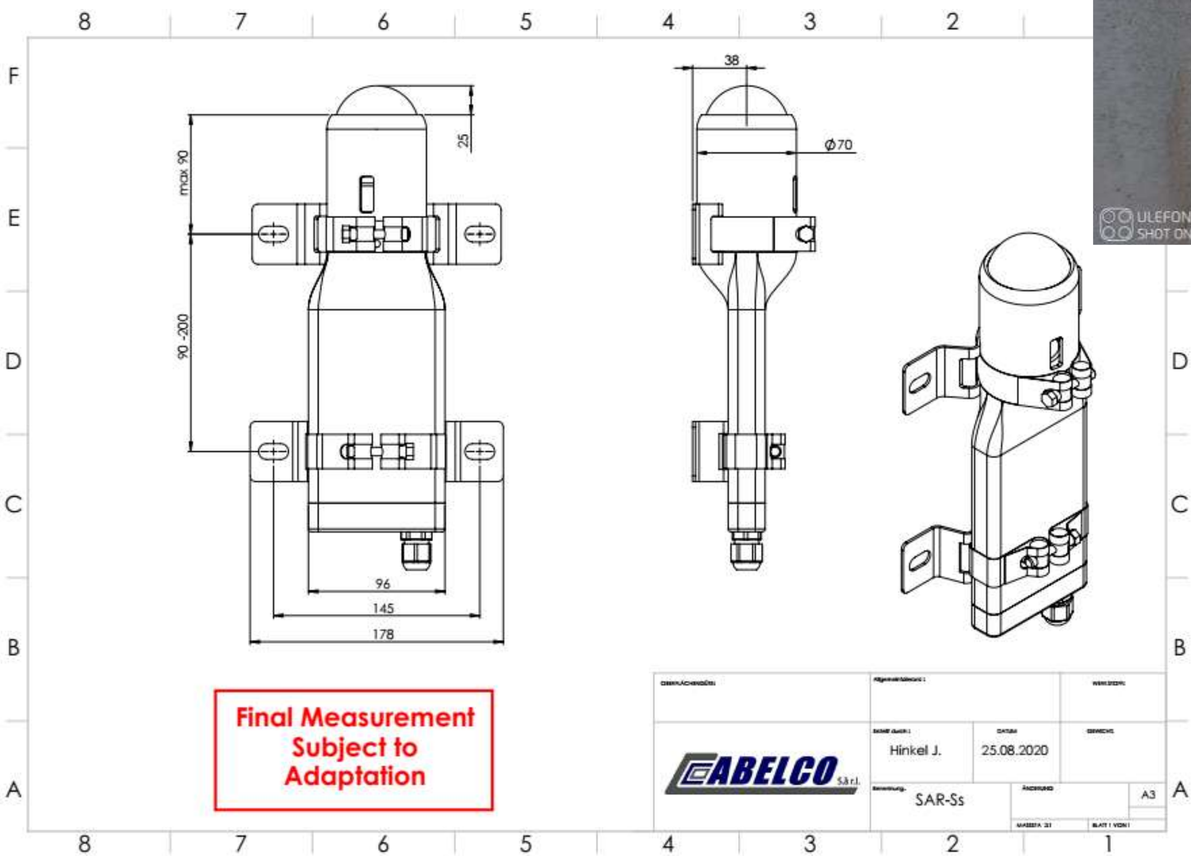
Hardware

Sensor



Hardware

Sensor



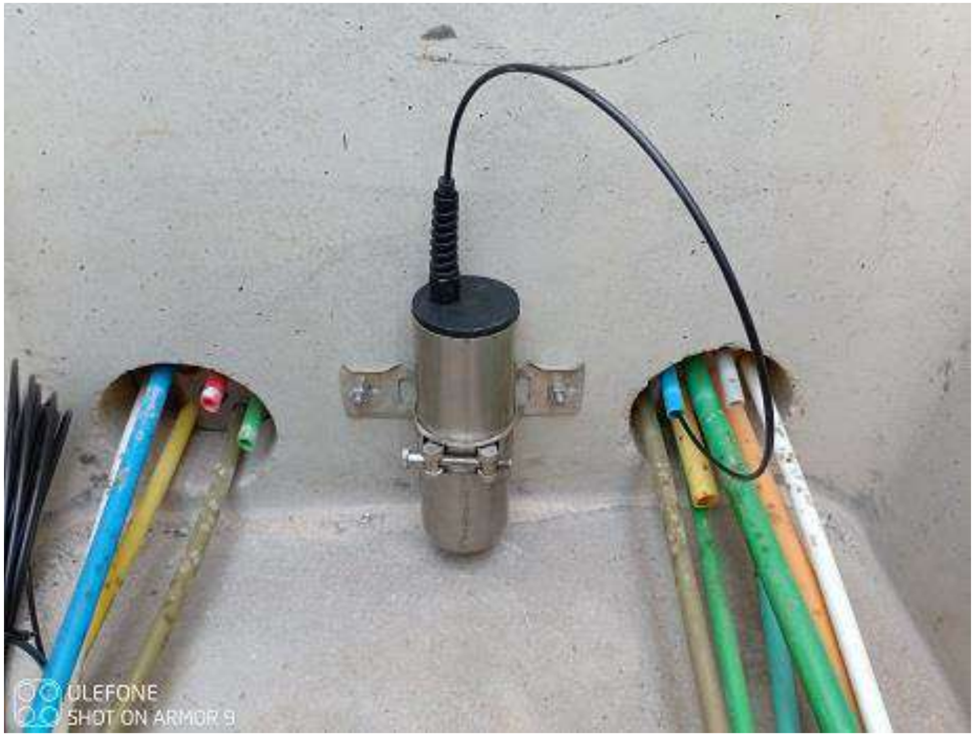
Sensor

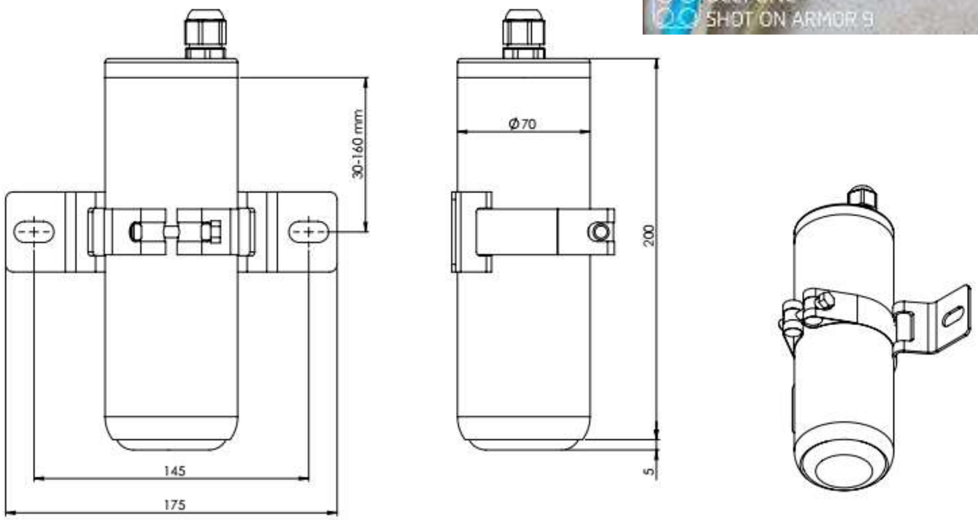
Hardware

Lavina és sziklaomlás érzékelés

Hardware

Víz érzékelés





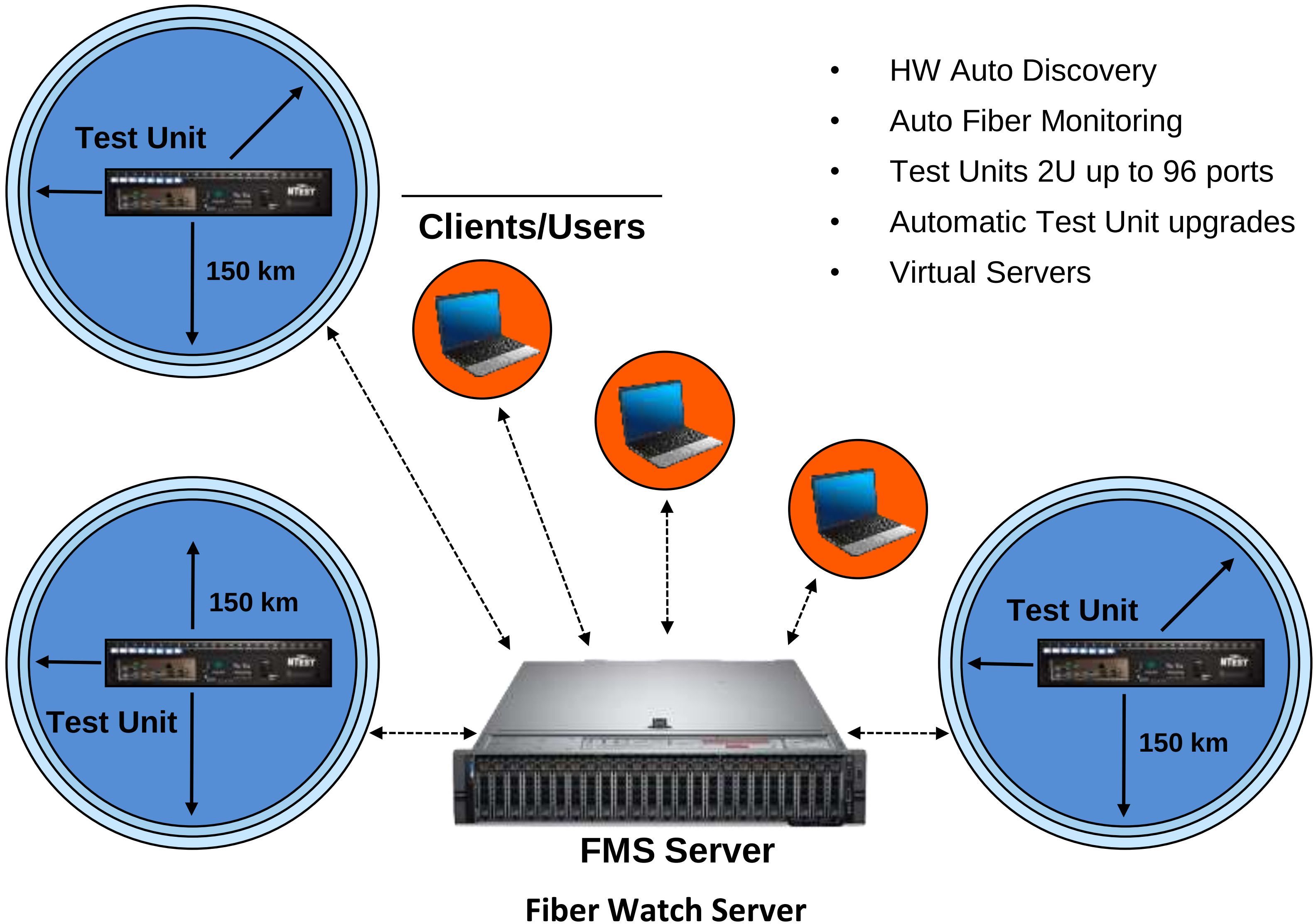
Hardware

Dőlés érzékelés

Hardware

FiberWatch™ FMS

- HW Auto Discovery
- Auto Fiber Monitoring
- Test Units 2U up to 96 ports
- Automatic Test Unit upgrades
- Virtual Servers



Software

FiberWatch™ FMS

OS Support:

- **Windows Server**
- **Ubuntu**
- **Oracle Linux (RHEL)**
- **CentOS, SUSE, etc.**

Database Support:

- **HSQLDB**
- **PostgreSQL**
- **Oracle**
- **Microsoft SQL Server**

External Interface Protocols Support:

- **RESTful Web service (JSON & XML)**
- **SNMP v1, v2, v3**
- **TL1, CORBA, FTP/SFTP, JMS, etc.**

Software

FiberWatch™ FMS

- Google Maps™ and Google Earth™ Support:
    - Alarm email with Goggle Maps™ link & Goggle Earth™ route
    - Goggle Earth™ route import and export capability
- Mapping and Network Schematic Views
- Supports OSM and other free maps from the internet
- Offer locally hosted NTest Base Maps

Summary

FiberWatch™

- Greatly reduce MTTR (Mean Time To Repair)
- Proactive Network Maintenance:
  - Reduced operational costs
  - Reduced network downtime
- Manage Service Level Agreements (SLAs)
- FMS used as differentiator over competitors
- Enhanced Network & Critical Infrastructure Security