Dark Fiber Testing & Reporting

in Backhaul, Metro and Fronthaul Environments

EXFO

TRS RenTelco℠

Agenda

- Welcome and Introductions
  - Jim Ranstrom, TRS-RenTelco Regional Sales Director
- EXFO: Dark Fiber Testing & Reporting
  - Kevin Peres, EXFO Applications Engineer, Advanced Technologies and Solutions
- EXFO/TRS-RenTelco Partnership: Equipment & Special Promotions
- Q&A – Joint TRS and EXFO

TRS RenTelco℠

We provide comprehensive Test & Measurement solutions delivering equipment-as-a-service.

Plan, acquire, and efficiently utilize instruments to maximize return on investment.

- End-to-end fulfillment from our Dallas, TX headquarters
- 5,000+ configurable models available, valued at over $500MM
- In-House Financing and flexible procurement programs to Rent, Lease, or Buy
- State-of-the-Art 20,000 sq ft Calibration Lab on site
- Same-Day-Shipping with Next Day Delivery Available

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Customer Service Excellence

Talk with a **Live Person** when you call

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Late-Order processing

Comprehensive Solutions

Customized **In-house Financing**

Deep and wide **Inventory**

Equipment ships **Ready To Use**

Fulfillment Accuracy & Speed

Same-day Shipping

80% of Calibrations Performed In-house

99.72% Customer-Scored Equipment Quality Ranking

Reliable Expertise

Strategic singular focus on the rental market

Top-tier rental partner to all major manufacturers

Financially Secure publicly traded company

Dark Fiber Testing & Reporting in Backhaul, Metro and Fronthaul Environments

Kevin Peres
Applications Engineer, Advanced Technologies and Solutions

Table of contents

Fiber Theory

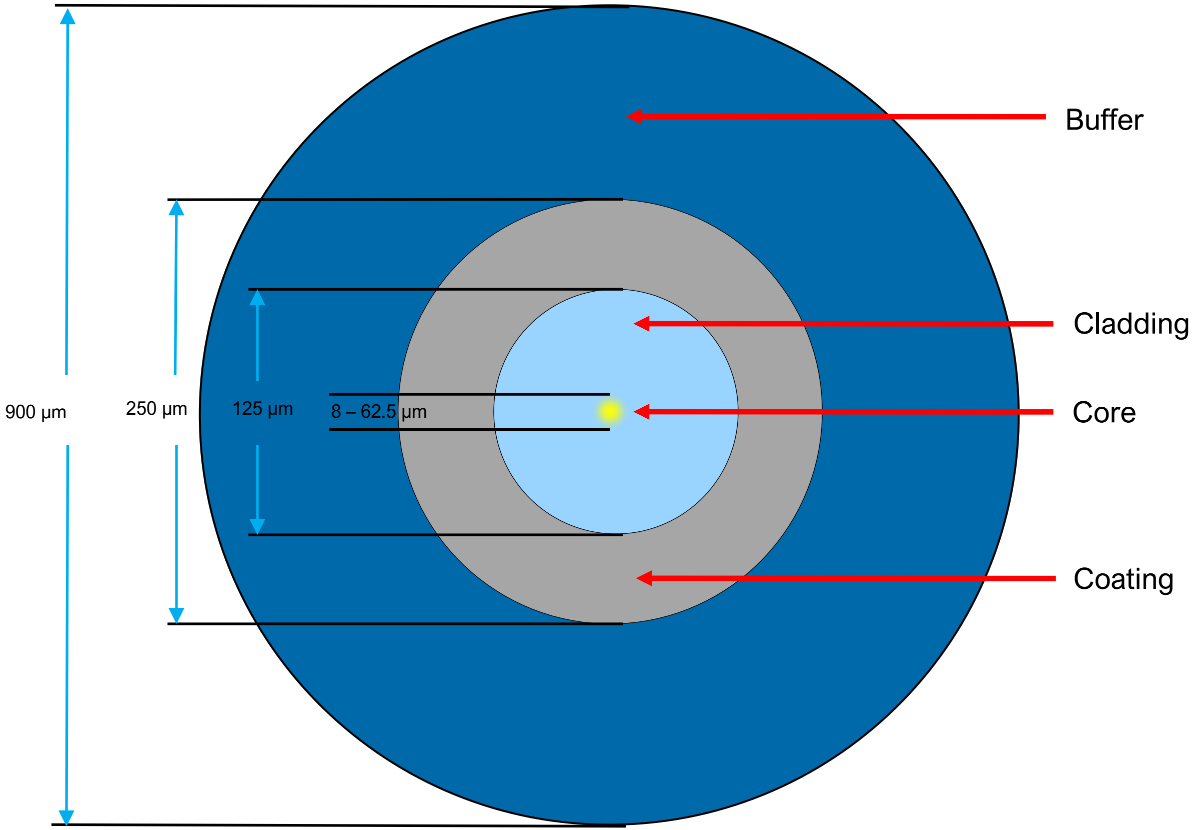
Fiber Optics - Summary

Fiber optic like twisted copper pairs is a medium used to transmit data. The big difference is that fiber-optics is drawn from glass (silica) and uses light pulses to transmit information down the fiber instead of using electronic pulses used in copper lines.

At one end of the system is a transmitter which transmits light pulses down the fiber and a receiver to detect or decode the light pulses.

A light-emitting diode (LED) or an injection-laser diode (ILD) can be used for generating the light pulses.

Fiber Sections

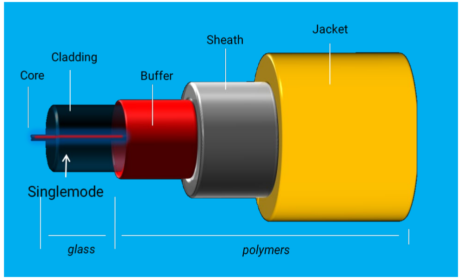


Core: Carries signal

Cladding: Keeps the light in the core

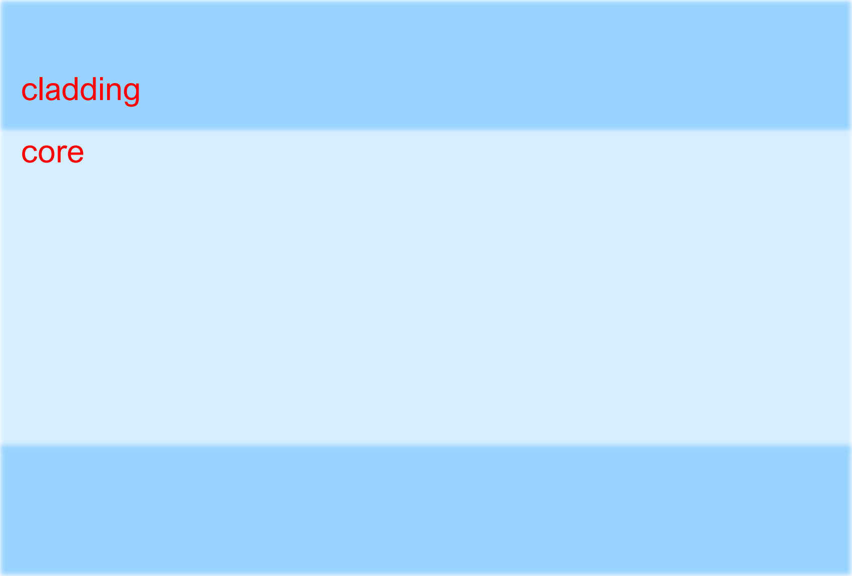
Coating: Protects the Core and Cladding

Buffer: Protects the Core and Cladding



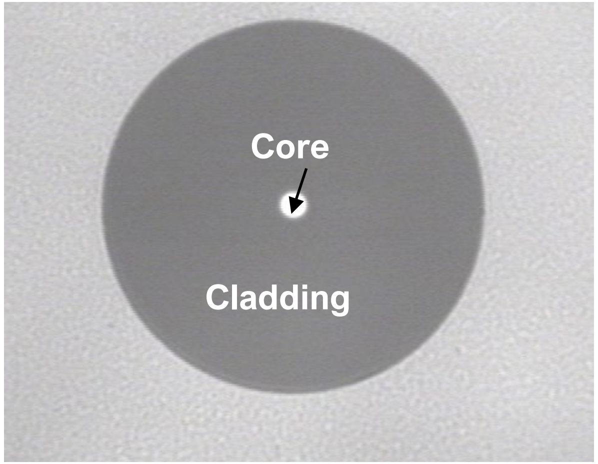
Total Internal Reflection

Total internal reflection is achieved in the fiber by having two different refractive indexes – the core IOR is higher than the cladding IOR



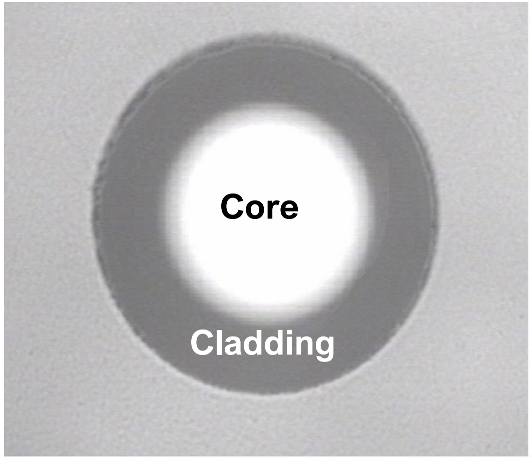
Fiber Types

Singlemode Fiber

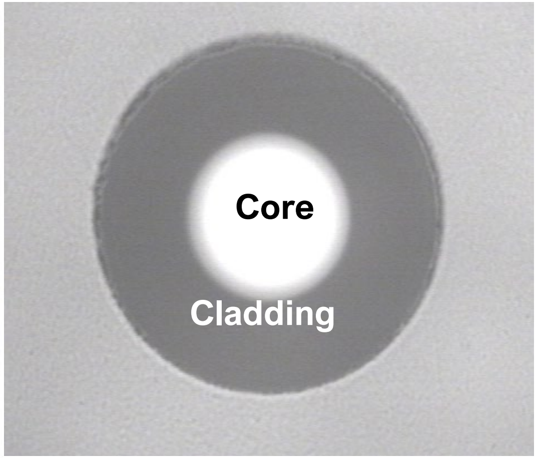


9/125 (µm)

Multimode Fiber



62.5/125 (µm)



50/125 (µm)

The diameter of a fiber is measured in micrometer, or **micron** (µm).

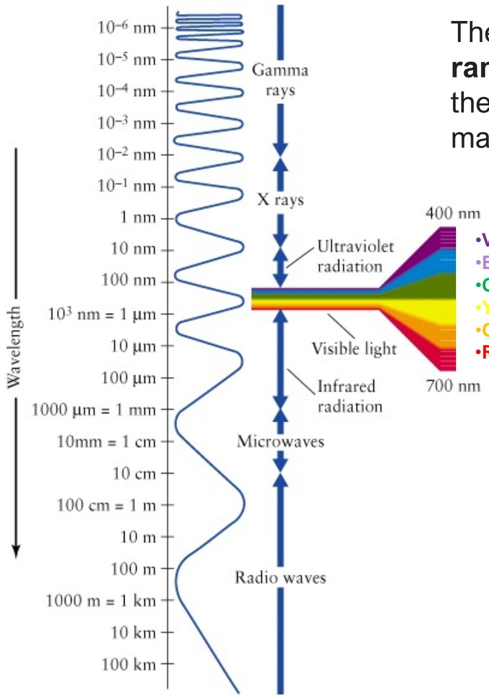
– One µm = one millionth of a meter.
– One µm = 0.000039 inches

One human hair is ~ 60-80 µm

Singlemode Fiber Standards

ITU-T G.652.D Fibers Singlemode Local "Characteristics of a single-mode optical fibre and cable"	Non-Dispersion Shifted Fiber NDSF
ITU-T G.653 A/B "Characteristics of a dispersion-shifted single-mode optical fibre and cable"	Dispersion-Shifted Fiber DSF
ITU-T G.654.B/D "Characteristics of a cut-off shifted single-mode optical fibre and cable"	Cut-off Shifted Fiber
ITU-T G.655.C/D "Characteristics of a non-zero dispersion-shifted single-mode optical fibre and cable"	Non-Zero Dispersion Shifted Fiber NZDSF
ITU-T G.656 Fibers "Characteristics of a fibre and cable with Non-Zero Dispersion for Wideband Optical Transport"	Low Slope Dispersion Shifted Fiber
ITU-T G.657.A1/A2/B3 "Characteristics of a bending loss insensitive single mode optical fibre and cable for the access network"	Bend Sensitive Fiber BIF

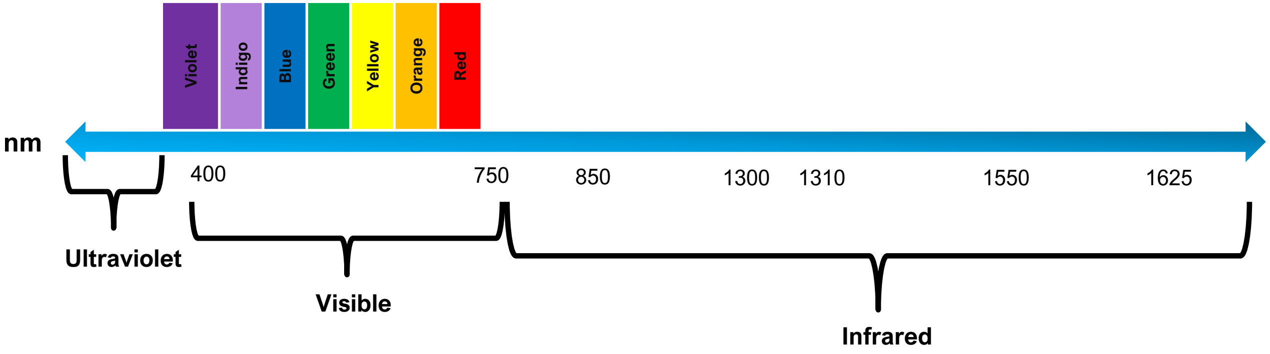
Electromagnetic Spectrum



https://energyeducation.ca/encyclopedia/Wavelength

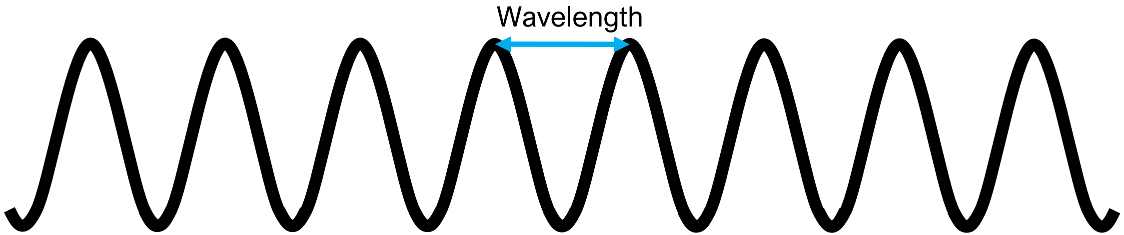
The **electromagnetic spectrum** is the term used to describe **the entire range of "light" that exists.** From radio waves to gamma rays. Most of the "light" is invisible to us. Light is a wave of alternating electric and magnetic fields.

- **Violet**: 380–450 nm
- **Blue**: 450–495 nm
- **Green**: 495–570 nm
- **Yellow**: 570–590 nm
- **Orange**: 590–620 nm
- **Red**: 620–750

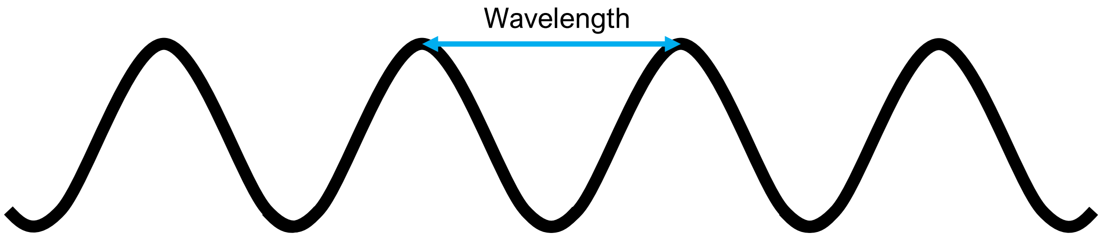


Wavelength

Wavelength, distance between corresponding points of two consecutive waves



Short Wavelength – High Frequency



Long Wavelength – Low Frequency

Wavelength Band	Wavelength Range
O Band	1260 – 1360 nm
E Band	1360 – 1460 nm
S Band	1460 – 1530 nm
C Band	1530 – 1565 nm
L Band	1565 – 1625 nm
U Band	1625 – 1675 nm

Index of Refraction

The Ratio of the velocity of the light in a vacuum to the velocity of light in any other medium.

Speed of light in a vacuum (**c**=299,792.458 km/second) divided by the speed of light in a material

Speed of light (vacuum)	299,792,458	m/s
IOR	1.468325	
Speed of light in fiber	204,173,094	m/s
	204.173	m/μs
	0.204	m/ns

Material	Velocity (Miles/s)	Velocity (KM/s)	Refractive Index
Space (Vacuum)	186,282	299,792	1.0
Air	186,232	299,890	1.0
Water	140,061	225,442	1.33
Glass	122,554	197,349	1.52

$$n = \frac{c}{v}$$

$$\text{IOR of Glass} = \frac{\text{Speed of light in space}}{\text{Speed of light in glass}} = \frac{299{,}792}{197{,}349} = 1.519$$

dB vs dBm – Relative vs Absolute

Measurement units:

dB (*decibel*) or dBm (*dB milliWatt*)

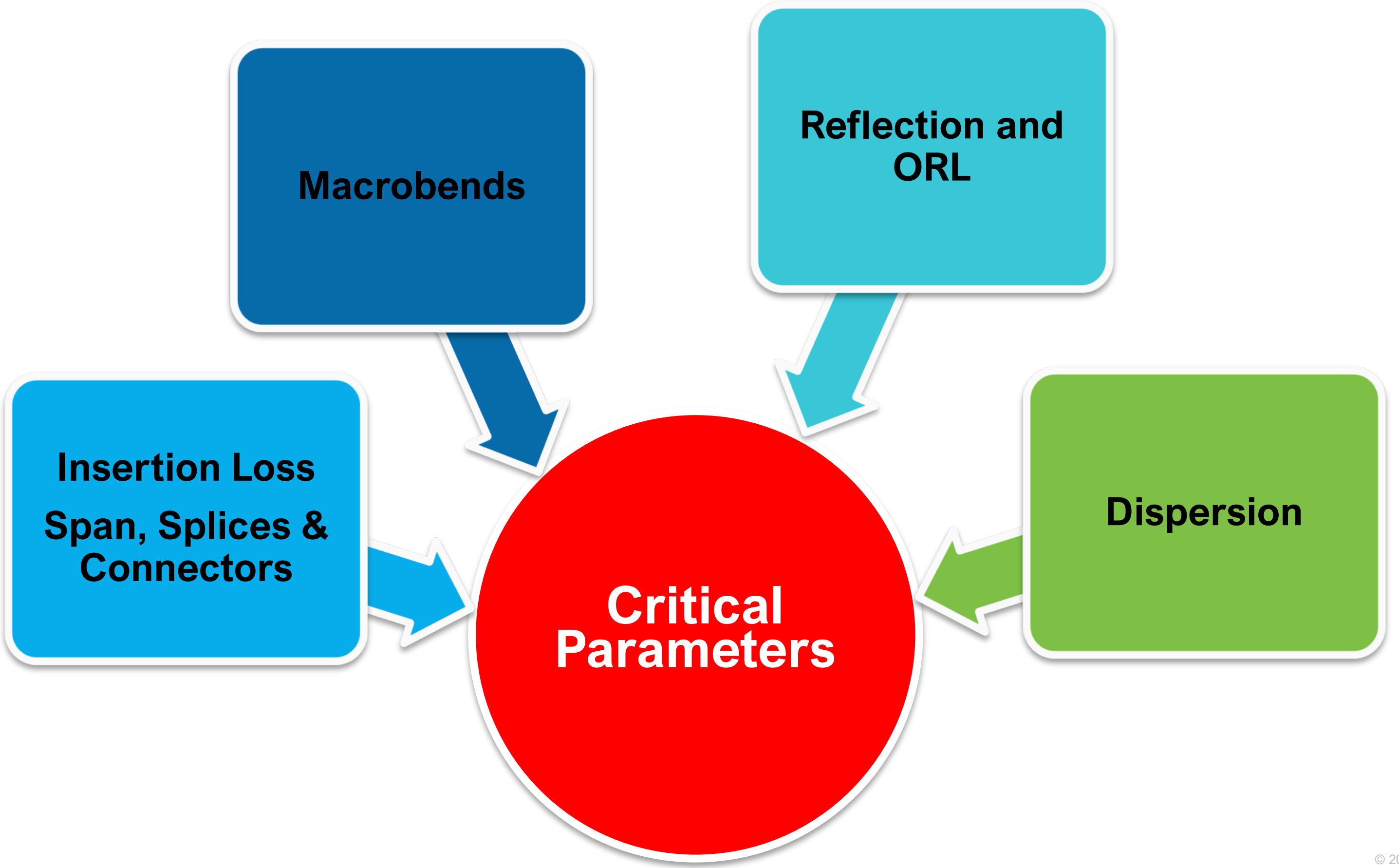
?

We use the dBm unit when we talk about the POWER which is an absolute value measured at a specific point in a link.
Example: Power coming out of a transmitter

We use the dB unit when we talk about a LOSS which is a referenced value.
Example: Loss of a fiber section

Power (dBm)	Power (watts)
-40	0.0001 mW
-30	0.001 mW
-20	0.01 mW
-10	0.1 mW
0	1 mW
10	0.01 W
20	0.1 W
30	1 W
40	10 W

Critical Parameters



Critical Parameters

Macrobends

Insertion Loss

Span, Splices & Connectors

Reflection and ORL

Dispersion

Test Equipment

FTB-1 Platform

FTBx-700 Series OTDR/iOLM

Critical Parameters

Macrobends

Insertion Loss
Span, Splices & Connectors

Reflection and ORL

MAX-945 OLTS

Test Equipment

Dispersion

Critical Parameters

Macrobends

Insertion Loss
Span, Splices & Connectors

Reflection and ORL

FIP-435B
Fiber Inspection Probe

Test Equipment

Dispersion

Critical Parameters

Macrobends

Insertion Loss
Span, Splices & Connectors

Reflection and ORL

Dispersion

FTB-5700 Singled Ended CD/PMD

FTB-5500B/5800 CD/PM Modules

Attenuation

Loss vs Power

It is critical to minimize the loss (attenuation) across the fiber cable and components.

For every 3dB of loss you suffer a 50% penalty.

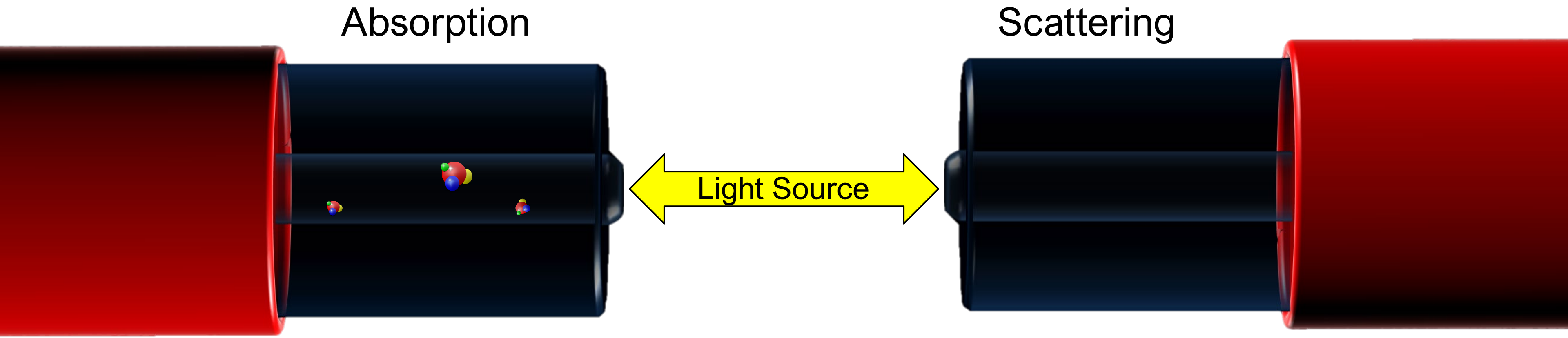
Loss	Power Loss %	Power Remaining %
0.10 dB	2%	98 %
0.20 dB	4.5%	95.5%
0.5 dB	11%	89%
1 dB	19%	79%
3 dB	50%	50 %
6 dB	75%	25 %
10 dB	90%	10 %
20 dB	99%	1 %
30 dB	99.9 %	0.1 %
40 dB	99.99%	0.01%
50 dB	99.999 %	0.001 %

Attenuation - Intrinsic

The steady decrease or loss in signal power in an optical fiber, primarily due to absorption and scattering.

The loss is wavelength-dependent and measured in decibels or dB.

Not affected by outside influences

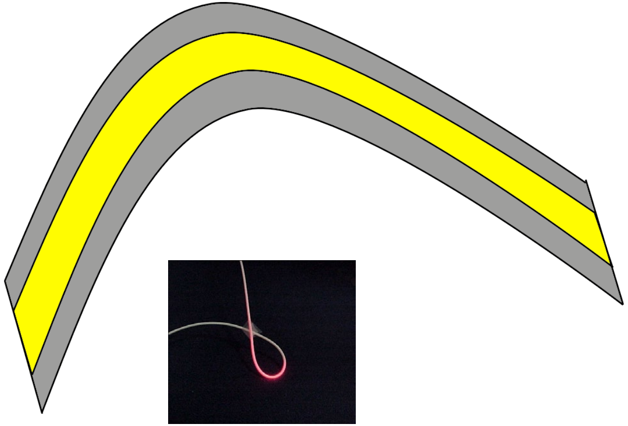


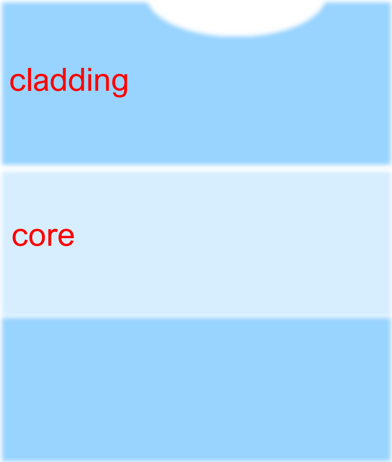
Attenuation - Extrinsic

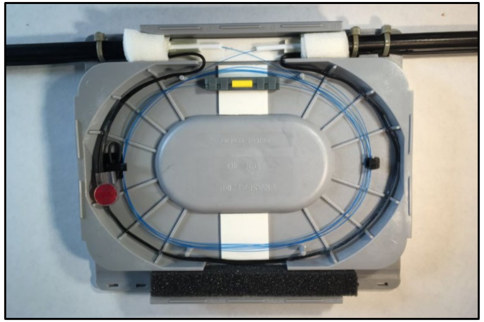
The decrease in signal power due to change in the properties in the fiber.

- Microbend
- Macrobend
- Splices
- Fiber Endface Connection

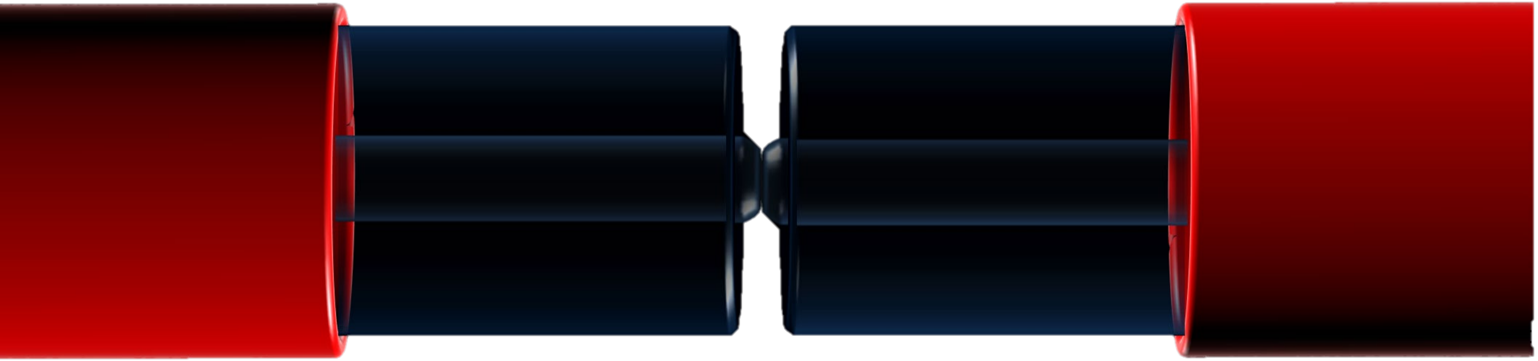
Caused by outside influences



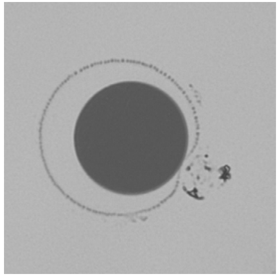


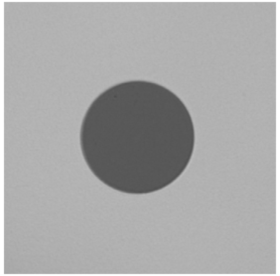


Connectors - Loss

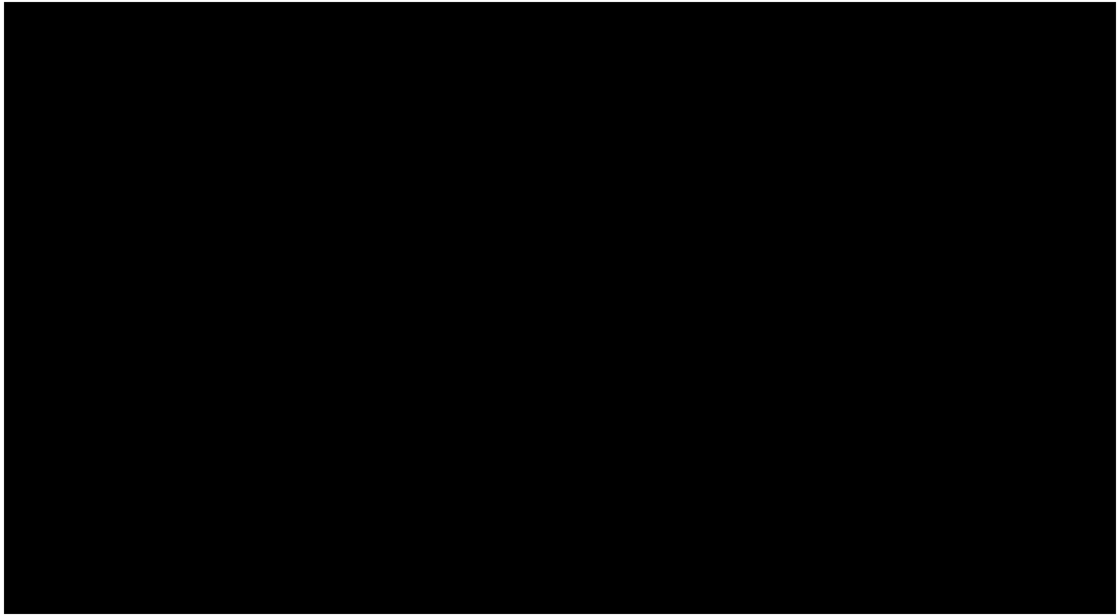


FIP-435B

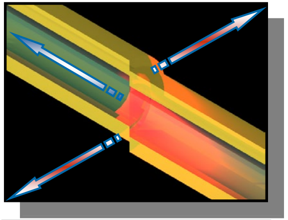


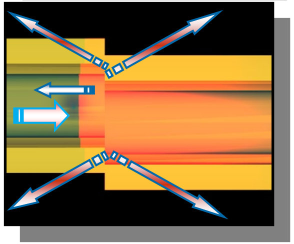


Splicing

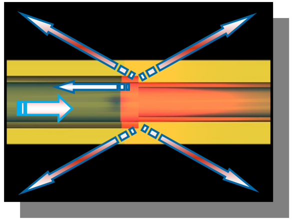


Misalignment





Mismatch

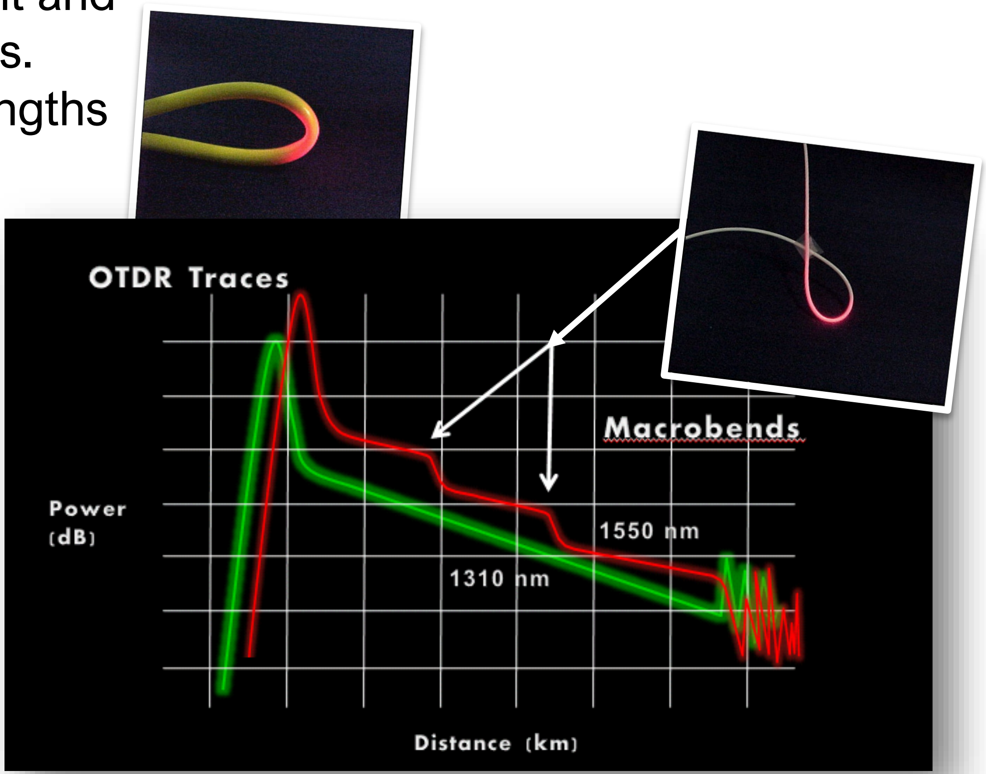


www.thefoa.org

Wavelengths and Macro-Bends

Bending loss is wavelength dependent and increases as the wavelength increases. Macrobends will affect longer wavelengths more than shorter wavelengths.

If 1550nm has **MORE** loss then 1310nm at a splice, connector or end-to-end there could be a macro-bend (pinch/compression) in the fiber



Attenuation Coefficient

The Attenuation (loss) Coefficient is the amount of loss per km. (dB/km)

To determine this value, you divide the span loss against the length.

$$dB/km = \frac{loss}{length}$$

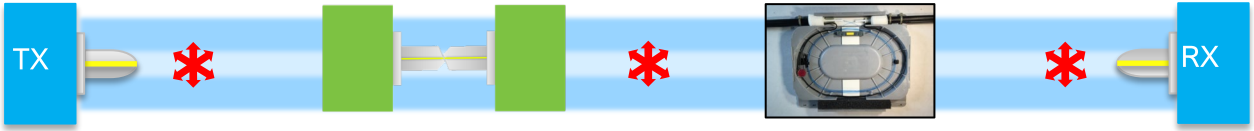
Multimode	Attenuation (dB/km)	
	850nm	1300nm
OM1	3.5	1.5
OM2	3.5	1.5
OM3	3.0	1.5
OM4	3.0	1.5
OM5	3.0	1.5

Singlemode Fiber	Core Diameter (µm)	Attenuation (dB/km)	
		1310nm	1550nm
OS1	8-9	1.0	1.0
OS2	8-9	0.4	0.4

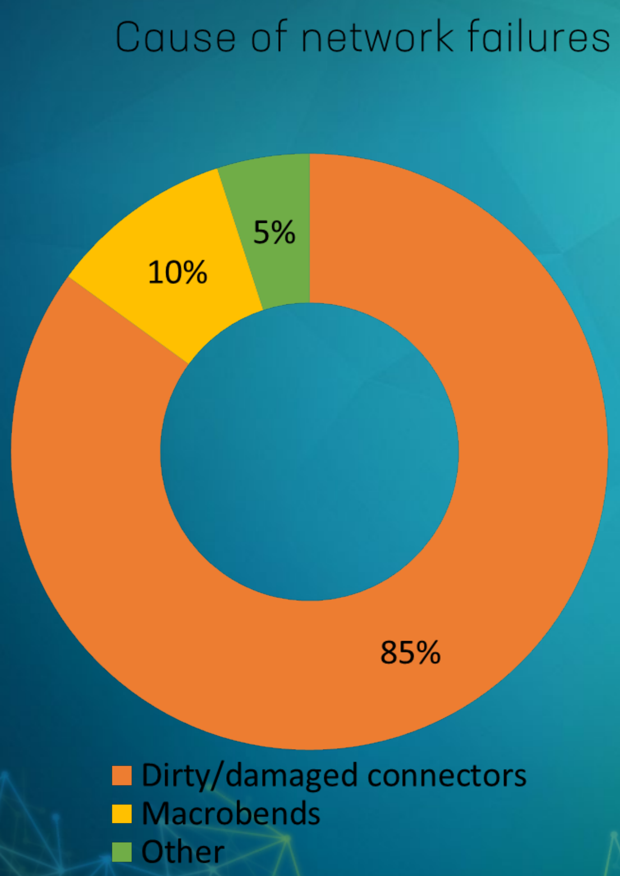
OS1 (ISO/IEC 11801 Ed.2.2:2010) OS2(ISO/IEC11801Ed.2.2: 2010)

Image Source :https://rfindustries.com/fiber-optic-cable-types-multimode-and-single-mode/

Optical Budget

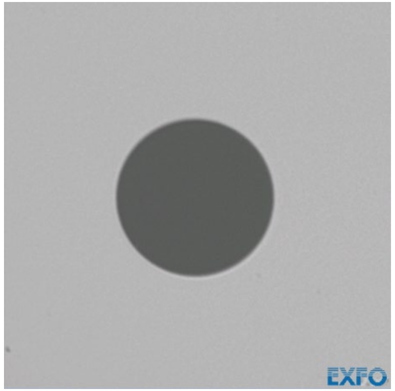


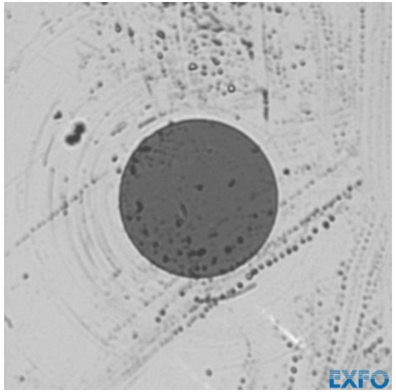
Reflection – Optical Return Loss



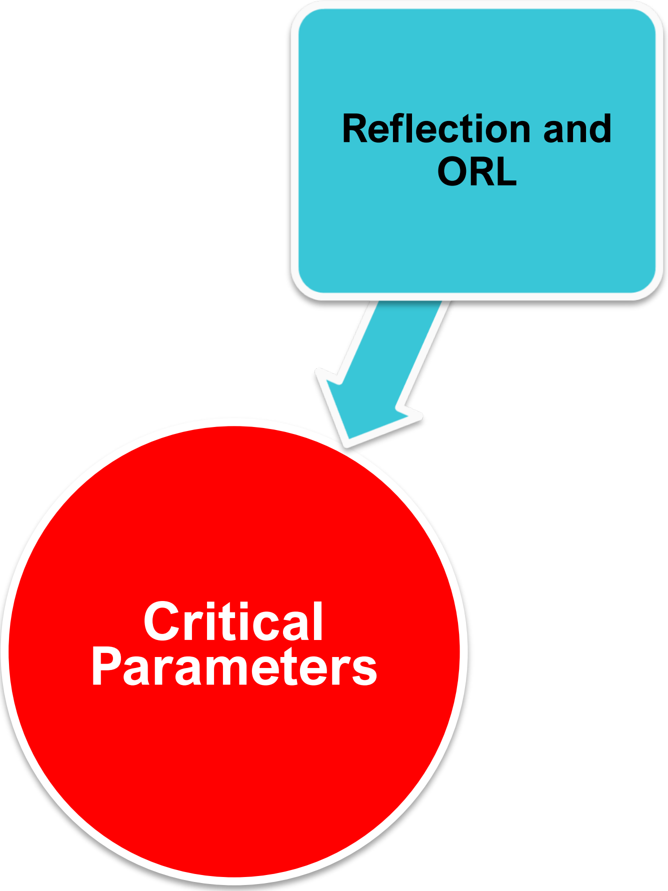
The number **1** cause of network failure is

BAD CONNECTORS





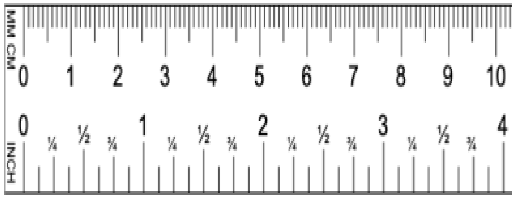
Critical Parameters



How small is a micron?

One micron is 1/1000 mm (1/25,000 of an inch). Airborne particles are general described in microns. The human eye can see debris and dust approximately 25 microns in size.

The Corona virus has a diameter of between 0.06 µm (micron or micrometer), and 0.14 µm.

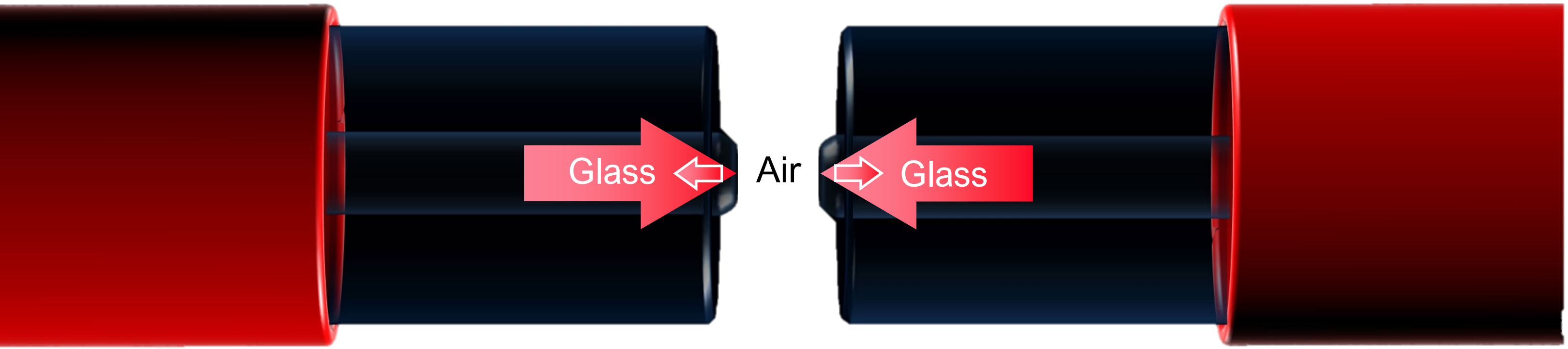


Reflection

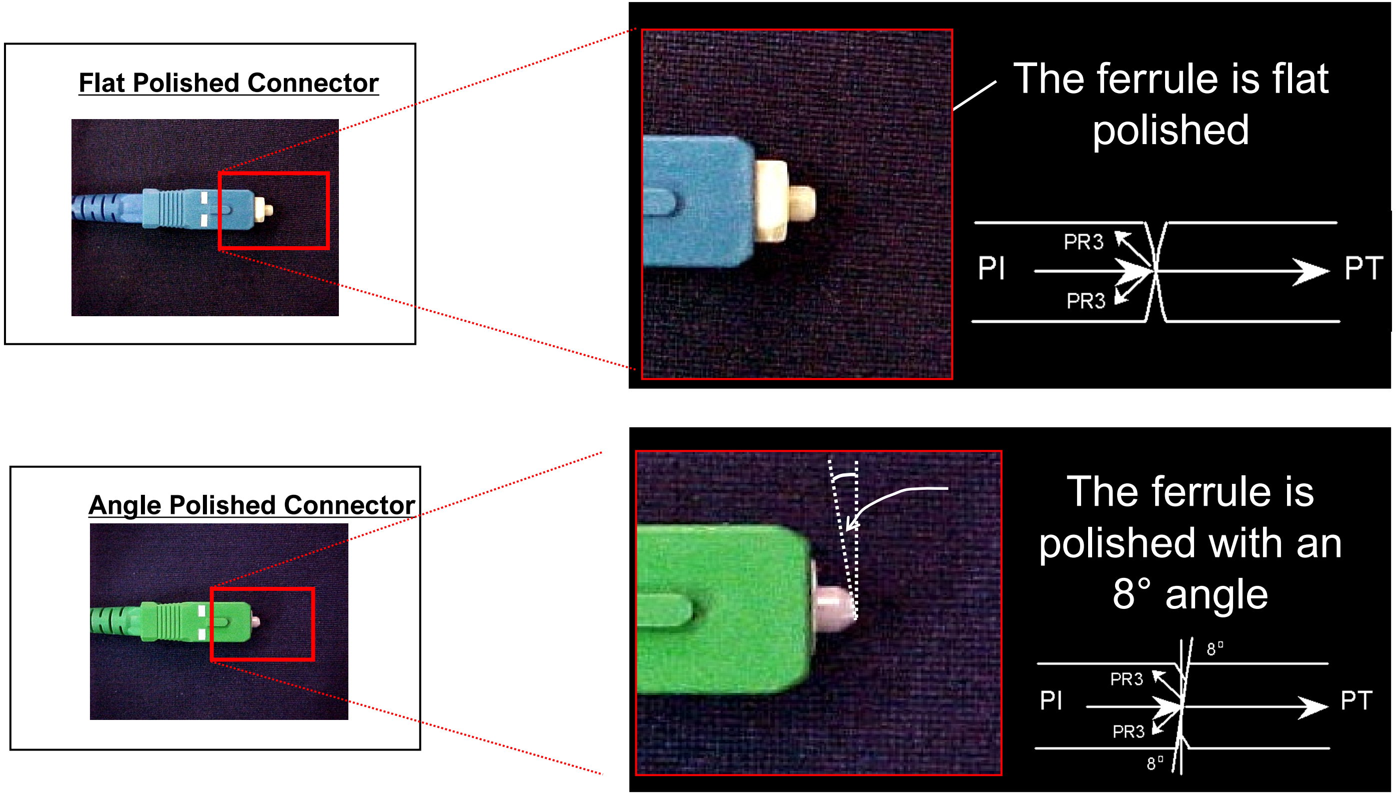
The change in direction of a light beam at an interface between two dissimilar media so that the light beam returns into the medium from which it originated. A good example is a window glass. The larger the difference of refractive index the larger the reflection. In an optical communications system, such reflections may cause disturbance of the laser transmitter and cause transmission errors.

Displayed in negative values
Ex. UPC

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

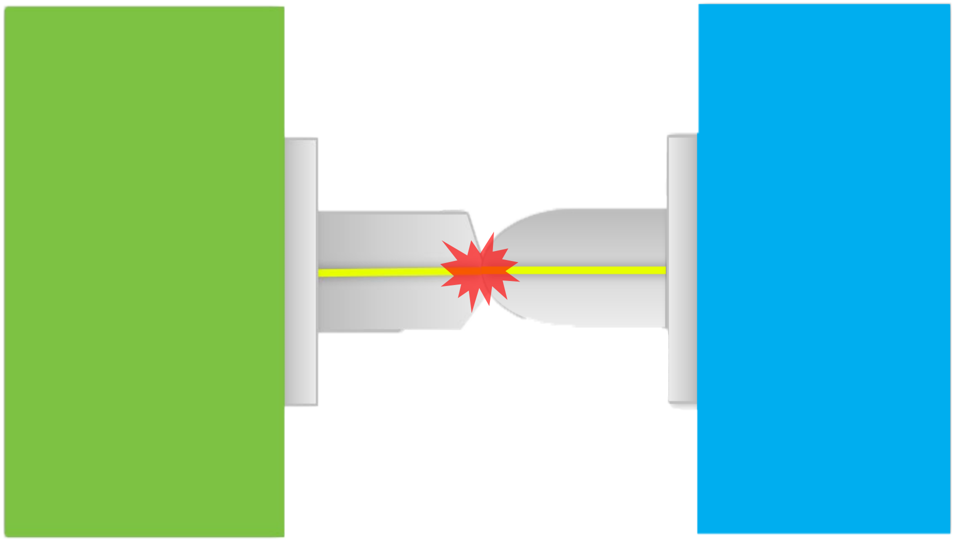


UPC vs APC


Flat Polished Connector
The ferrule is flat polished
PI
PR3
PR3
PT
Angle Polished Connector
The ferrule is polished with an 8° angle
8°
PI
PR3
PR3
PT
8°

Not compatible

Never plug a UPC (blue) connector with an APC (green)
It can damage the end face!



Connector Evolution

Over the year's connectors have had to evolve to handle higher bandwidth and more amplification

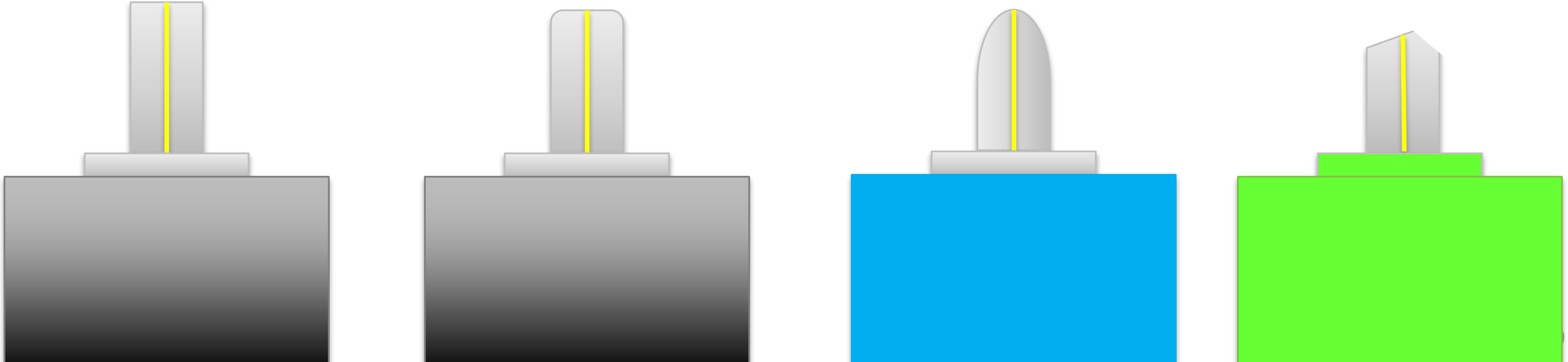
While there were improvement in loss much of the increased performance was focused on reducing reflection (noise)

FLAT
<-30dB Reflection
0.1% to 1% return

PC
<-35dB Reflection
0.01% return

UPC
<-55dB Reflection
0.001% return

APC
<-65dB Reflection
0.0001% return



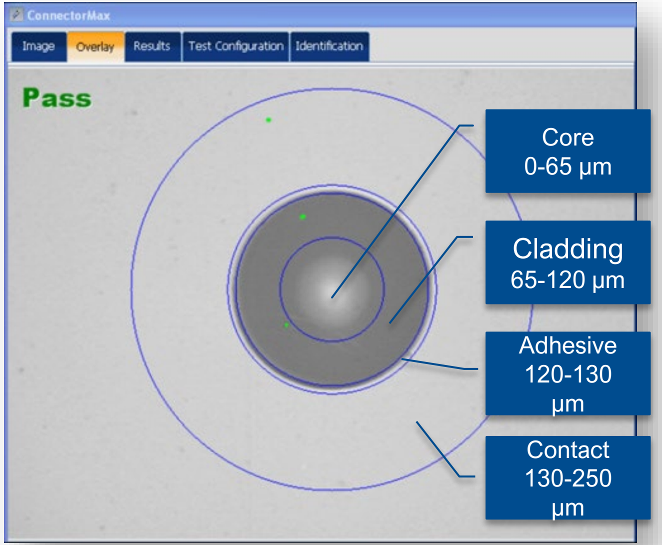
IEC 61300-3-35 Zones

A connector endface is divided into multiple zones

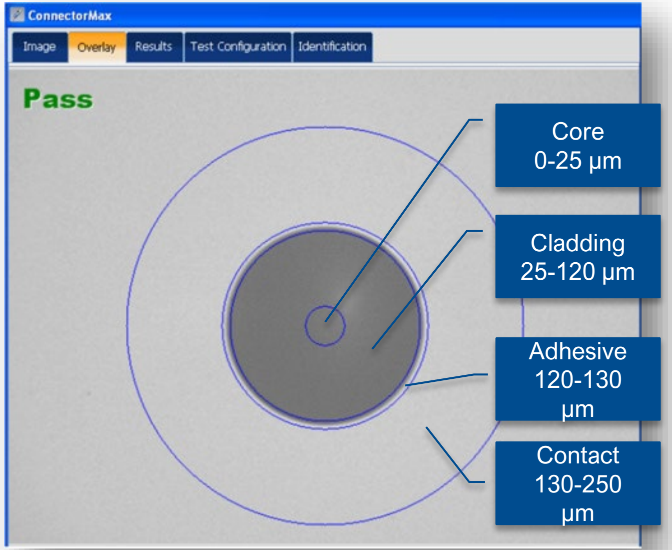
Dimensions will depend on the connector and fiber type

Multimode and singlemode connectors have different sizes

IEC zone sizes for PC polished connectors, multimode fibers



singlemode non-dispersion shifted fiber, RL ≥45 dB



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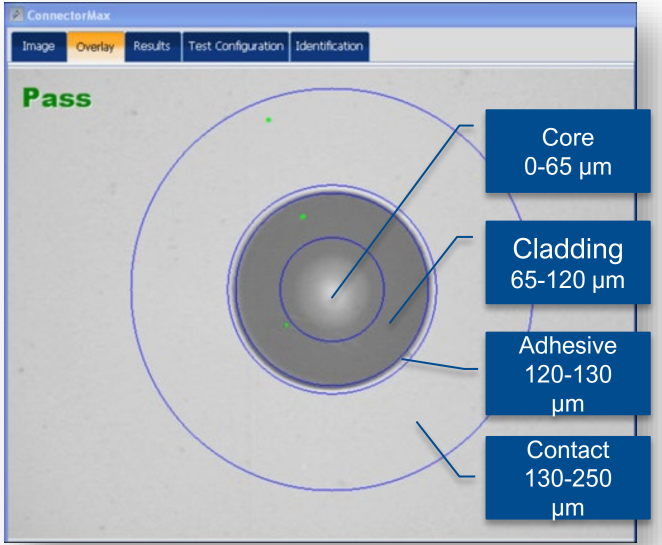

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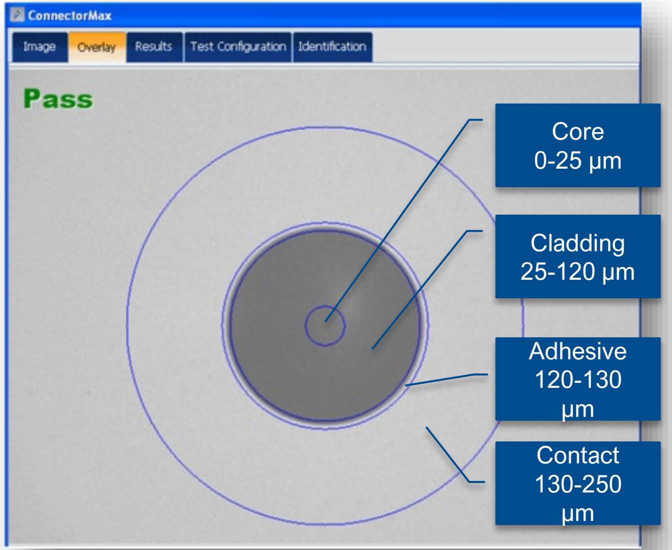
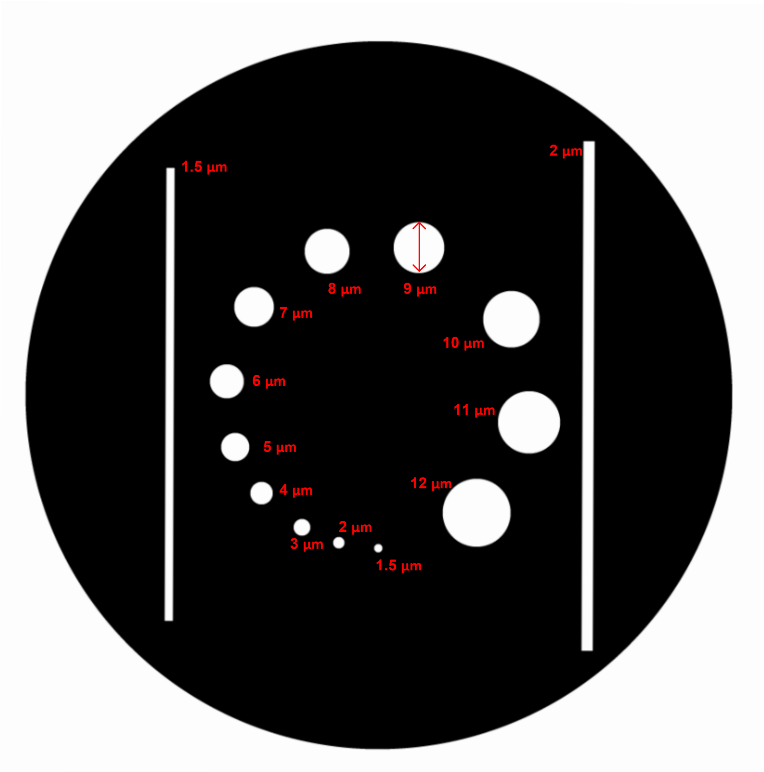
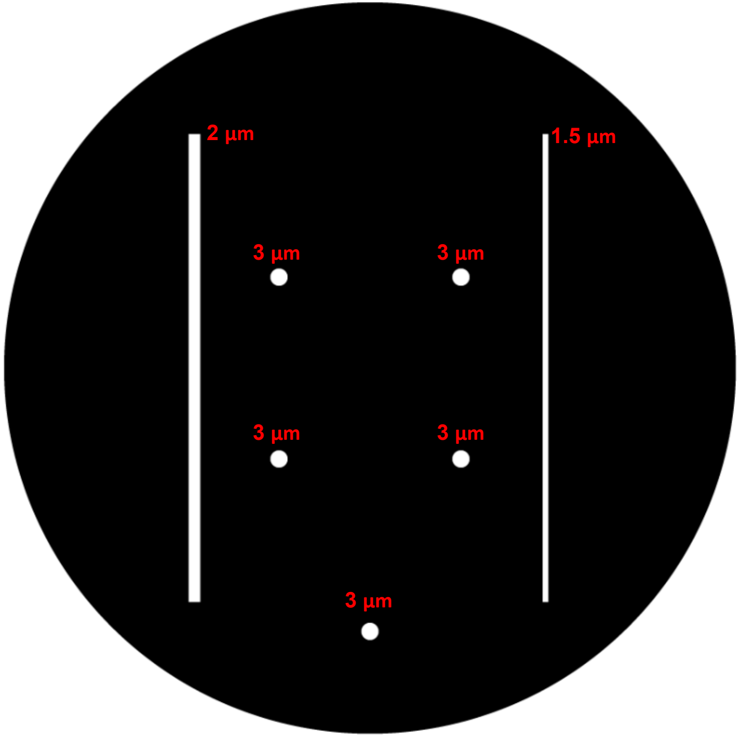
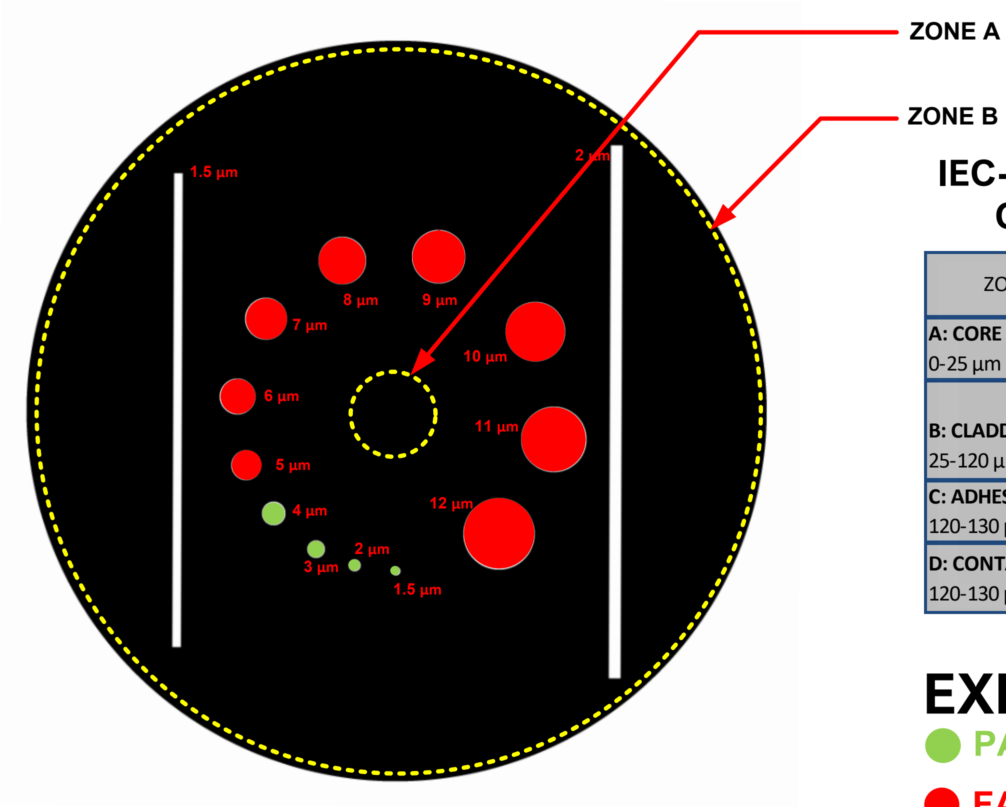


Contamination Size Comparison





Contamination Size Comparison



IEC-613000-3-35 Single-Mode UPC Connector with ORL ≥ 45 dB

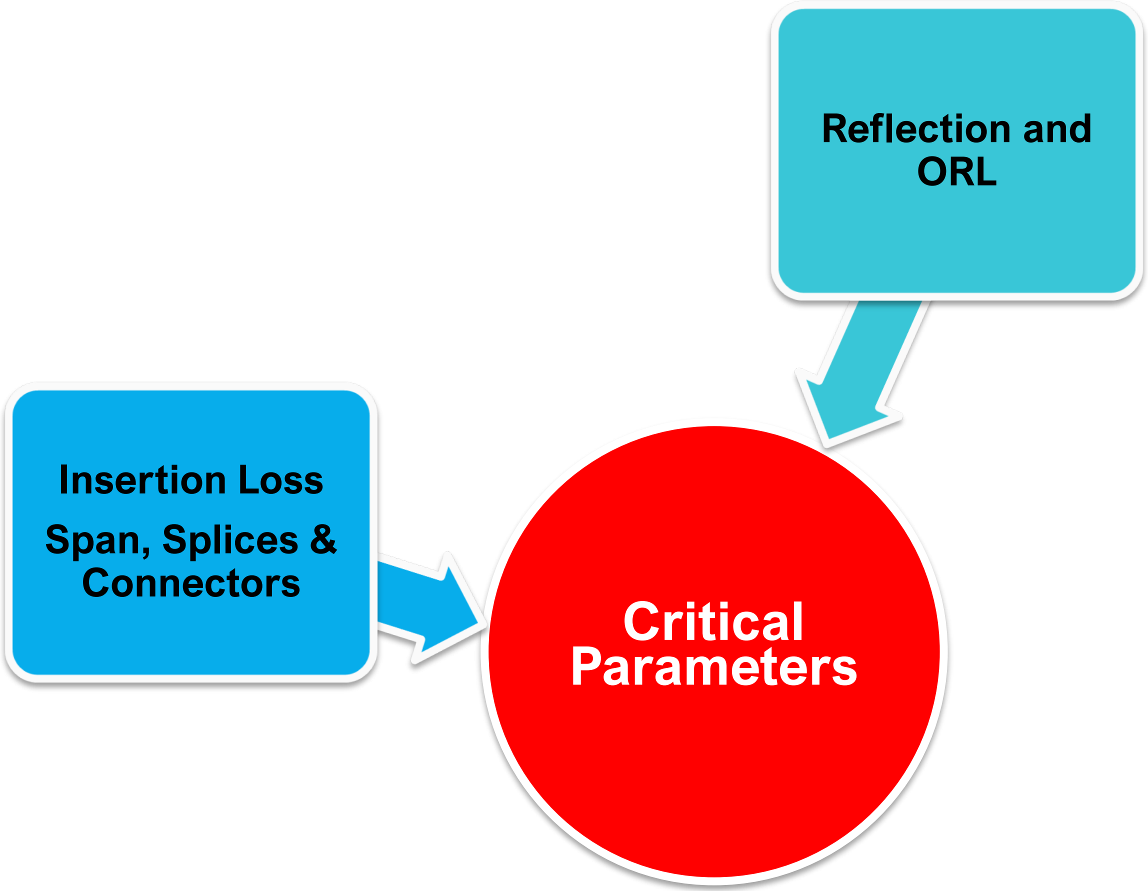
ZONE	DEFECTS	
	Criteria	Thresholds
A: CORE 0-25 µm	0 µm ≤size< ∞	0
B: CLADDING 25-120 µm	0 µm ≤ size < 2 µm 2 µm ≤ size < 5 µm 2 µm ≤ size <∞	any 5 0
C: ADHESIVE 120-130 µm	-	-
D: CONTACT 120-130 µm	0 µm ≤ size < 10 µm 10 µm ≤ size < ∞	any 0

EXPECTED RESULTS:

- PASS
- FAIL

Connector Cleaning

Critical Parameters



Cleaning

Inspection and Cleaning are Critical

Any contamination in the fiber connection can cause failure of the component or failure of the whole system.

A 1 micrometer dust particle on a single-mode core can block up to 1% of the light resulting in around 0.05 db of loss

A 9 micrometer speck is still too small to see without assistance of a scope, but it could completely block the fiber core.

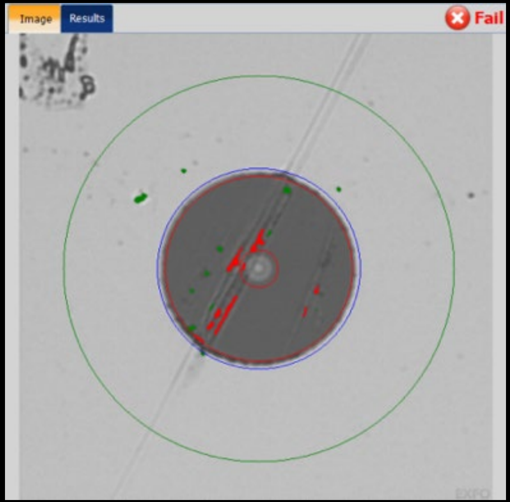
For comparison, a typical human hair is 50 to 75 micrometers in diameter, as much as eight times larger. So, even though dust may not be visible, it is still present in the air and can deposit onto the connector.

When to clean?

Inspect Clean – Inspect Connect (ICIC)

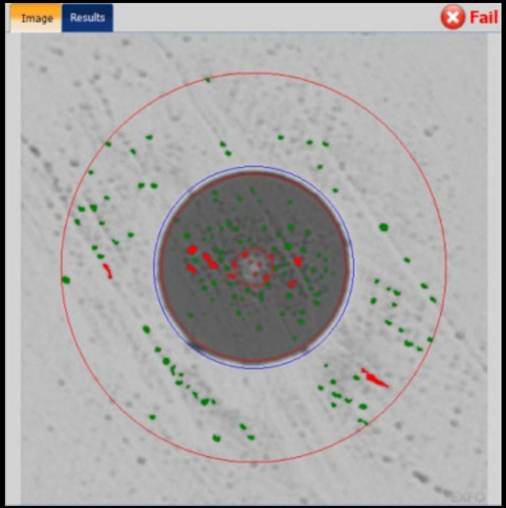
DAMAGED = REPLACE

Cleaning is worthless



DIRTY = CLEAN

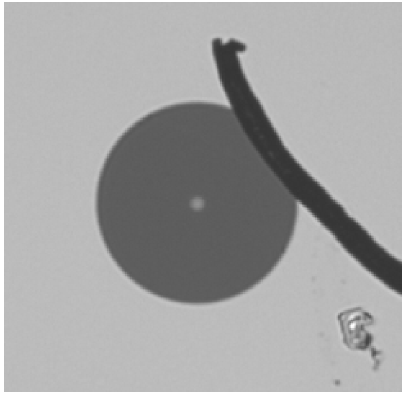
Clean ONLY if needed



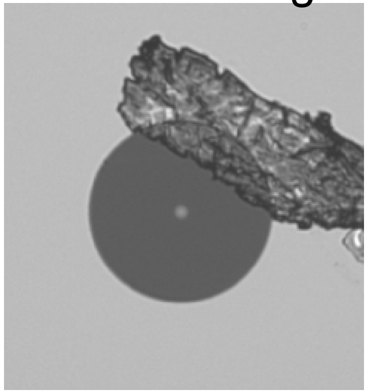
CLEAN = CONNECT

NO cleaning required

Before mating



After mating



Connector Cleaning

Dry method

An efficient technique for removing light contaminants

Often considered the technique of choice in a controlled manufacturing environment where speed and ease of use are important factors

Advantages	Disadvantages
Convenience of readily available tools	Can possibly create electrostatic charges
Fast and easy	Not effective in removing all contaminant types

Example of dry cleaning supplies:

Specialized lint free wipes and swabs

Mechanic cleaning devices



Connector Cleaning

Combination method (hybrid)
Combination cleaning is a mix of the wet and dry cleaning methods
The first step in hybrid cleaning is to clean the connector end-face
with a solvent and to dry any remaining residue with either a wipe or a swab

Advantages	Disadvantages
Cleans all soil types	Requires multiple products
Reduces potential static field soil accumulation	
Automatically dries moisture and solvent used in the cleaning process	
Captures soil in wiping material as an integrated aspect of cleaning procedure	
Not expensive	

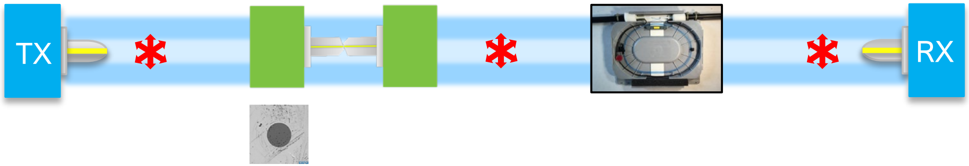
Example of combination cleaning supplies:
Specialized wipes and solvents

Optical Return Loss (ORL)

ORL is the reflected light that returns to the source. It is the ratio between the transmitted power and receive power.

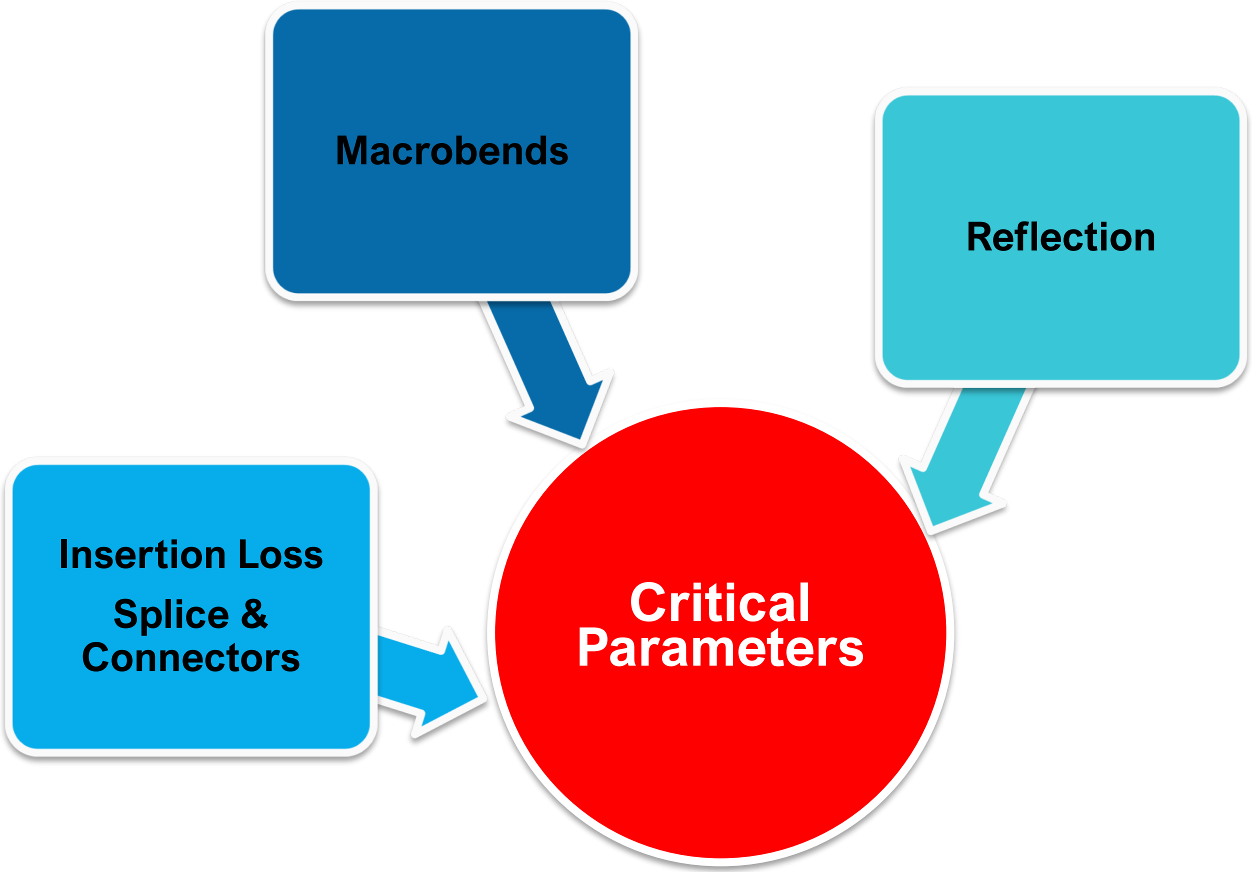
Optical Return Loss of Single Mode Fiber vs Length

Length	ORL
1 Meter	70 dB
10 Meters	60 dB
100 Meters	50 dB
1000 Meters	40 dB
Infinity	32 dB



OTDR Theory

Critical Parameters



Loss vs Power

It is critical to minimize the loss (attenuation) across the fiber cable and components.

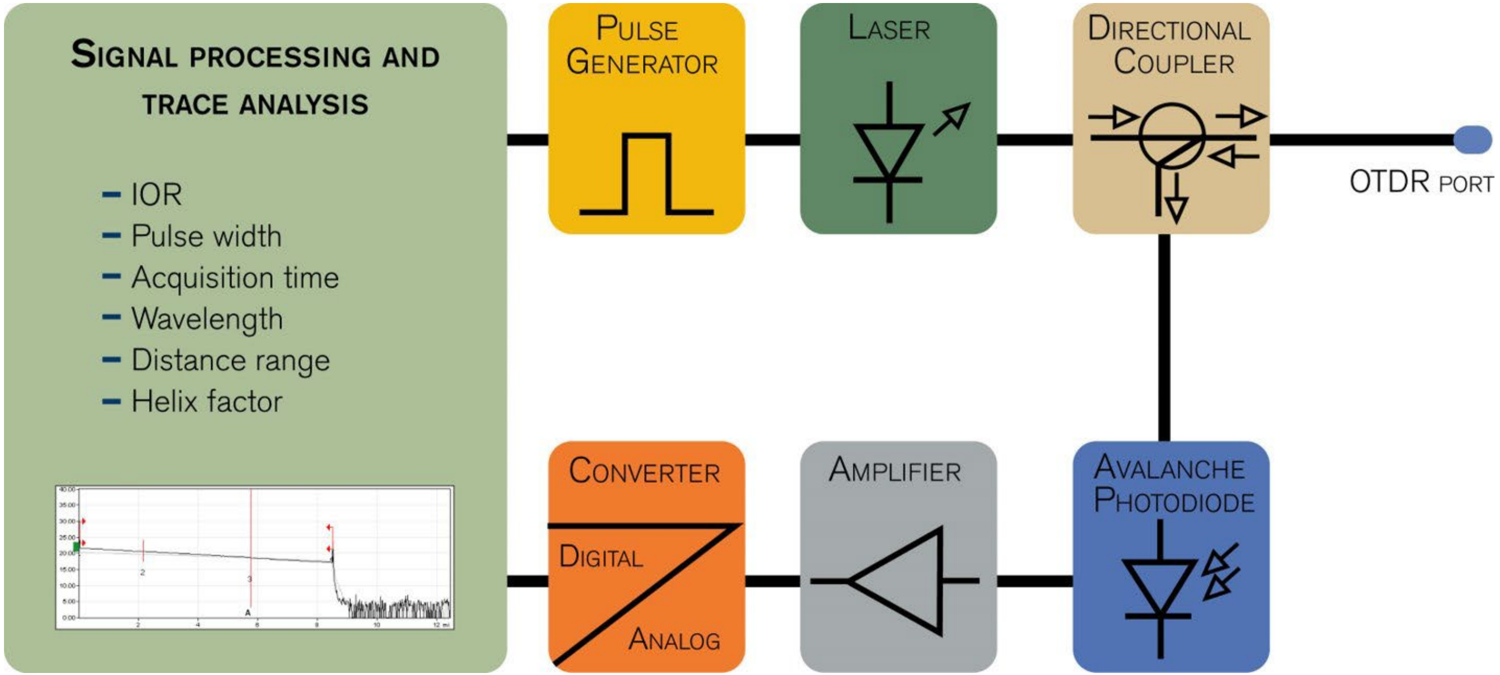
For every 3dB of loss you suffer a 50% penalty.

Loss	Power Loss %	Power Remaining %
0.10 dB	2%	98 %
0.20 dB	4.5%	95.5%
0.5 dB	11%	89%
1 dB	19%	79%
3 dB	50%	50 %
6 dB	75%	25 %
10 dB	90%	10 %
20 dB	99%	1 %
30 dB	99.9 %	0.1 %
40 dB	99.99%	0.01%
50 dB	99.999 %	0.001 %

OTDR – Optical Time Domain Reflectometer

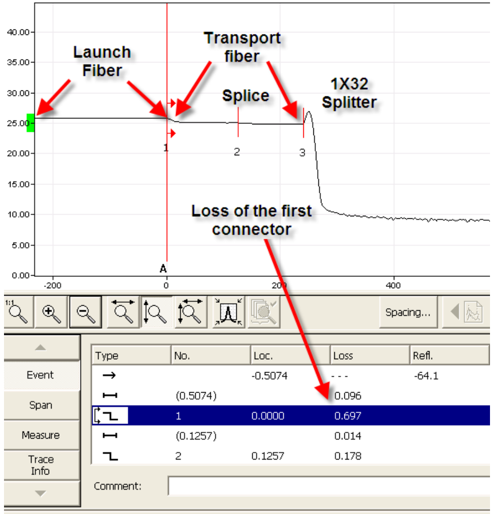
An optical test instrument used to detect light loss in a single fiber by injecting short laser pulses into the core and then measuring the subsequent backscatter level at all points along the fiber.

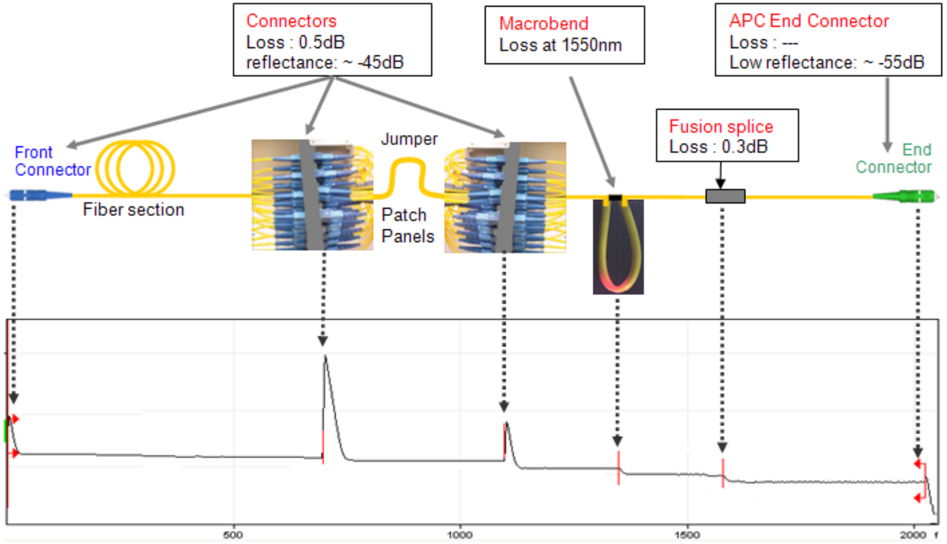
Reflectometry theory



What does an OTDR do?

- ✓ Break points
- ✓ Splice and connector losses
- ✓ Point-to-point distances
- ✓ Total cable length
- ✓ Connector quality (return loss)
- ✓ Fiber attenuation





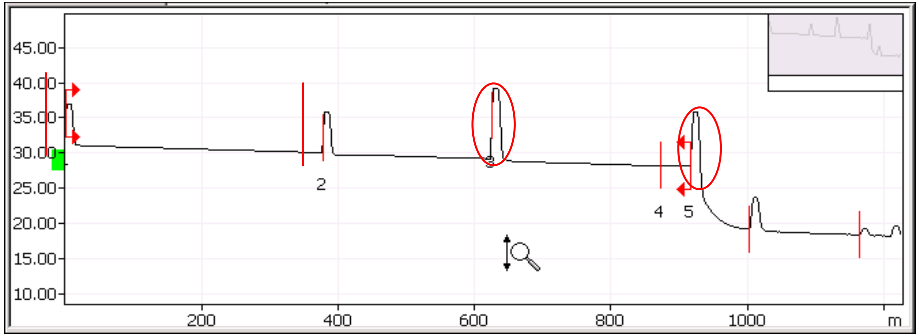
When to use an OTDR:

- ✓ Installation and commissioning
- ✓ Maintenance
- ✓ Emergency restoration
- ✓ Fiber identification
- ✓ Characterization

Reflectometry theory

<u>Fresnel back reflections</u>

- 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 time
higher than fiber's backscattering level
- Will create a Dead Zone after the reflection



An open UPC connector is -14.7dB of reflection. Terminated the reflection is -55dB at specification.

Pulse vs Dynamic range vs dead zone (example)

Pulse		Distance		Dead zone	
3	ns	5	Km	0.4	m
5	ns	14	Km	0.6	m
10	ns	22	Km	1.3	m
30	ns	37	Km	4	m
50	ns	60	Km	6	m
100	ns	69	Km	13	m
275	ns	78	Km	34	m
500	ns	96	Km	63	m
1000	ns	110	Km	125	m
2500	ns	117	Km	313	m
10000	ns	130	Km	1250	m
20000	ns	142	Km	2500	m

Note: Settings are based on typical fiber results. High loss spans will require adjusted settings.

Pulse vs Resolution

Speed of light in vacuum	299,792,458	m / s
IOR	1.468325	
Speed of light in fiber	204,173,094	m / s
	204.173	m / µs
	0.204	m / ns

1	s
1,000,000	µs
1,000,000,000	ns

Pulse Duration		Pulse Length	
3	ns	0.61	m
5	ns	1.02	m
10	ns	2.04	m
30	ns	6.13	m
50	ns	10.21	m
100	ns	20.42	m
275	ns	56.15	m
500	ns	102.09	m
1,000	ns	204.17	m
2,500	ns	510.43	m
5,000	ns	1,020.87	m
10,000	ns	2,041.73	m
20,000	ns	4,083.46	m

Spatial resolution

It exists a relationship between the Spatial Resolution and the Pulse Width of the probing signal.

$$\Delta_{zr} = (\nu_g \times \Delta_{ts}) / 2$$

$(\nu_g \times \Delta_{ts})$ = pulse length in meter

Spatial resolution = (pulse length) / 2

Δ_{zr} : Spatial Resolution
ν_g : Group Velocity, speed of the pulse - $\nu_g = c / n$
Δ_{ts} : Pulse duration

Pulse vs Distance

Pulse Width and Acquisition times based on Range		
Range	**Pulse Width**	**Time**
0 to 1.5km	5ns	15s
1.5 to 5km	5ns	15s
5 to 10km	10ns	30s
10 to 20km	30ns	30s
20 to 40km	100ns	30s
40 to 80km	275ns	60s
80 to 120km	1us	60s
120 to 160km	2.5us	60s

Note: Settings are based on typical fiber results. High loss spans will require adjusted settings.

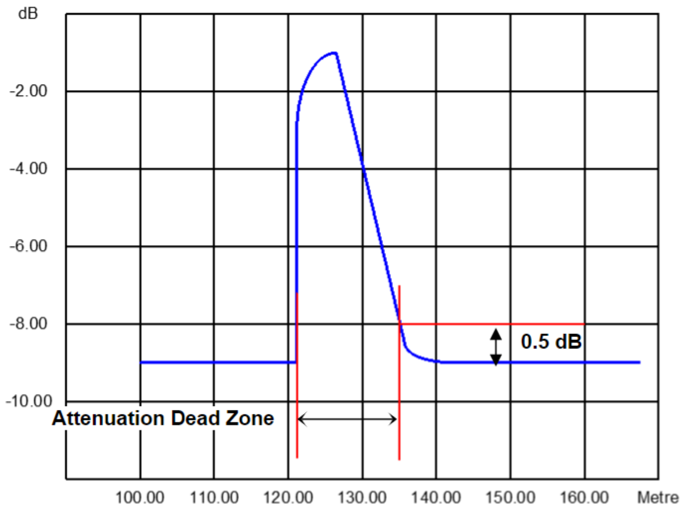
OTDR Specification and limitations

Attenuation dead zone

- Dead zone concerns only reflective events
- The attenuation or non-reflective dead zone is the minimum distance after which a consecutive reflective event and attenuation measurement can be made.

If a reflective or non-reflective event is outside the « Attenuation Dead Zone » of the preceding event, it will be localized and measured for loss.

It is the distance between:
The beginning of the events the point on the falling edge where the receiver sees a value around ±0.5dB from the normal backscatter trace



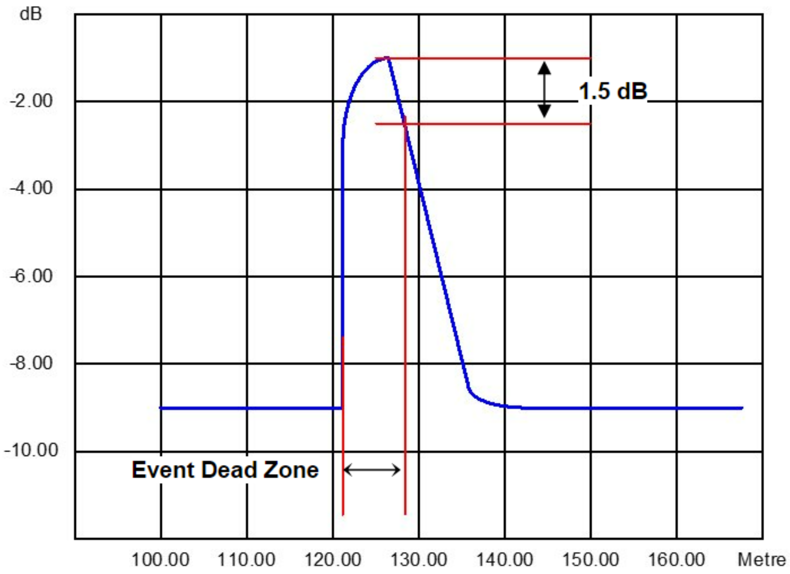
OTDR Specification and limitations

Event dead zone

- The event or reflective dead zone represents the minimum distance between the beginning of a reflective event and the point where a consecutive reflective event should clearly be recognized.

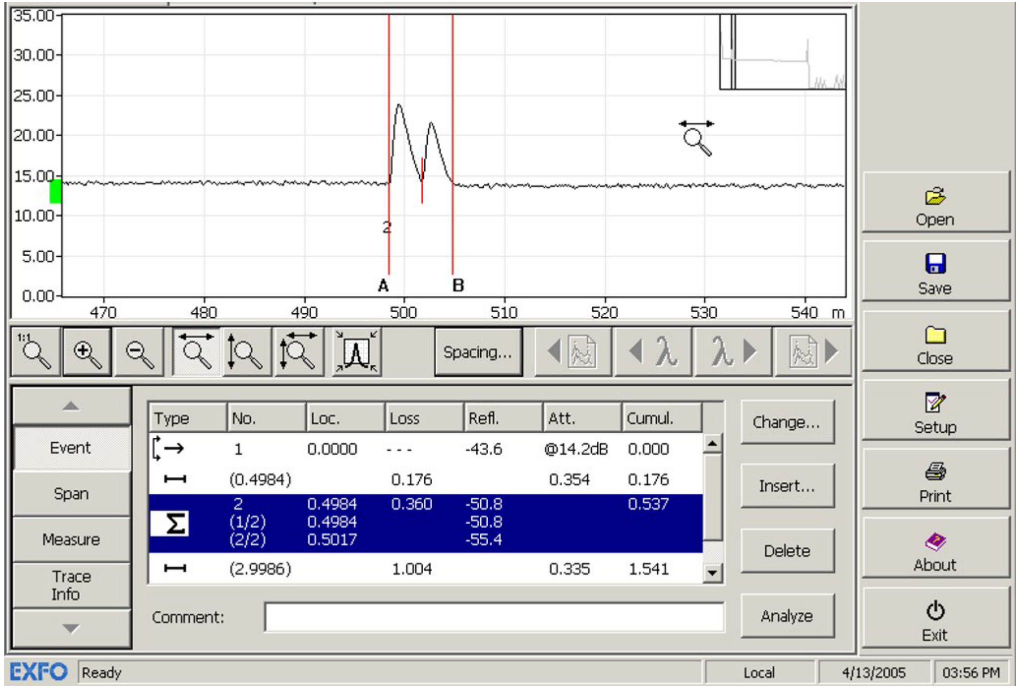
If a reflective event is outside the « Event Dead Zone » of the preceding event, it will be localized and the distance will be calculated.

It is the distance between:
The beginning of the events
the -1.5 dB point on the falling edge



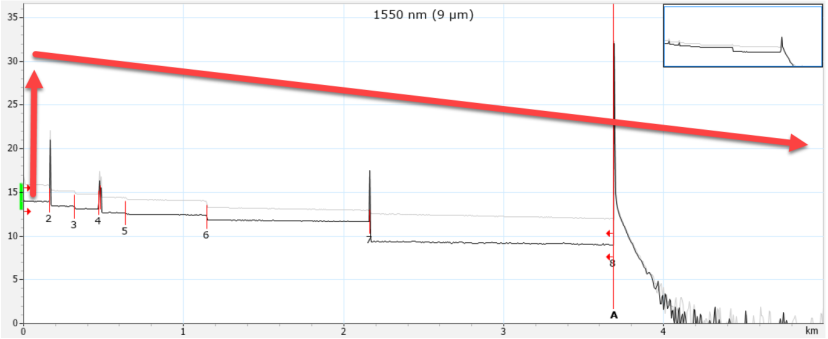
OTDR Specification and limitations

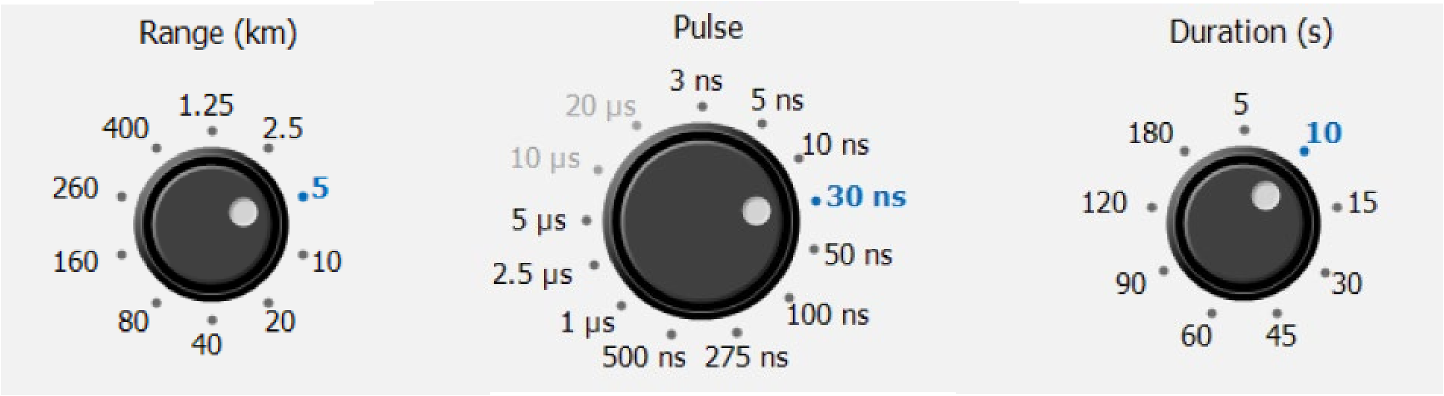
If the spacing between two events is shorter than the « Attenuation Dead Zone » but longer than the « Event Dead Zone », the OTDR will show « Merged Events »



Three primary settings

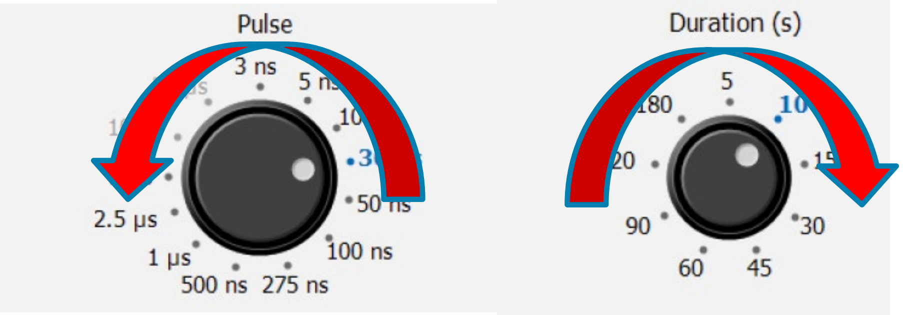
- Range: Determines the measurement range of the test.
- Pulsewidth: Determines the dynamic range and resolution of the test.
- Duration: Sets the test duration per wavelength. The longer the test time the more noise is averaged out.





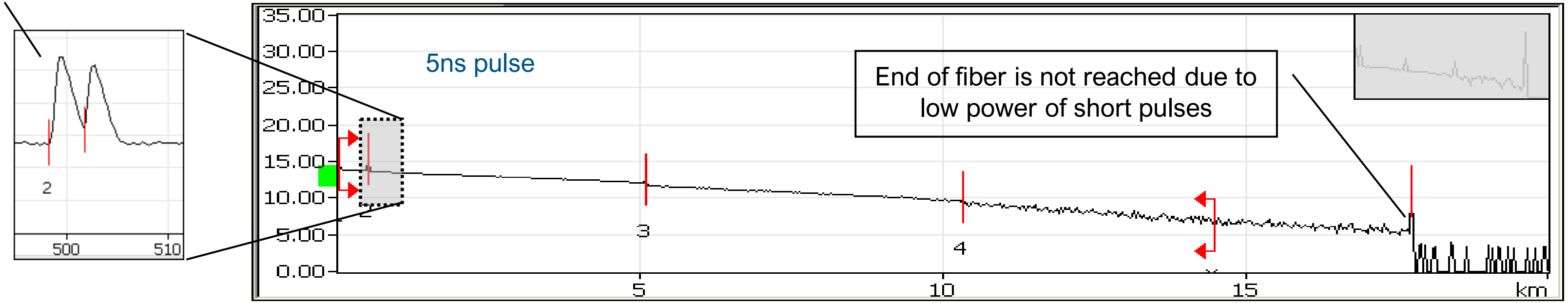
Better resolution

If I want to see closely spaced events, you need to reduce the Pulse-width and increase the averaging time to clean up the noise. Trace will have more tail noise and less distance.



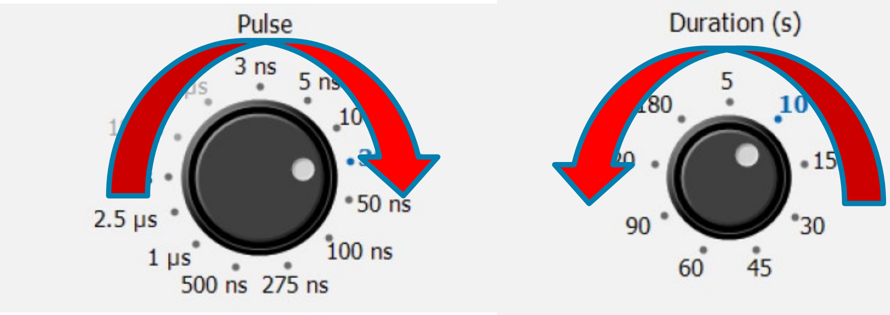
Increased averaging time will allow the use of shorter pulse-width for improved fault isolation and troubleshooting of closely spaced events.

Connectors are measured for distance and marked as separate events

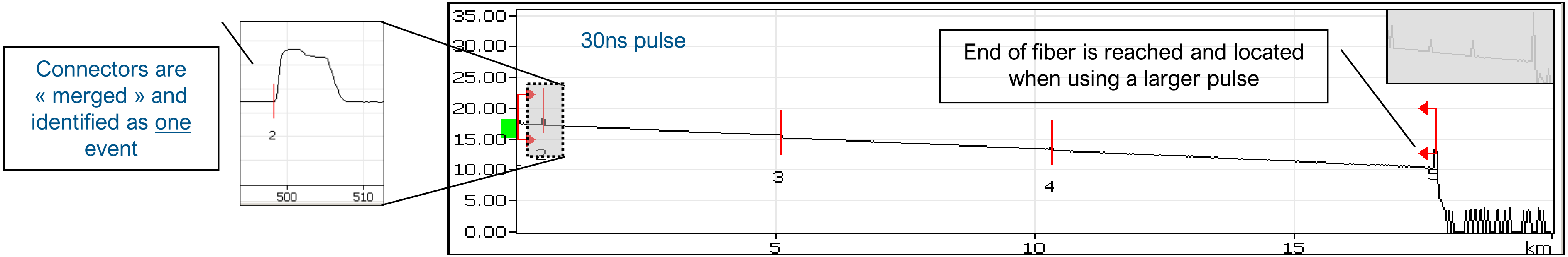


Longer distance

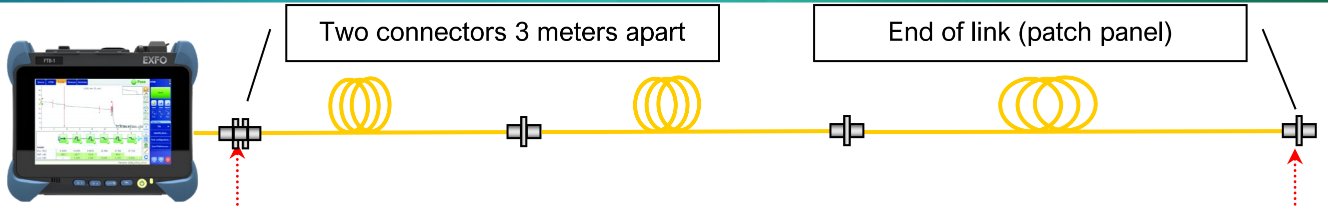
For longer distance you can increase the pulse-width to improve dynamic range. You can also reduce your test duration with an increased pulse-width for shorter test times. Be careful not to sacrifice the quality of your results.



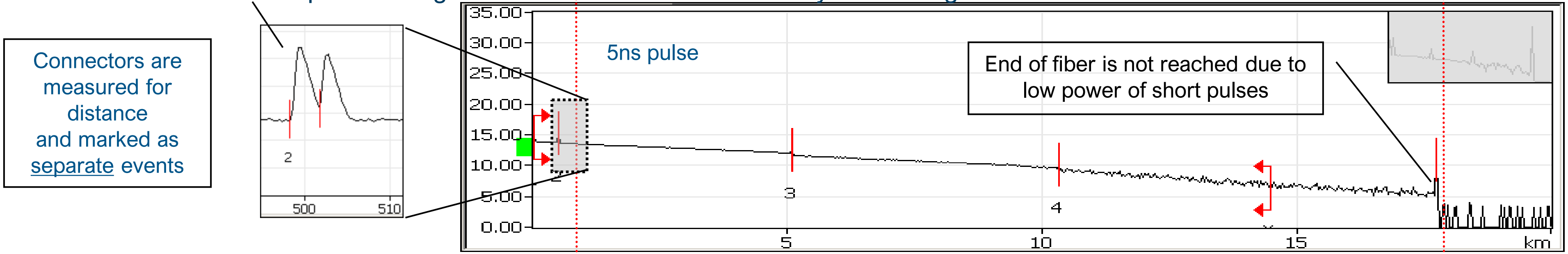
Shorter duration can be a benefit for high count fiber.
Testing an 864 fiber at 2 wavelengths at 60 seconds per wavelength will result in over 40 hours of test time.



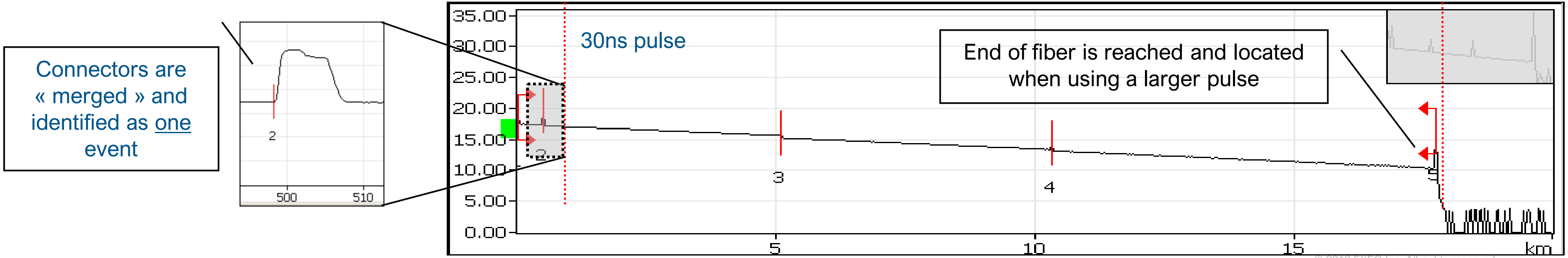
OTDR specifications & limitations



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

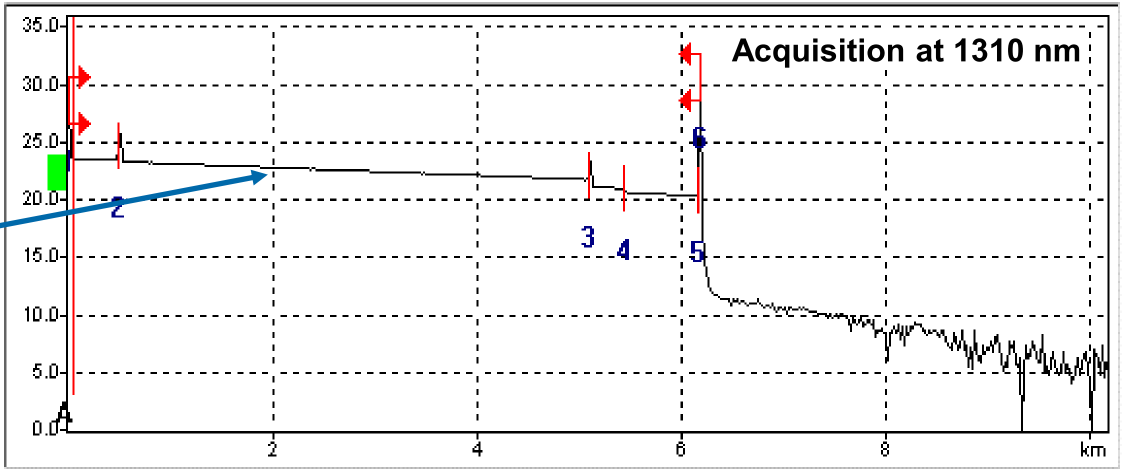


Long pulses will give a better dynamic range but less resolution:

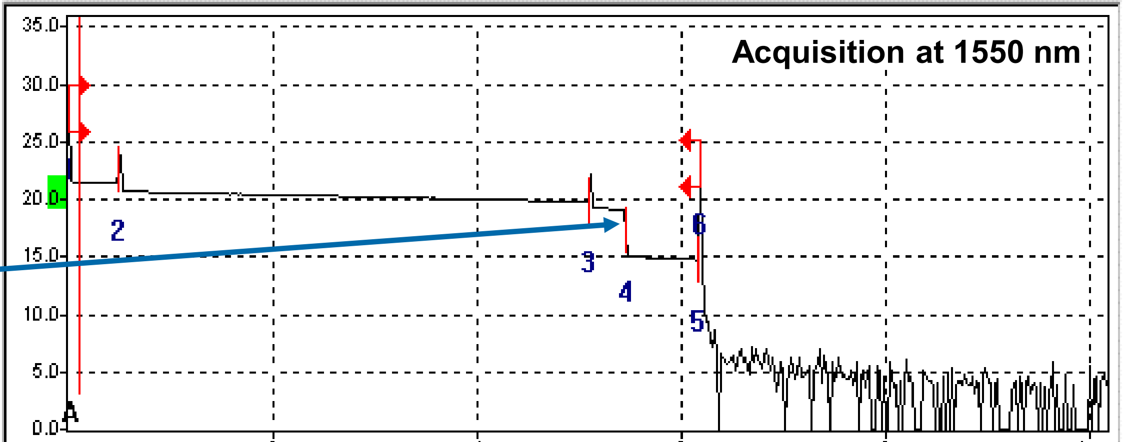


Wavelengths and Macro-Bends

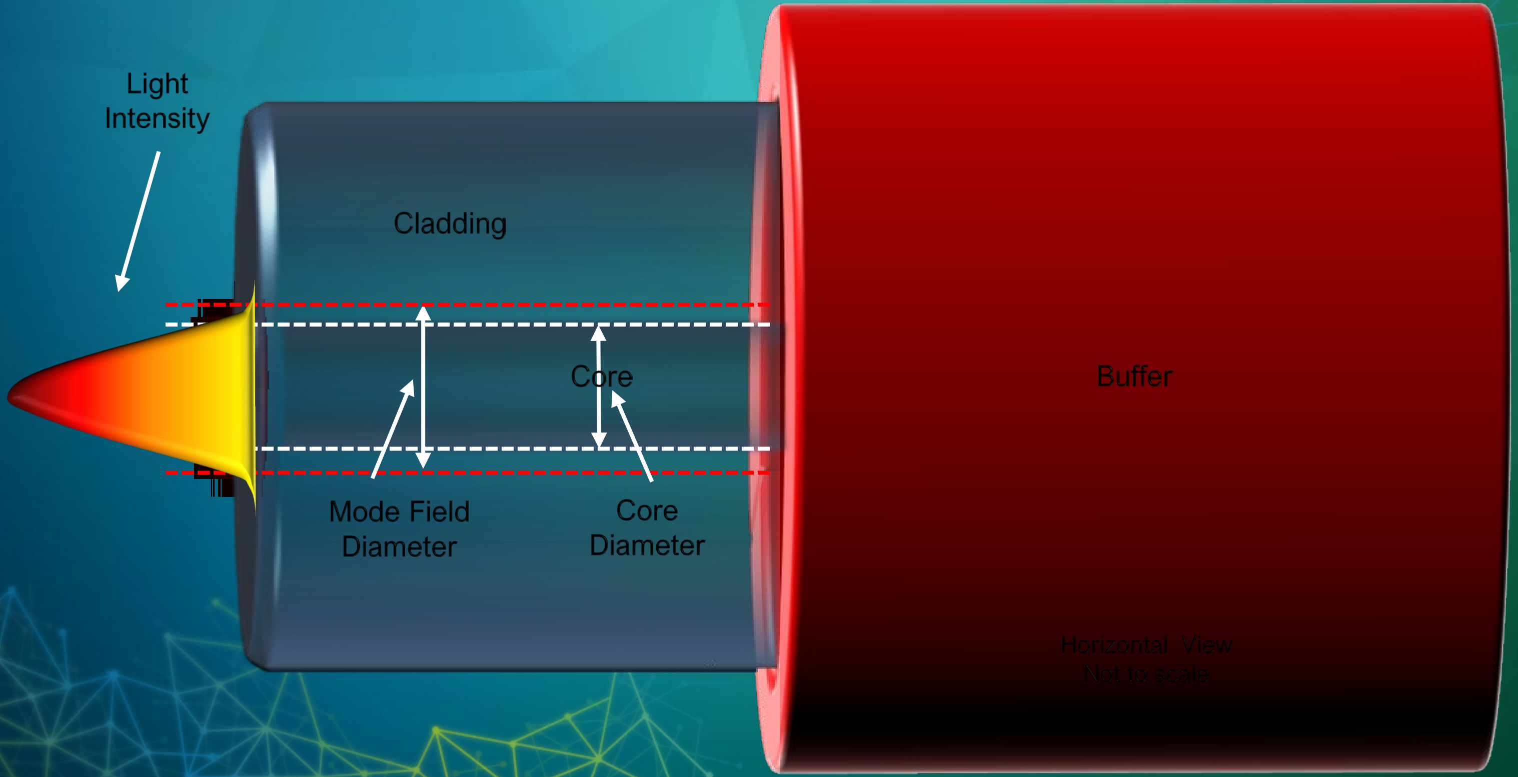
- Shorter wavelengths are more attenuated by fiber's scattering



- Longer wavelengths tends to leak out of the fiber easier due to bending



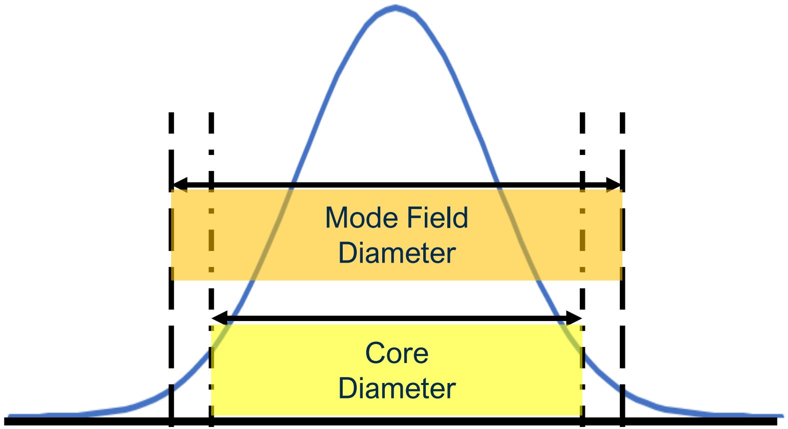
Mode Field Diameter



Mode Field Diameter

Core Size vs Mode Field Diameter

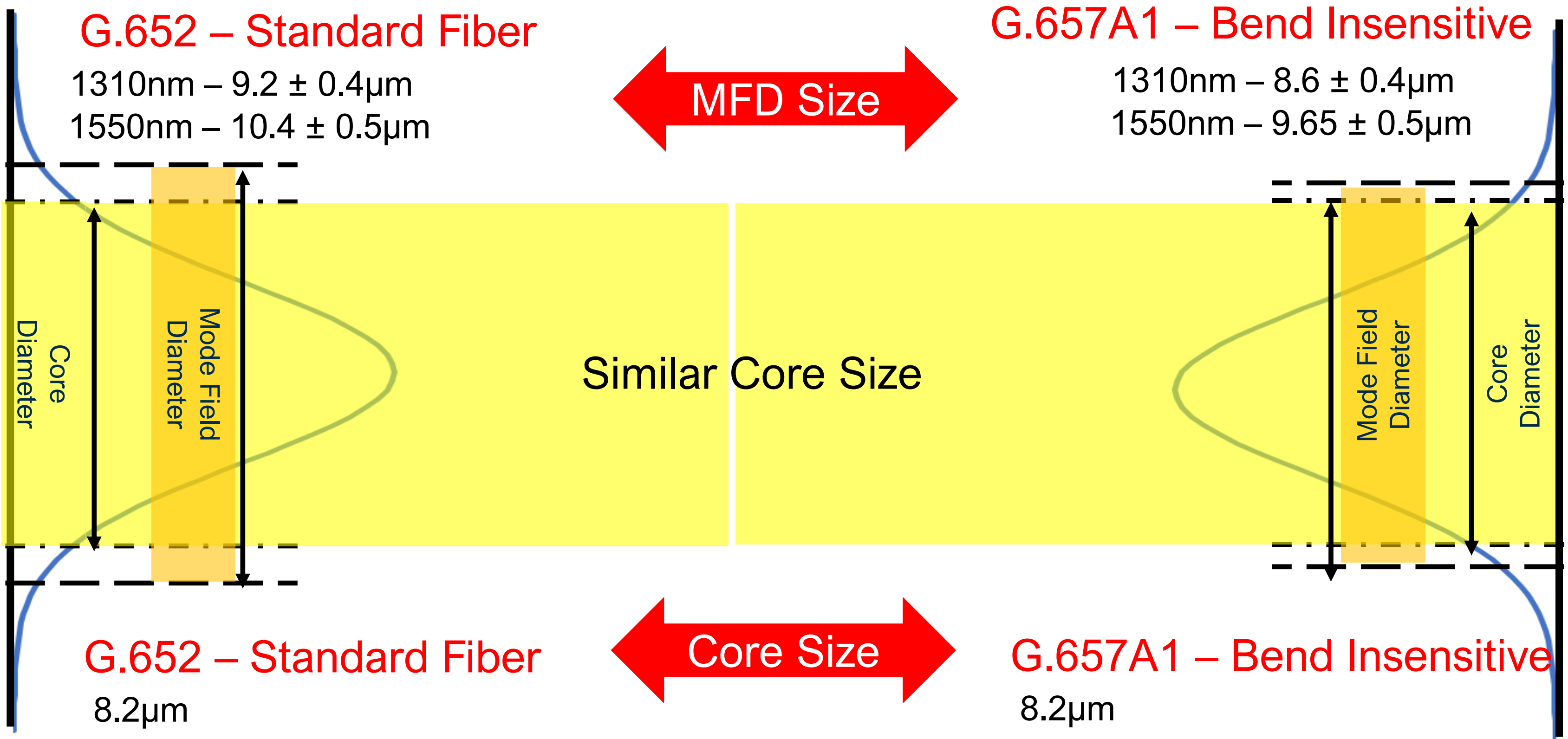
Core diameter and Mode field diameter are **NOT** the same.



Core diameter is just as it says. The diameter of the optical fiber core.

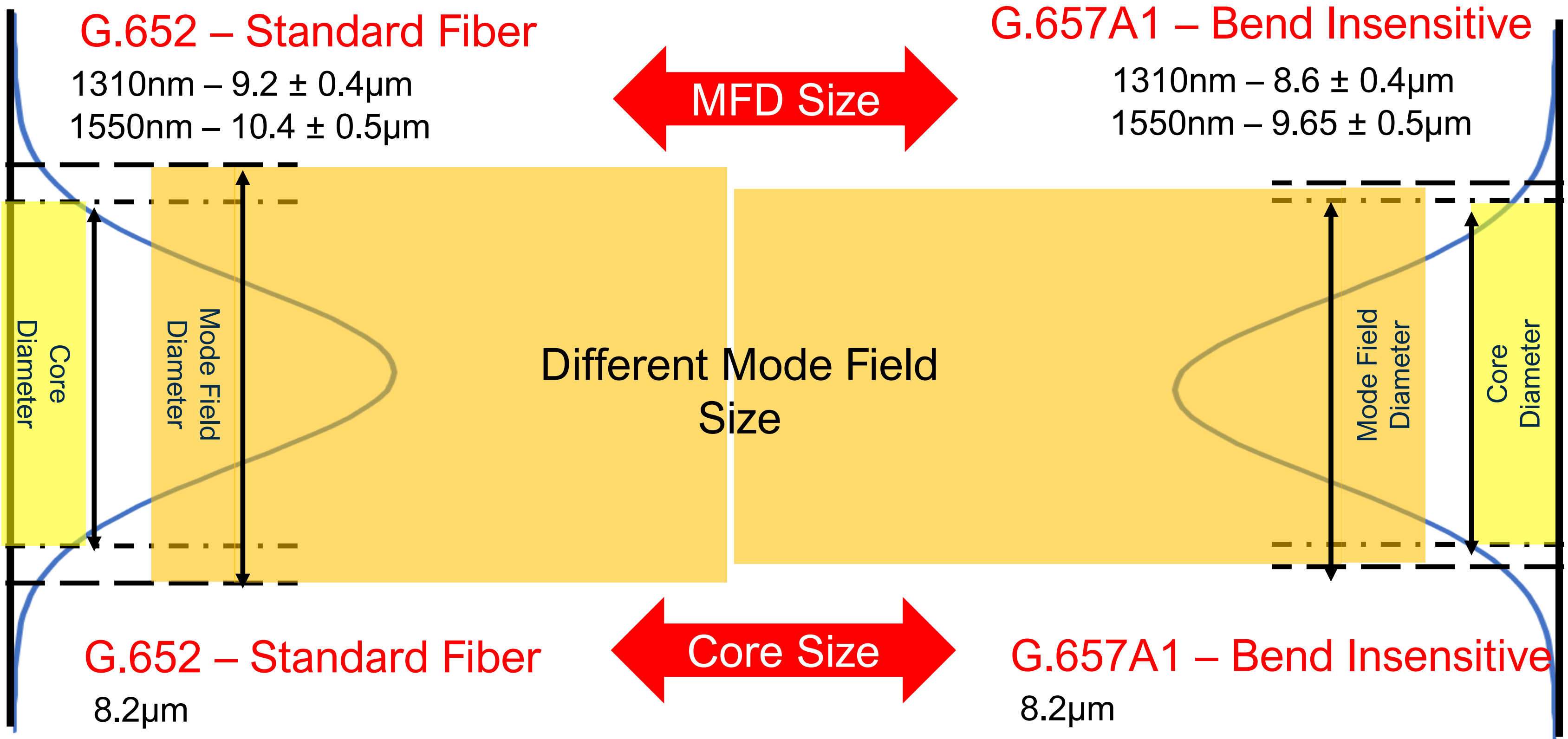
Mode field diameter is the area of the fiber the signal travels through and can include a portion of the cladding.

Mode Field Diameter



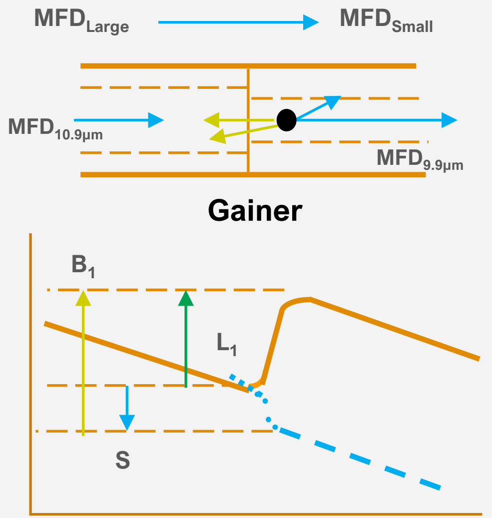
Specifications from Corning.com

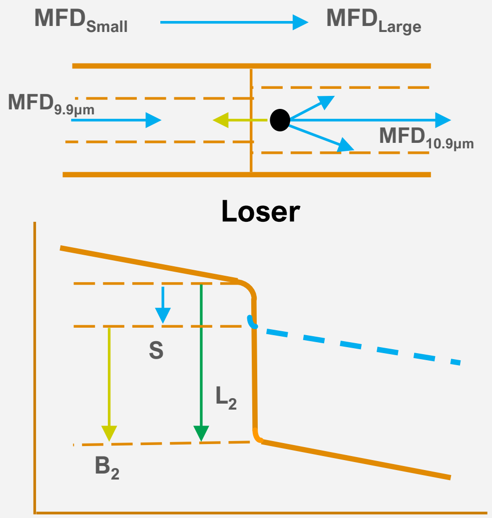
Mode Field Diameter



Specifications from Corning.com

Mode Field Diameter Miss-Match





L = Apparent Optical Loss/Gain

S = Actual Optical/Splice Loss

B = Backscattered Light

Mode Field Diameter

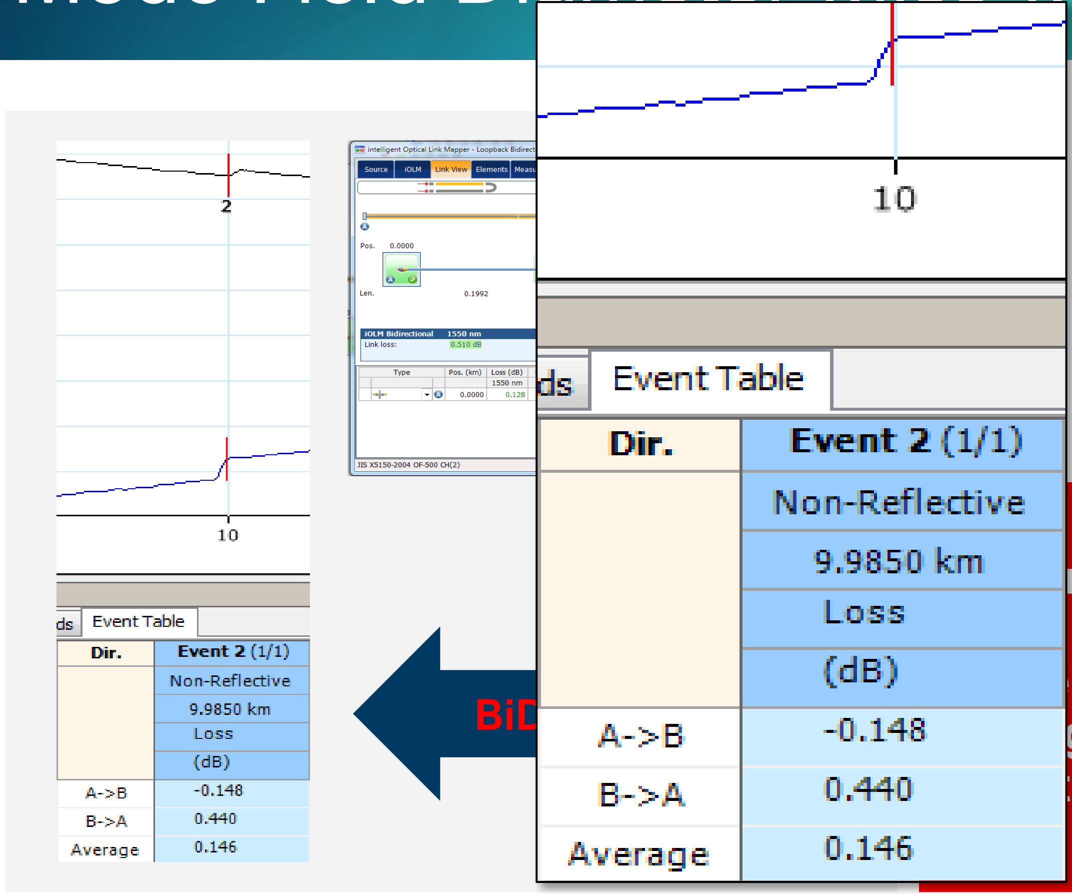
Wavelength (nm)	Mode Field Diameter (µm)
1310	9.2 ± 0.4
1550	10.4 ± 0.5

G.652 specification

Going from a larger to smaller MFD results in a “Gainer” or an exaggerated gain in power.

Going from a small to larger MFD results in a “Loser” or an exaggerated loss in power.

Mode Field Diameter Miss-Match

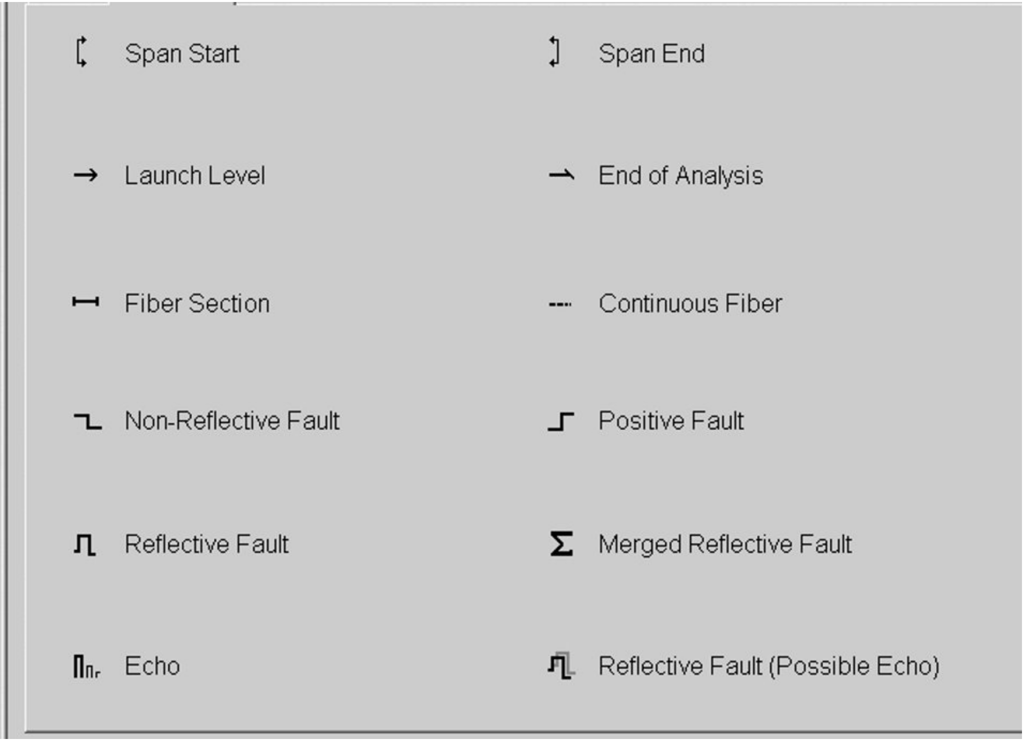


Going from a larger to smaller MFD results in a "Gainer" or an exaggerated gain in power.

Going from a small to larger MFD results in a "Loser" or an exaggerated loss in power.

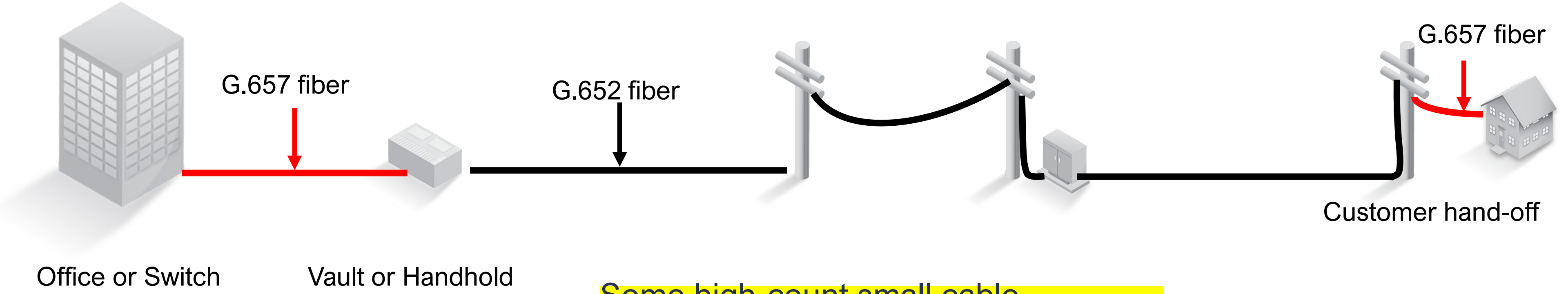
nly way to have the true loss event is to perform a ctional measurement and ge the losses from both tion

Event types


Span Start
Span End
Launch Level
End of Analysis
Fiber Section
Continuous Fiber
Non-Reflective Fault
Positive Fault
Reflective Fault
Merged Reflective Fault
Echo
Reflective Fault (Possible Echo)

Hand-offs

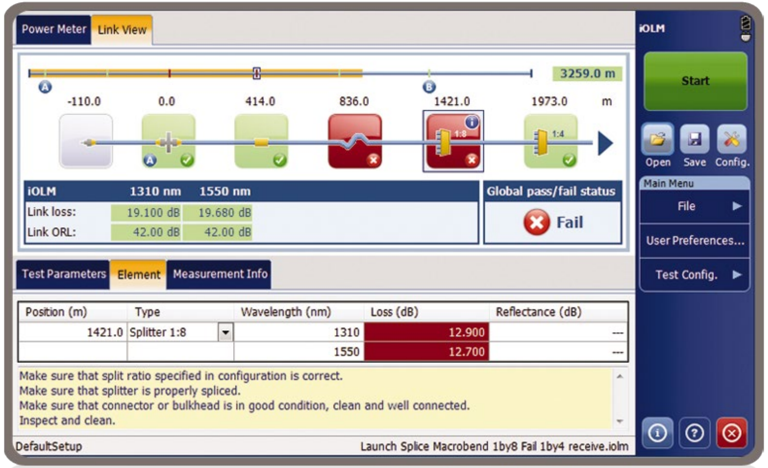
Most common locations of Mode Field Diameter miss-match is the transition splice from ISP to OSP outside a HUB or from the F2 feeder to the customer handoff.



Some high-count small cable deployments are using G.657A1 fiber for improved compression performance.

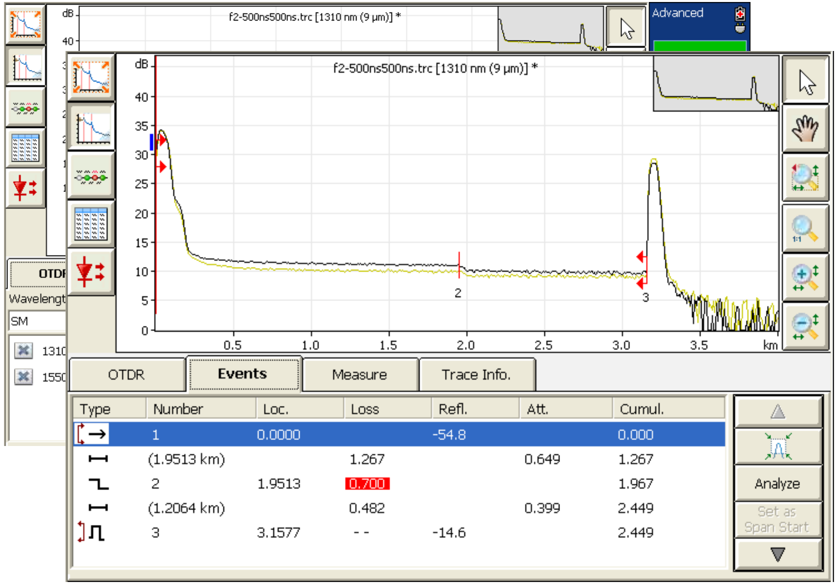
Next Generation OTDR in iOLM

Improvements in OTDR technology testing has led to more intelligent ways to characterize a fiber span by using multi-pulse technology to ensure you are always capturing all the test data in one single capture.

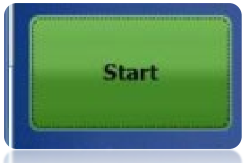


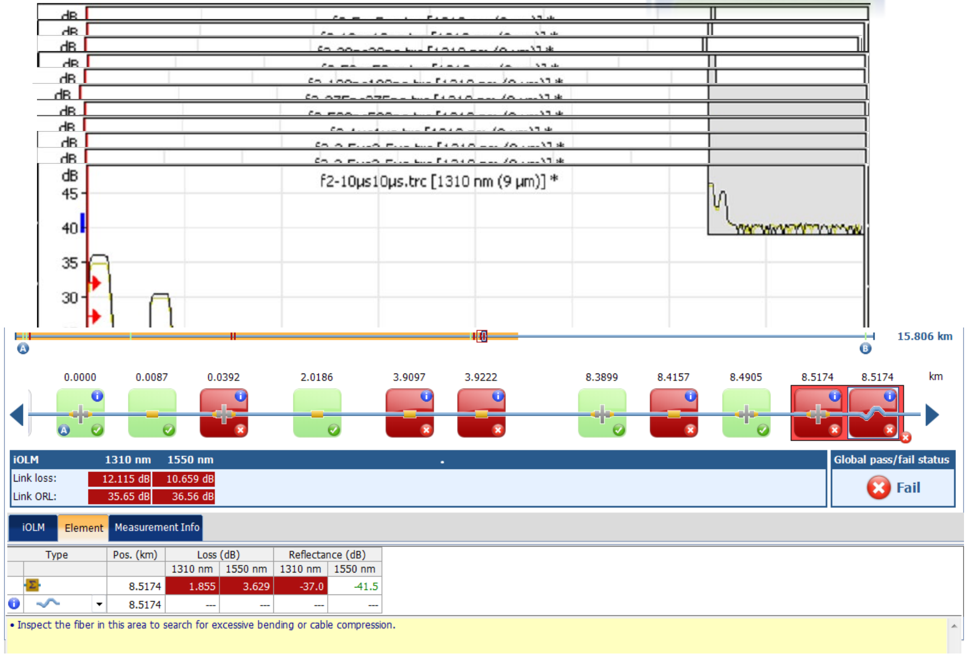
iOLM – Multi-pulse acquisition.

OTDR: Single pulse



IOLM™: Adaptative Multipulses acquisition
with smart recognition and diagnostic

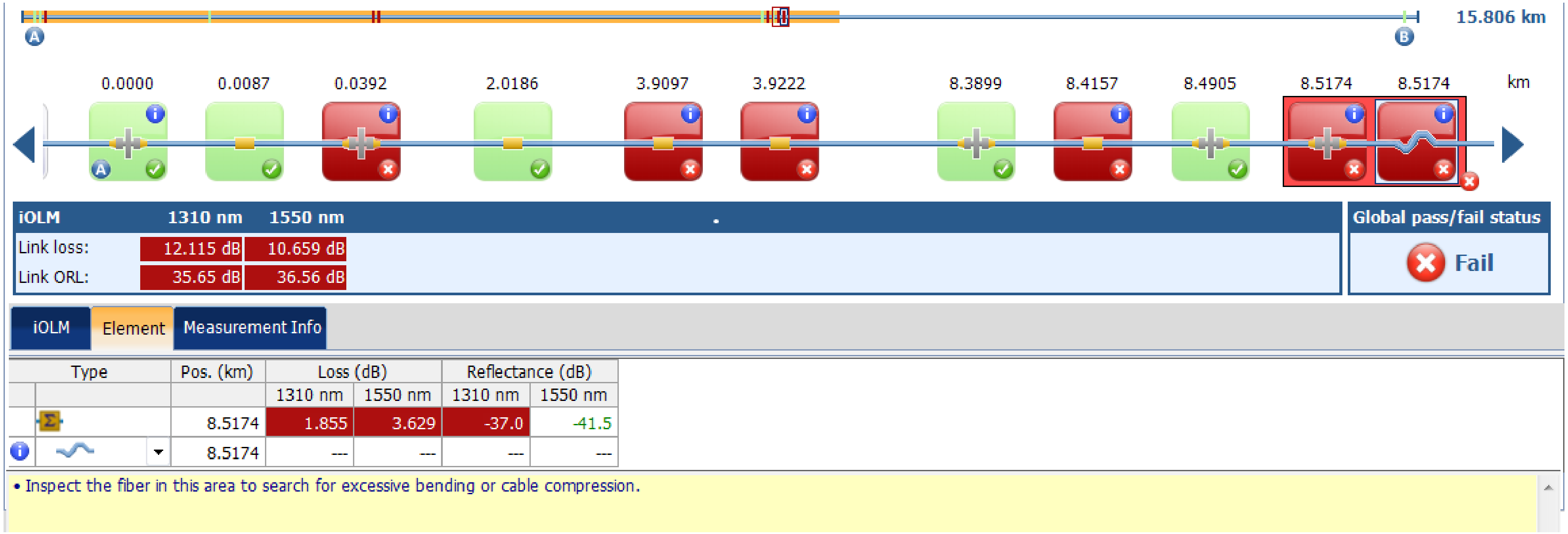




With **iOLM** multiple acquisitions are run in the background and relevant data is coorelated and compared and combined for a single composite result. You will always see a splice at 60 feet and a splice at 60 miles.

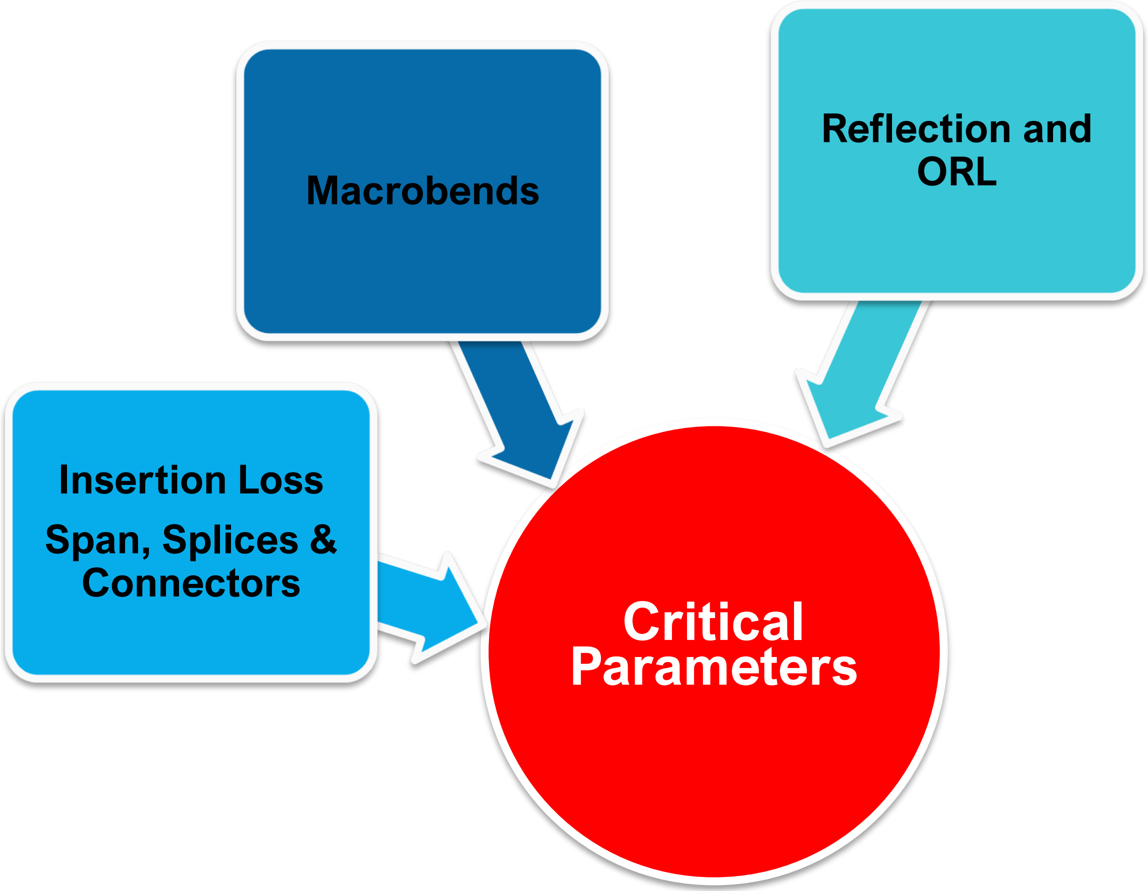
Results

One button testing creating one composite trace with short, intermediate, long and everything in between.



OLTS Theory

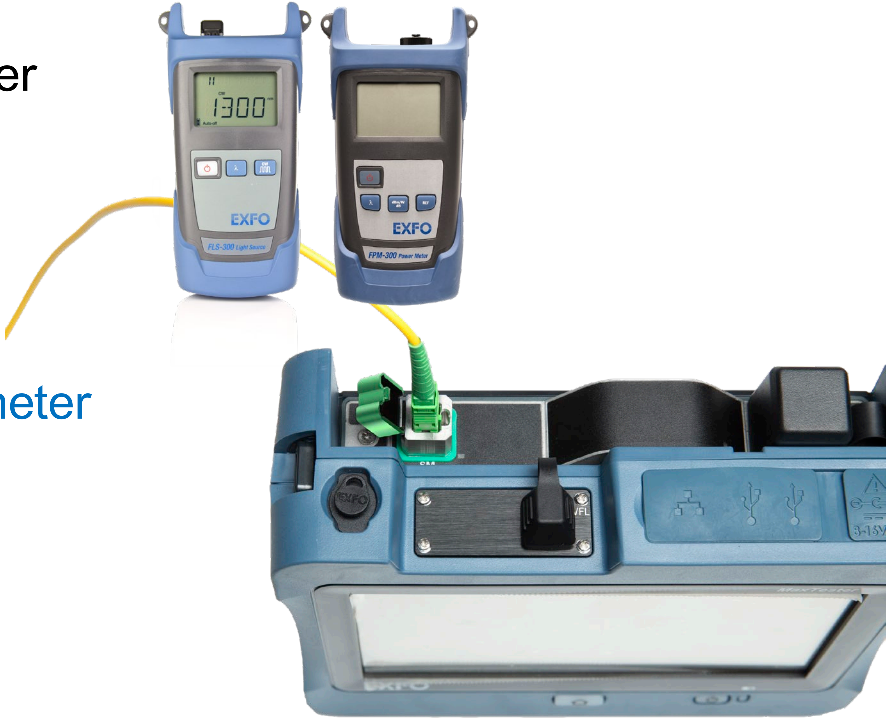
Critical Parameters



What is OLTS and OCWR?

OLTS: Optical Loss Test Set

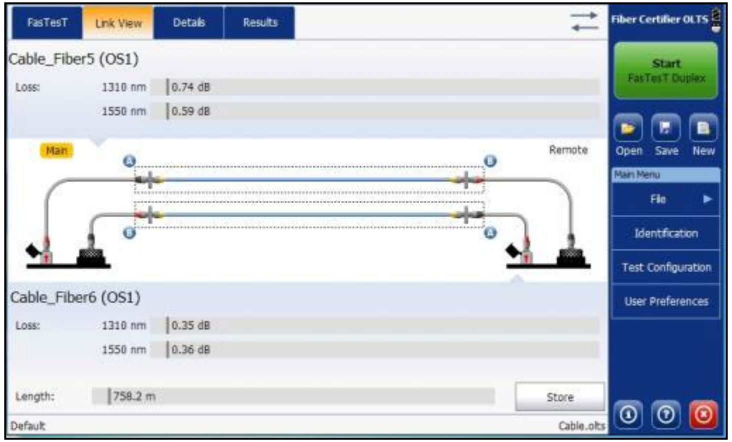
An OLTS is comprised of a source and power meter and used to measure span loss and verification of continuity.

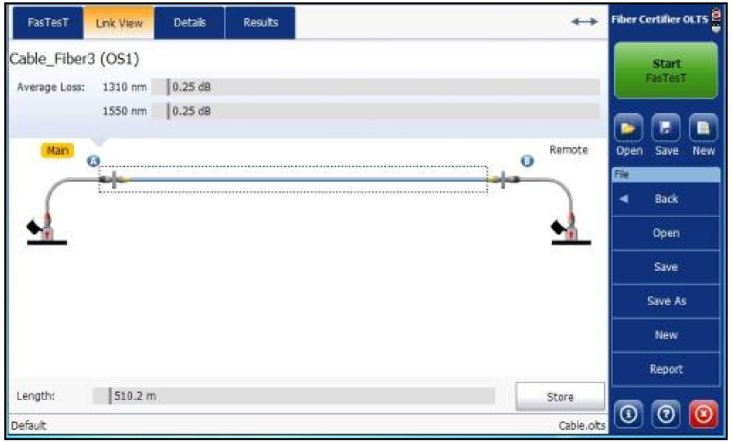


OCWR: Optical Continuous Wave Reflectometer

The OCWR monitors its continuous output power and simultaneously measures the amount of power reflected back.

Simplex vs Duplex





DUPLEX Testing

- Two fibers at a time
- FasTesT to Power Meter port
- Enterprise/DataCenter approved method
- Available in SM and MM

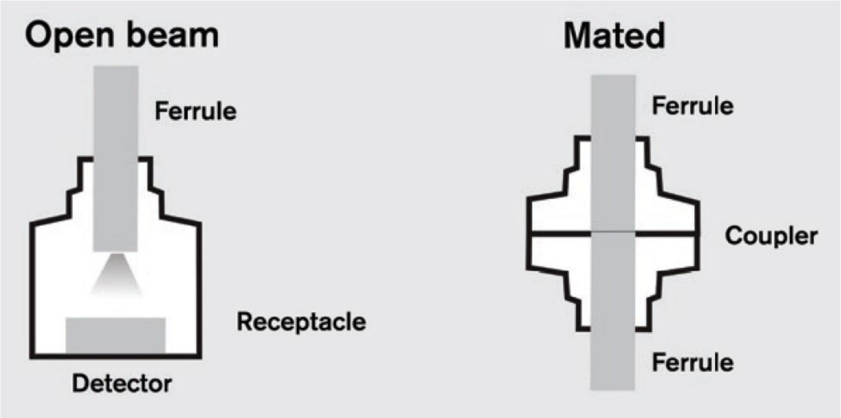
SIMPLEX Testing

- One fiber at a time
- FasTesT to FasTesT port
- TelCo approved method
- Available in SM ONLY

Open beam vs mated connection

When referencing the test cord, the ferrule does not contact the detector window.

Because of this, the connector will not exhibit the same loss when mated to another ferrule. Imperfections due to defects, scratches or even dust and dirt may not exhibit the same loss. When mated connectors are used to measure the link under test, it is imperative to verify the connector loss once mated to confirm that we are in fact using a connector exhibiting good performance and that is ready for testing.



Reference Types – One-cord

One-cord reference method

The one-cord reference method is the most commonly used method in the industry. This is the preferred method, as it will yield the most accurate testing results

It is also the method recommended by TIA and IEC. The one-cord method allows for testing of the fiber optic link from end-to-end including losses from all connectors. Including connector losses becomes very important as the link gets shorter, since connectors are the major contributor to the overall loss, not the fiber itself.

Reference Types – Two-cord

Two-cord reference method

The two-cord reference method is used mainly when the connector on the power meter differs from the one on the fiber link to be tested.

It involves using a hybrid test cord to match connector types between the link to be tested and the power meter. This method will yield less accurate test results than the recommended one-cord reference method, since it includes a connection mating in the reference. With today's interchangeable connector interfaces on testers, this method is less frequently used.

Reference Types – Three-cord

In some instances, it may not be possible to use the recommended method. Such cases may include situations where connectors at both ends of the DUT are from different types.

These cases call for the **three-cord method**.
Using this method, one must take extreme care of the connector state, as it may greatly impact measurements. If using bad, dirty or worn out connectors, results may become highly inaccurate and even yield negative loss readings (gain). This method includes two connections during the reference step.

Reference App Note

Application Note 340

Choosing the Right Reference Method

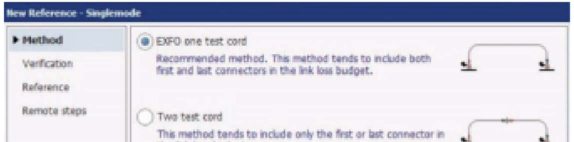
By Vincent Racine–Product Line Manager, Mario L'Heureux–Senior Systems Engineering Specialist and Romain Tursi–Product Specialist

WHEN AND WHY TO USE THE ONE-CORD, TWO-CORD AND THREE-CORD REFERENCE METHODS

Over the past decades, network data rates have tremendously increased. This has resulted in pushing the limits of fiber optic components, including test instruments. Tight loss budget and short distance links are often encountered. Accuracy is no longer a luxury; it has become vital in ensuring valid measurements for both outside and inside plant testing.

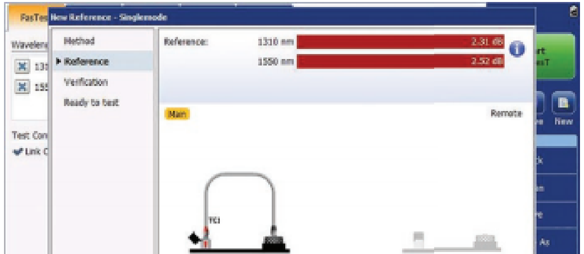
Proper references are key to ensure accurate and valid measurements. This means that in addition to an accurate instrument, good test cords and a proper reference technique must also be adopted.

However, there seems to be lot of confusion when choosing the appropriate reference method. Even if the test set comes with preprogrammed reference routines, one still must know which routine should be used; and, this is where it becomes challenging.



For multimode tests, it becomes even more important to use EXFO's reference grade test cord specifically: Encircled-flux (EF) conditioners are installed within the test unit. To maintain EF conditions, EXFO provides test cords with controlled fiber core size and geometry. Test cords are consumable and occasionally need to be replaced. The internal conditioner with EF *transparent* test cords design is one of the best cost-effective solutions on the market.

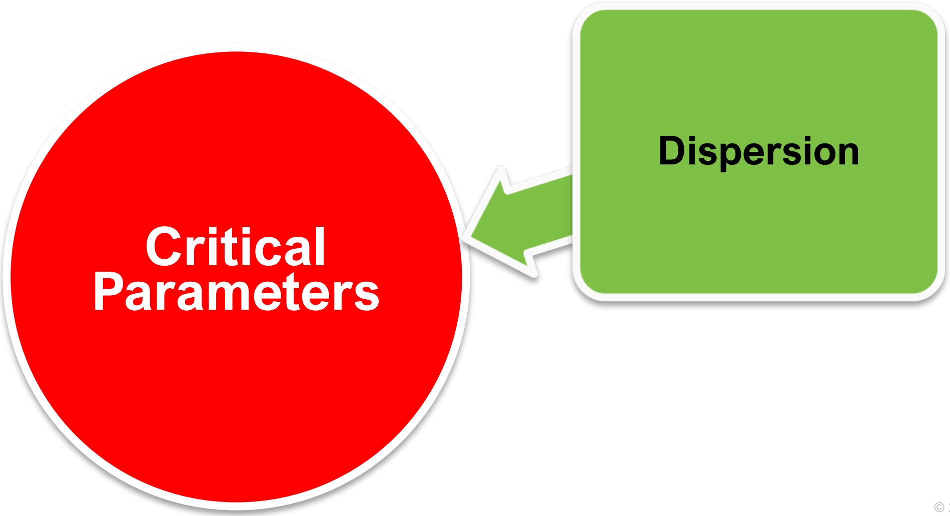
Connectors must be kept clean and free of defects, as they may play a major role in the overall loss and ORL being measured. Inspection tools, such as the FIP-430B fiber inspection probe, are critical and must be used to validate a connector's state; cleaning alone or using brand new test cords out of the bag does not ensure connector cleanliness. Without an inspection tool, achieving accurate and repeatable results will become a challenge.



https://www.exfo.com/umbraco/surface/file/download/?ni=13012&cn=en-US

Dispersion Theory

Critical Parameters



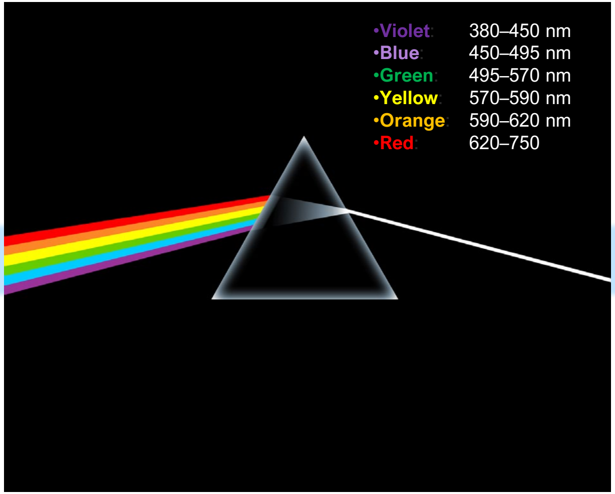
Addressing bandwidth demand—Why WDM?

- Single-lane roads are built to give access to homes and businesses in populated areas.
- When demand for access increases, engineers look for ways to address this demand.
- If the road is already built, how can this be done?

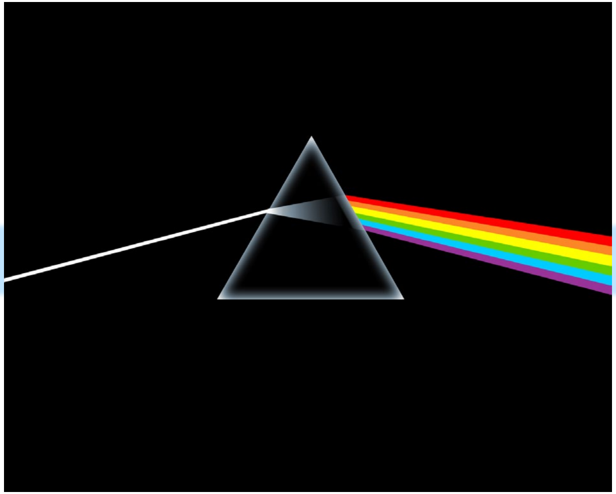
- Adding additional lanes can be a solution to reduce the demand for access.
- Can we funnel traffic without chaos?

Wavelength division multiplexing (WDM)

WDM is a technology which multiplexes a number of optical carrier signals onto a single optical fiber by using different wavelengths.



The Dark Side of
the Moon technology



WDM types

Classes of WDM devices

Wide WDM devices: Access

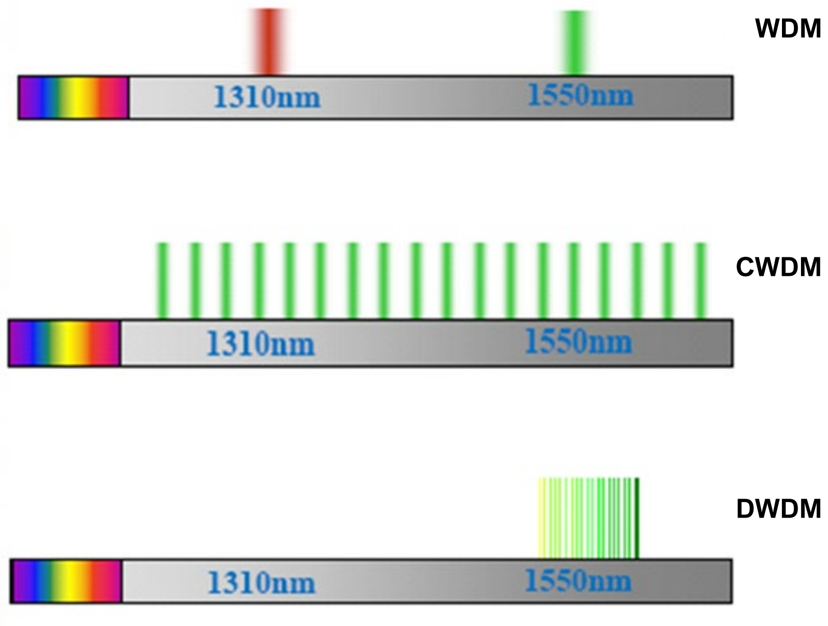
- Channel spacing > 100 nm
- 1310 nm and 1550 nm

Coarse WDM devices (CWDM): Metro

- Channel spacing 20 nm
- 18 channels *typical less than 16 lambdas*

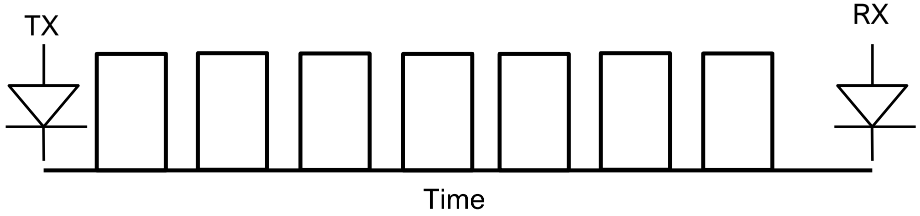
Dense WDM devices (DWDM): Longhaul

- Channel spacing ≤ 200 GHz
- Spacing: ≤ 0.8 nm



Dispersion – Pulse Spreading

A square **pulse** of light spreads as it travels through an optical fiber eventually two adjacent pulses will overlap one another, and the bits will become indistinguishable. This is phenomenon known as **dispersion**.



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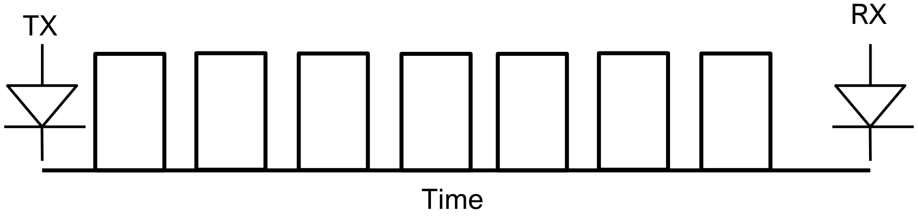

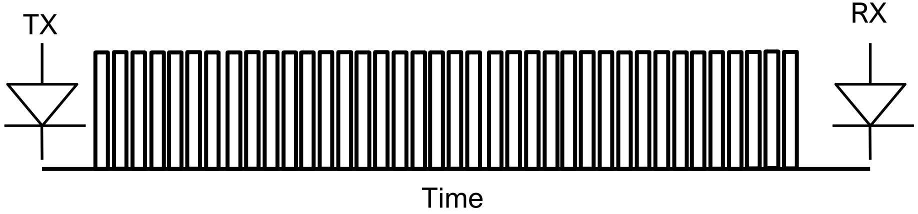

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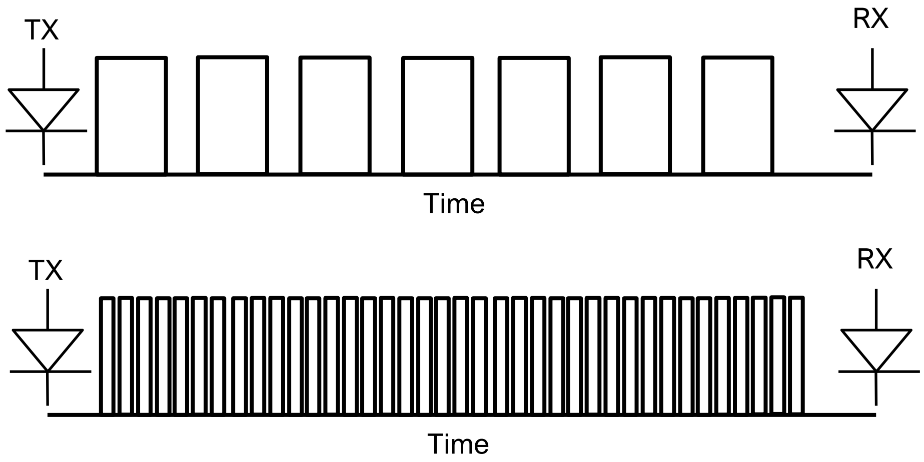
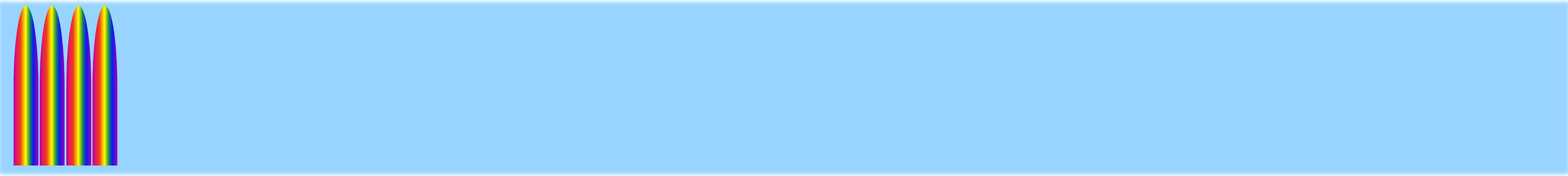


Chromatic Dispersion

Different Wavelengths travel at different speeds as it propagates along the fiber.

- Different wavelengths travel at different speeds
- Causes spreading of the light pulse
- Limits how fast and how far a signal will travel
- Higher Bit rates are less robust



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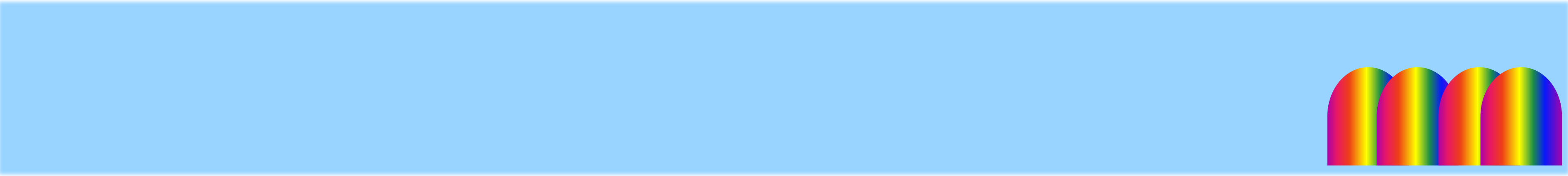

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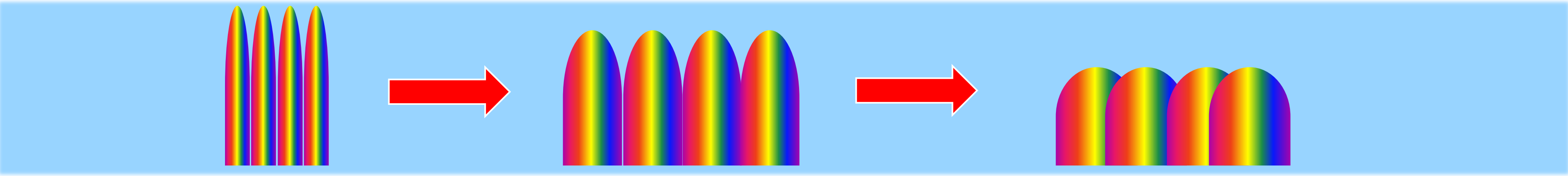

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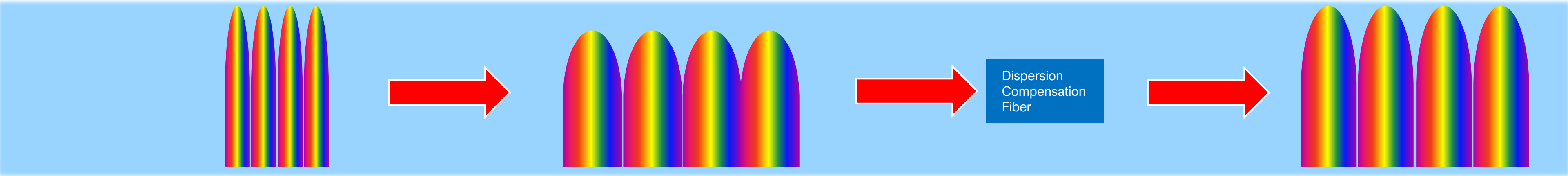
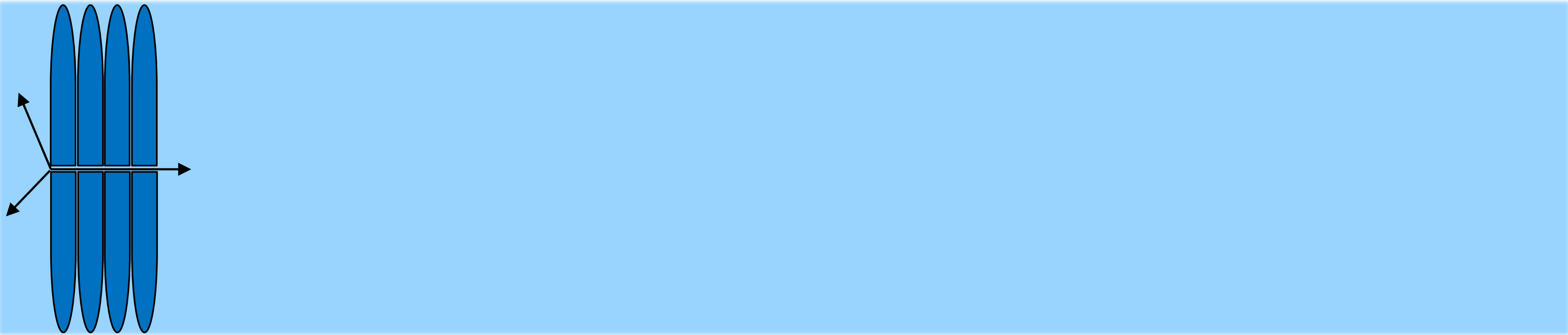


Polarized Mode Dispersion

Pulse-spreading caused by Non-Linearity of the fiber geometry.

- Single-mode fiber supports two polarization states
- Fast and slow axes have different group velocities
- Causes spreading of the light pulse
- Limits transmission rate



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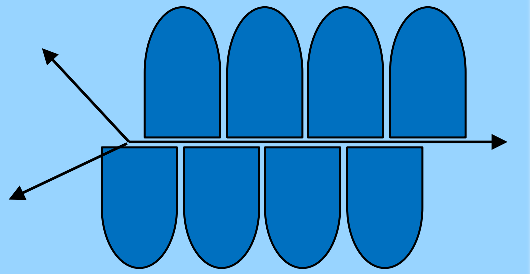
Causes

- Fiber Manufacturing Process
- Cable Manufacturing Process
- Cable Installation Process
- Environmental Changes



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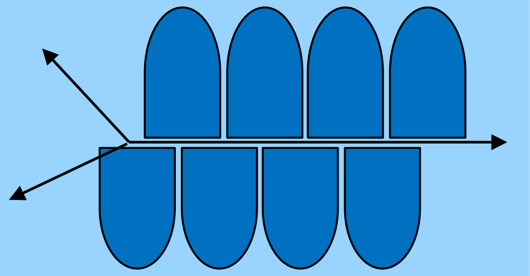
Solutions

- Regeneration
- Improved placing method
- Improved Fiber



Singlemode Fiber Standards

ITU-T G.652.D Fibers Singlemode Local "Characteristics of a single-mode optical fibre and cable"	Non-Dispersion Shifted Fiber NDSF
ITU-T G.653 A/B "Characteristics of a dispersion-shifted single-mode optical fibre and cable"	Dispersion-Shifted Fiber DSF
ITU-T G.654.B/D "Characteristics of a cut-off shifted single-mode optical fibre and cable"	Cut-off Shifted Fiber CSF
ITU-T G.655.C/D "Characteristics of a non-zero dispersion-shifted single-mode optical fibre and cable"	Non-Zero Dispersion Shifted Fiber NZDSF
ITU-T G.656 Fibers "Characteristics of a fibre and cable with Non-Zero Dispersion for Wideband Optical Transport"	Low Slope Dispersion Shifted Fiber
ITU-T G.657.A1/A2/B3 "Characteristics of a bending loss insensitive single mode optical fibre and cable for the access network"	Bend Sensitive Fiber BIF

CPRI to validate fiber link

Close out package

Post-Processing software is the 1 stop tool for:

Validate compliancy

Analyze measurements

Define test configuration

Edit traces

Documentation

Correct mistakes from the field

Combine different types of jobs

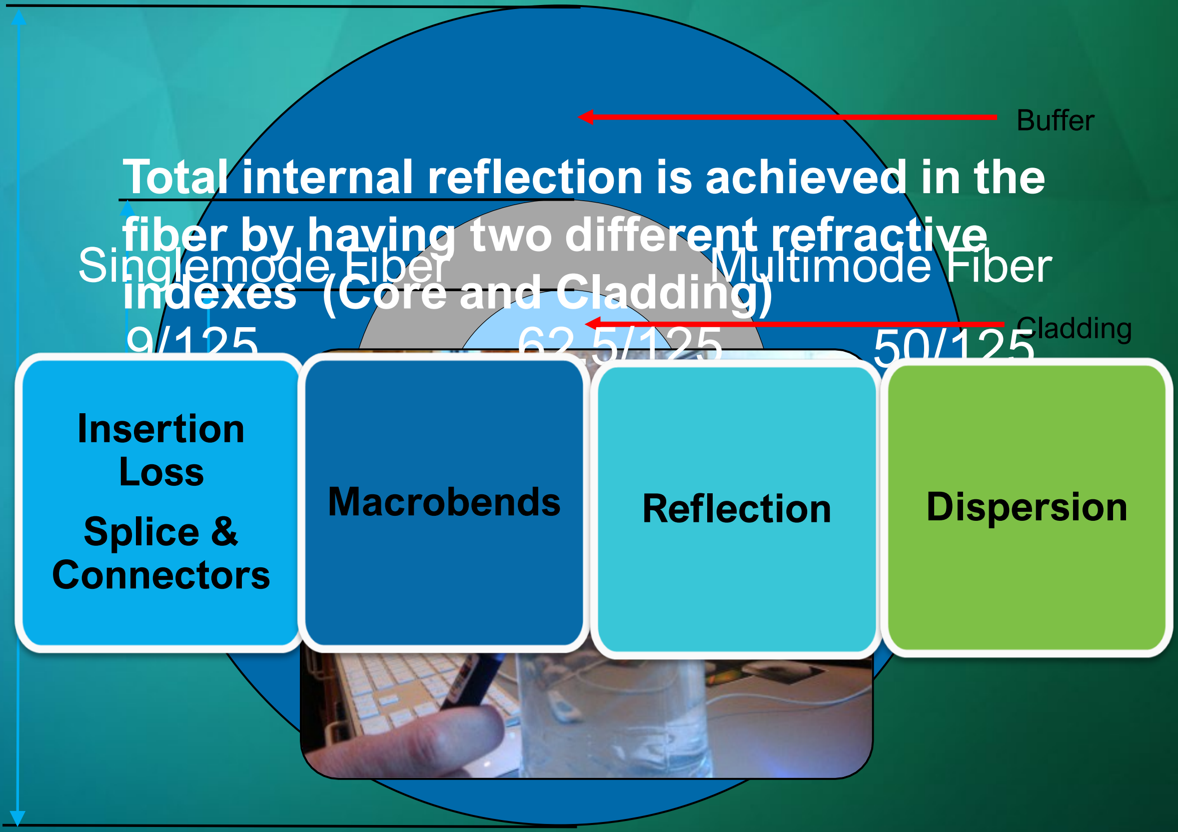
Generate report

Recap

Fiber Optic 101

1. Fiber Sections
2. Total Internal Reflection
3. Fiber Types
4. Mode
5. Critical Parameters

Total internal reflection is achieved in the fiber by having two different refractive indexes (Core and Cladding)



Insertion Loss

Splice & Connectors

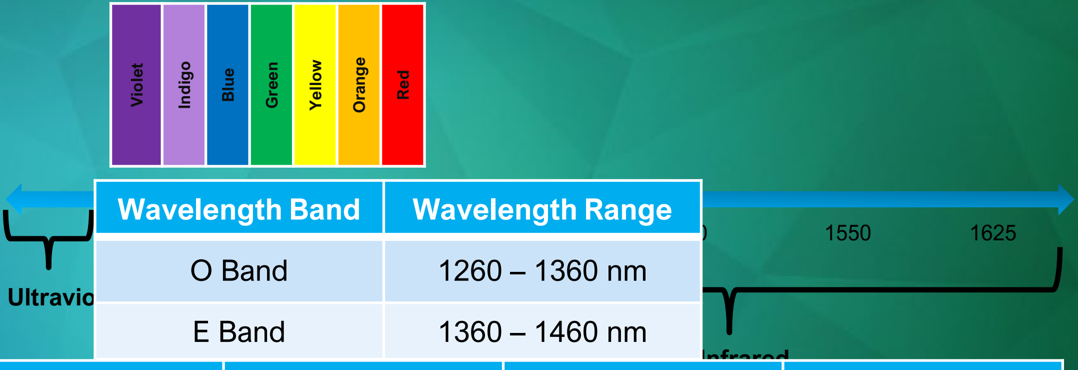
Macrobends

Reflection

Dispersion

Fiber 101

1. Electromagnetic Spectrum
2. Wavelength
3. Index Of Refraction (IOR)
4. dB vs dBm



Wavelength Band	Wavelength Range
O Band	1260 – 1360 nm
E Band	1360 – 1460 nm

Material	Velocity (Miles/s)	Velocity (KM/s)	Refractive Index
Space (Vacuum)	186,282	299,792	1.0
Air	186,232	299,890	1.0
Water	140,061	225,442	1.33
Glass	122,554	197,349	1.52

We use the dBm unit when we talk about the POWER which is an absolute value measured at a specific point in a link.

Example: Power coming out of a transmitter

IOR describes how fast light travels through the material.

We use the dB unit when we talk about a LOSS which is a referenced value.

Example: Loss of a fiber section

Long Wavelength – Low Frequency

Attenuation

1. Loss vs Power
2. Attenuation
3. Attenuation Coefficient
4. Optical Budget

It is critical to minimize the loss (attenuation) across the fiber cable and components.

For every 3dB of loss you suffer a 50% penalty.

Intrinsic

Absorption

Scattering

Extrinsic

Microbend

Macrobend

Splices

Fiber Endface Connection

The Attenuation (loss) Coefficient is the amount of loss per km. (dB/km)

To determine this value, you divide the span loss against the length.

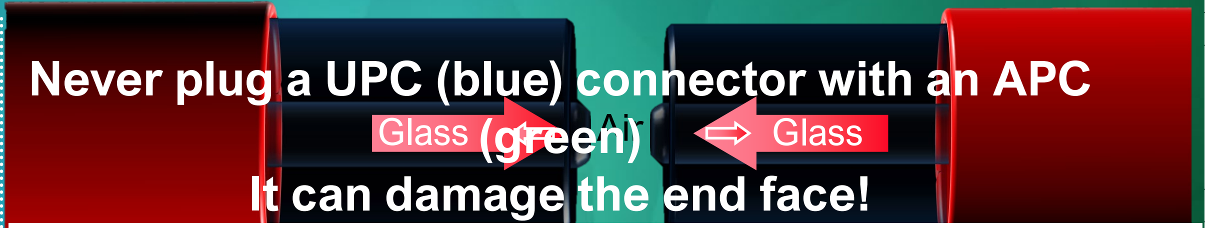
dB/km = loss / length

The **loss budget** is the amount of loss that a cable plant should have if it is installed properly.

It is calculated by adding the estimated average losses of all the components used in the cable plant to get the estimated total end-to-end loss.

Reflection – Optical Return Loss

- Reflection
- UPC VS APC
- Connector Evolution
- Connector Performance



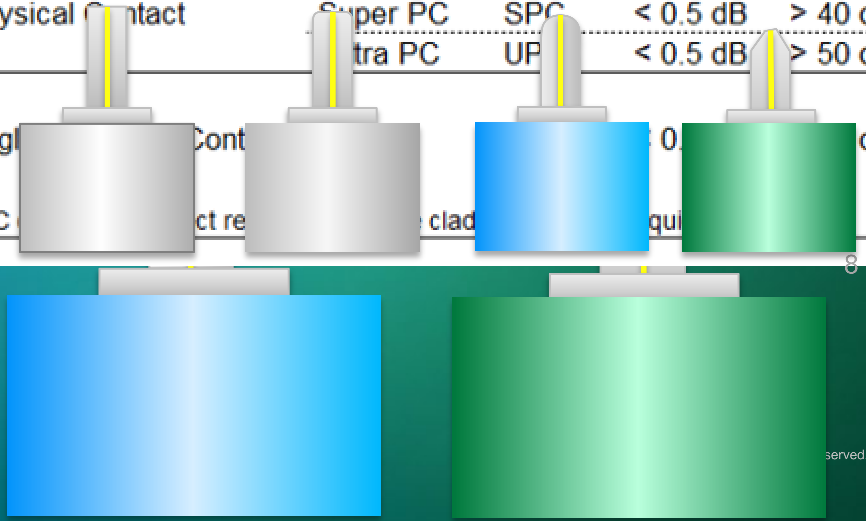
Never plug a UPC (blue) connector with an APC (green)

It can damage the end face!

Connector Performance

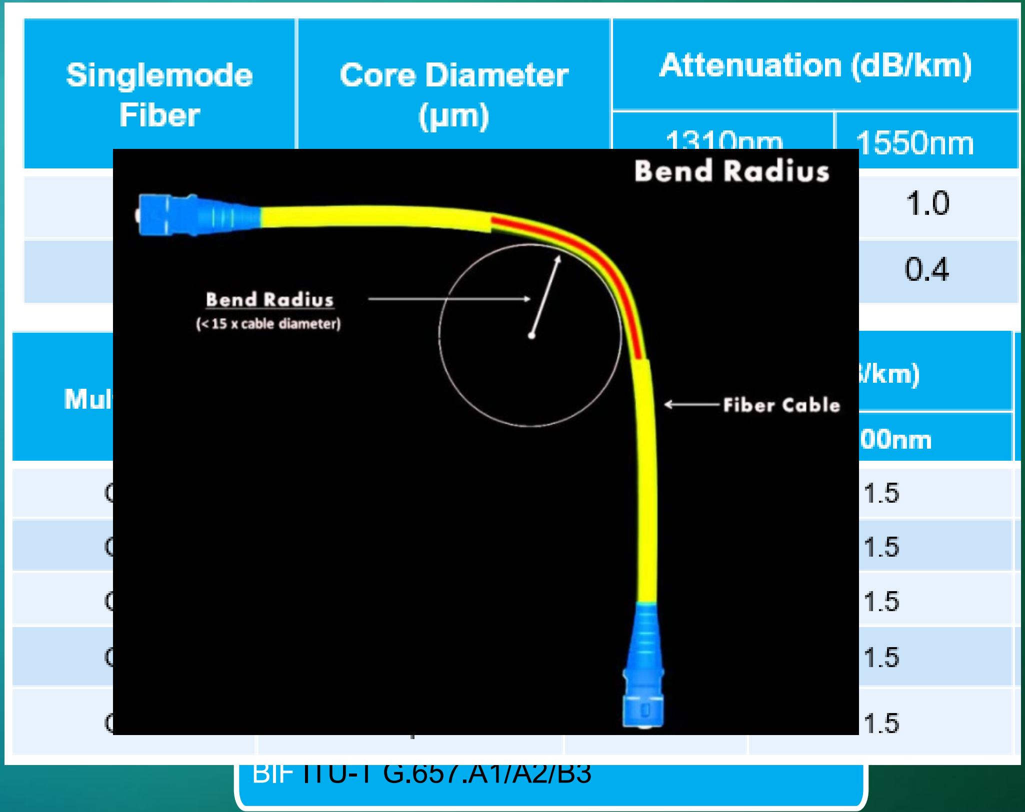
			Insertion Loss	Return Loss
Physical Contact	Physical Contact	PC	< 0.7 dB	> 30 dB
	Super PC	SPC	< 0.5 dB	> 40 dB
	Ultra PC	UPC	< 0.5 dB	> 50 dB
Angl... Cont...			0...	...dB

APC ... ct re... clad... qui...



Fiber Optic Types

1. Singlemode Fiber Standards
2. Fiber Categories
3. Fiber Bend Radius



Mode Field Diameter

Core VS MFD

MFD Miss-Match

Core diameter is just as it says. The
dia

Mo
fib
inc

The only way to have the true loss of the event is to perform a bidirectional measurement and average the losses from both direction

an exaggerated loss in power.

Dispersion

1. Pulse Spreading
2. WDM
3. ITU-T Grid
4. CD
5. PMD
6. SM Fiber Standards

Non-Dispersion Shifted Fiber
NDSF **ITU-T G.652.D**

Dispersion-Shifted Fiber
DSF **ITU-T G.653 A/B**

Cut-off Shifted Fiber
CSF **ITU-T G.654.B/D**

Non-Zero Dispersion Shifted Fiber
NZDSF **ITU-T G.655.C/D**

Low Slope Dispersion Shifted Fiber
ITU-T G.656 Fibers

Bend Sensitive Fiber
BIF **ITU-T G.657.A1/A2/B3**

Physical-layer field testing

Optical fiber multimeters

OLTS and fiber certifiers

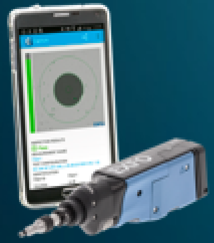
OTDR and iOLM

Optical spectrum analyzers (OSA)

Dispersion

TestFlow
FastReporter

Automation and reporting



Fiber inspection

Multifiber MPO/MTP®

Light sources, power meters and VFL

xDSL/Copper

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Questions?