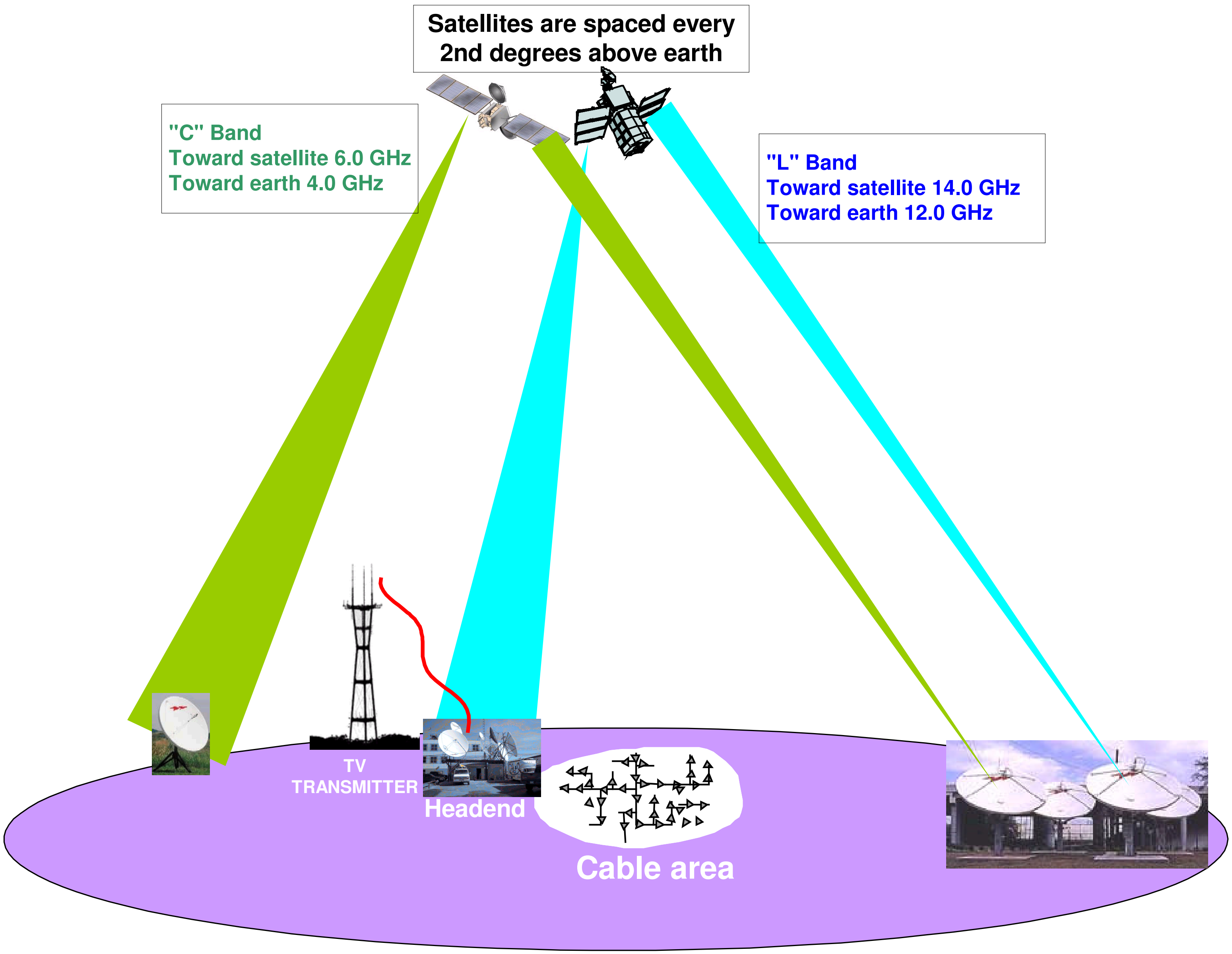
Broadband System - H



Welcome to the Fiber Optic Topics & Testing Seminar

Topics to be Covered during this seminar.

- Fiber Optics Systems
- Nature of Light
- Optical Fiber Characteristics
- Optical Measurements
- Light Sources & Meters
- OTDR

Fiber Optic Milestones.

- You will see a short movie on fiber optic technology.

Fiber Optic Milestones.

- **1854** John Tyndall demonstrated the optical waveguide principle.
- **1960** Theodore Maiman developed the first laser.
- **1972** 4 dB/km loss fiber fabricated.
- **1982** Single mode fiber optic first reported.
- **1991** SONET telecommunications standards created.
- **1995** DWDM deployment began.
- **1998** > 1 Tbps demonstrated on one fiber.
- **2000** L-Band System and 40 Gbps transport system demonstrated.

Optical Scale of Measurements.

Fiber & Associated components are microscopic.
Distances covered are over 50 Kilometers!

- **Time = *billionths* of a second:**
  nanoseconds (ns)
- **Size = *millionths* & *billionths* of a meter:**
- **microns & nanometers (um & nm)**
- **Lengths = *thousands* of meters:**
  kilometers (km)

Optical Scale of Measurements.

Data Powers of Ten.

•Bit	Single character (0 or 1)
•Byte	8 bits (Single word)
•Kilobyte	1000 bytes (A low-revolution photograph)
•Megabyte	1,000,000 bytes (A small novel- 1.44 Diskette)
•Gigabyte	1,000,000,000 bytes (A movie at TV quality)
•Terabyte	1,000,000,000,000 bytes (X-ray film in hospital)
•Petabyte	1,000,000,000,000,000 bytes (3 years of ESO data)
•Exabyte	1,000,000,000,000,000,000 bytes (All words ever spoken by human)
•Zettabyte	1,000,000,000,000,000,000,000 bytes
•Yoattabyte	1,000,000,000,000,000,000,000,000 bytes

EOS = Earth Observing System.

Optical Overview.

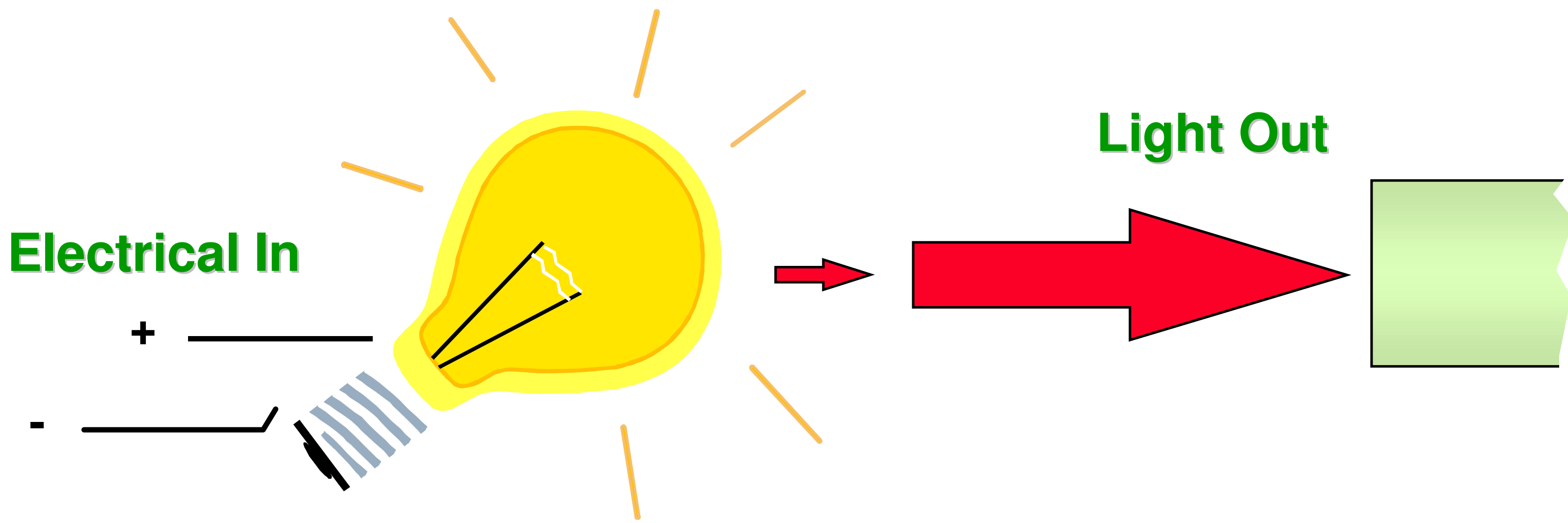
Fiber Optics Transmission System

All Fiber Optic Systems have:

- Transmitter (E > O)
- Optical Waveguide
- Receiver (O > E)

Optical Transmitter.

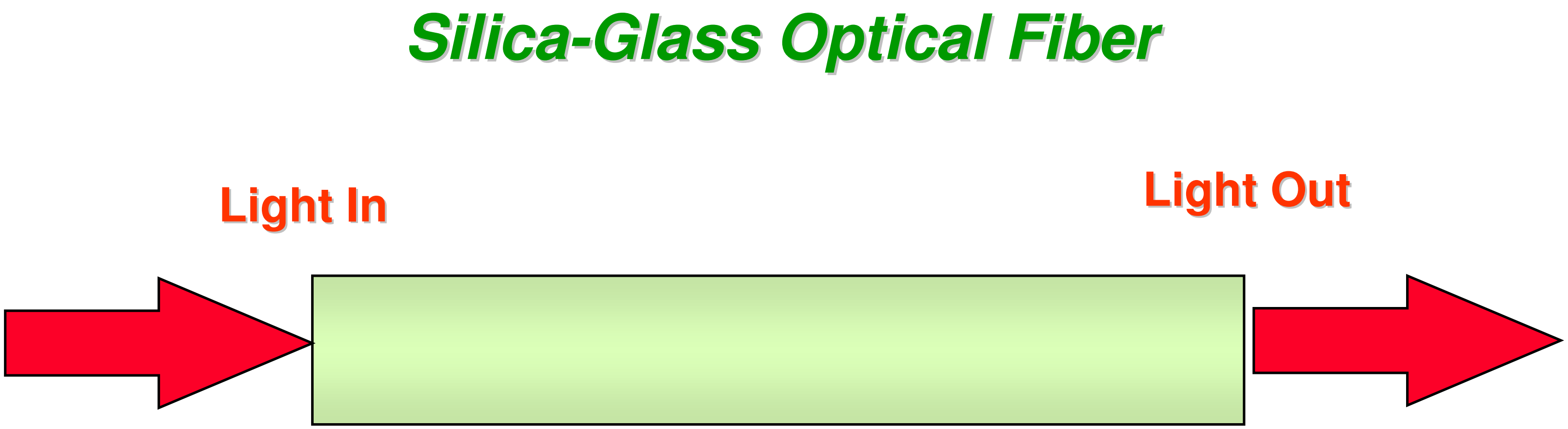
Electrical to Optical (E-O) Converter



Variable Intensity = Analog

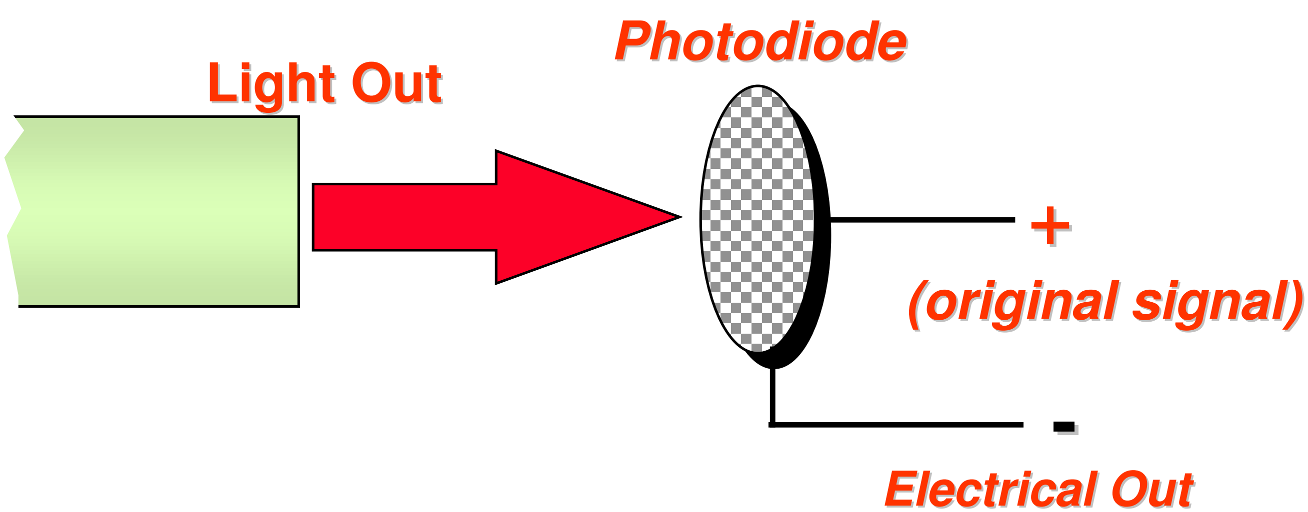
Blink On & Off = Digital

Optical Waveguide.



Optical Receiver.

Optical to Electrical (O-E) Converter



Classifying Light.

- **Power (Watts or Decibels)**

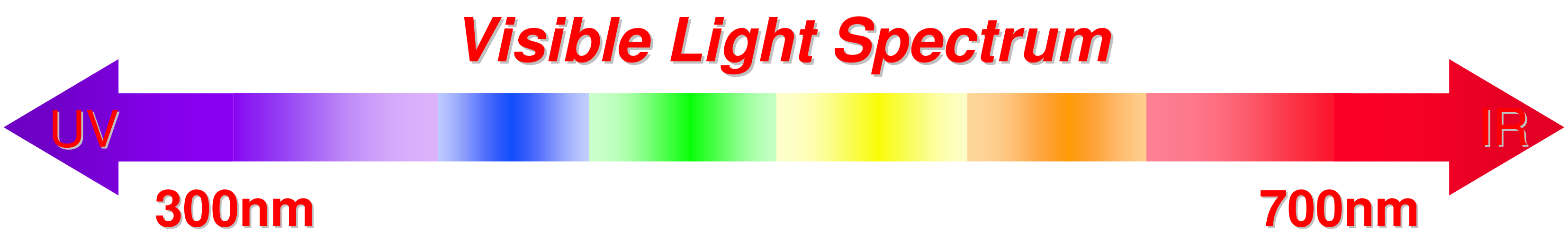
  dBm is typical measurement unit of optical power

  It is measured with a: Optical Power Meter

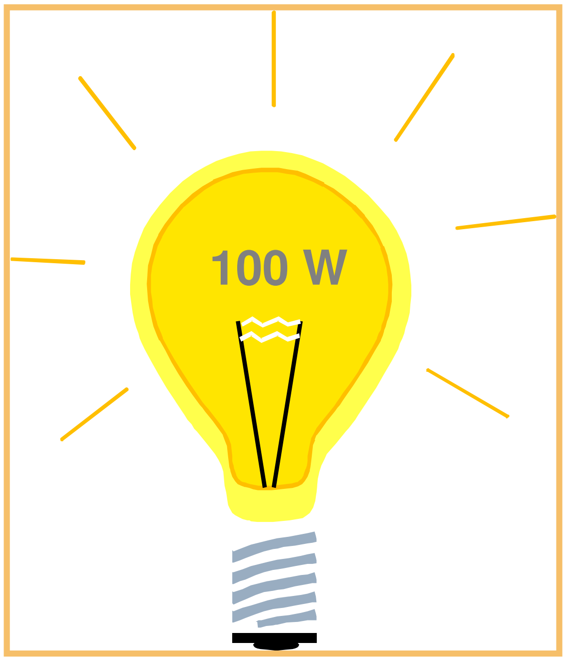
- **Color (Wavelength)**

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

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



Optical Power.



- **Like a light bulb:**
  more wattage = brighter light
- **FO transmitters:**
  about 1mw to 40 mW

  (0 to 16 dBm)
- **Power ranges:**
  +20 dBm to -70 dBm

Optical 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

Optical Reflection & Refraction.

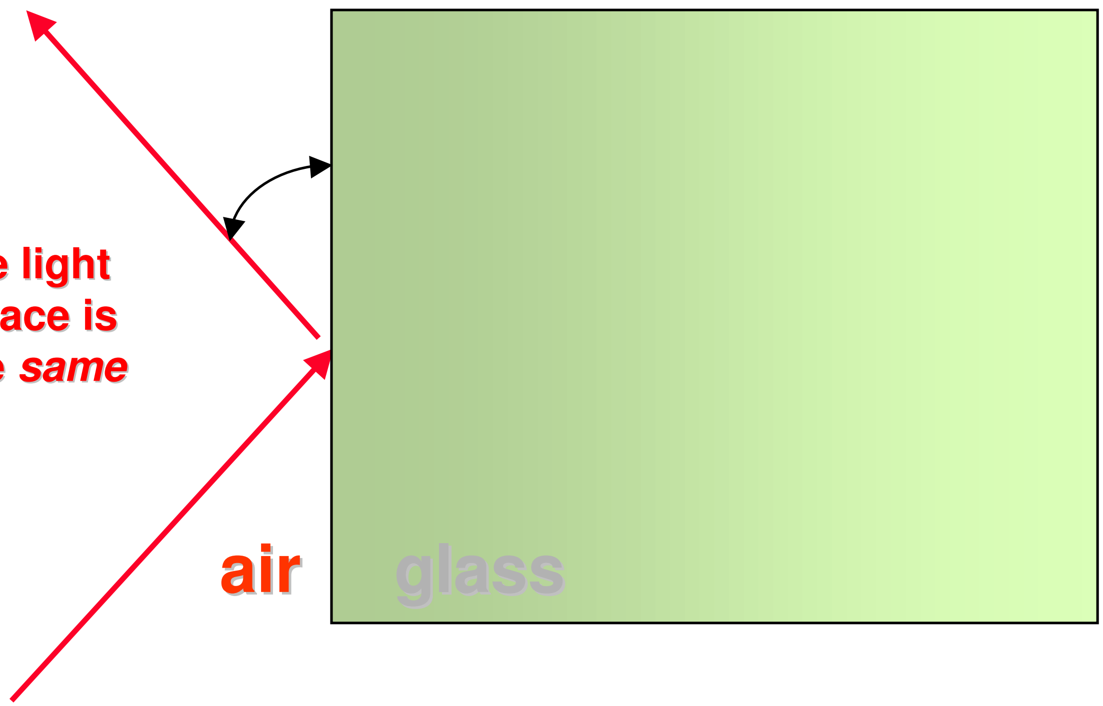
- **Reflection is a light ray *BOUNCING* off of the interface of two materials**

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

Optical Reflection.

Reflection

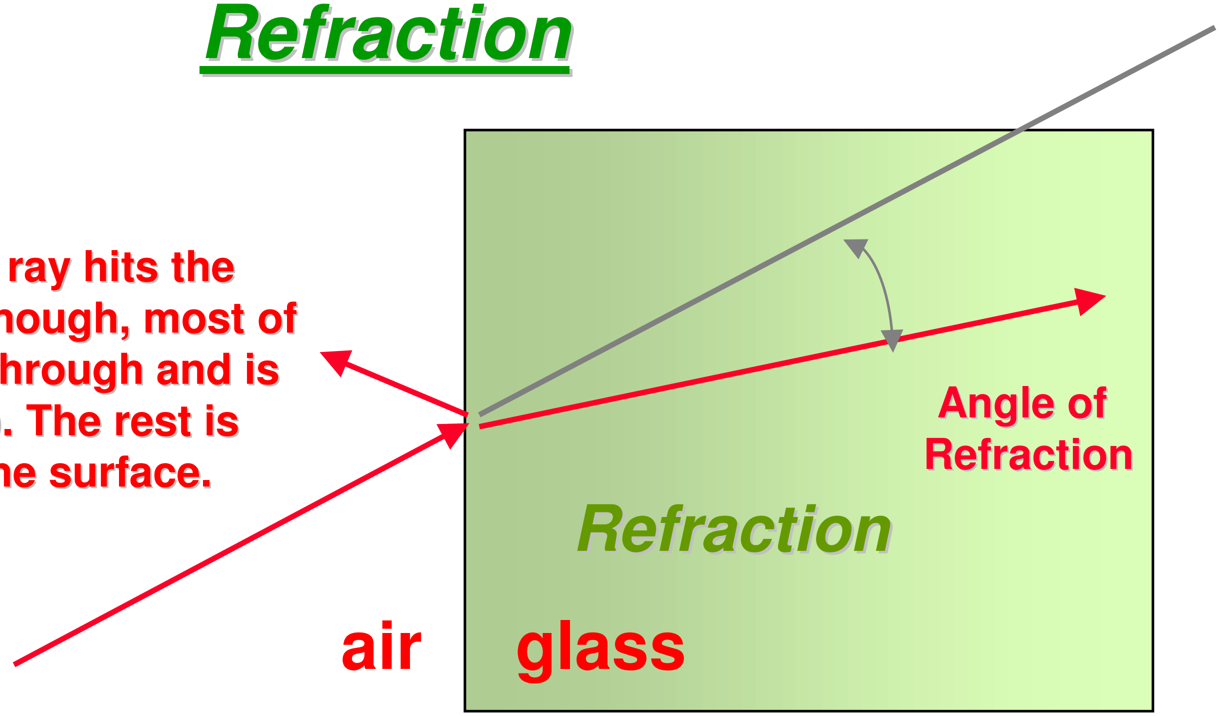
Some or all of the light that strikes a surface is reflected off at the *same angle*.



Optical Refraction.

Refraction

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.

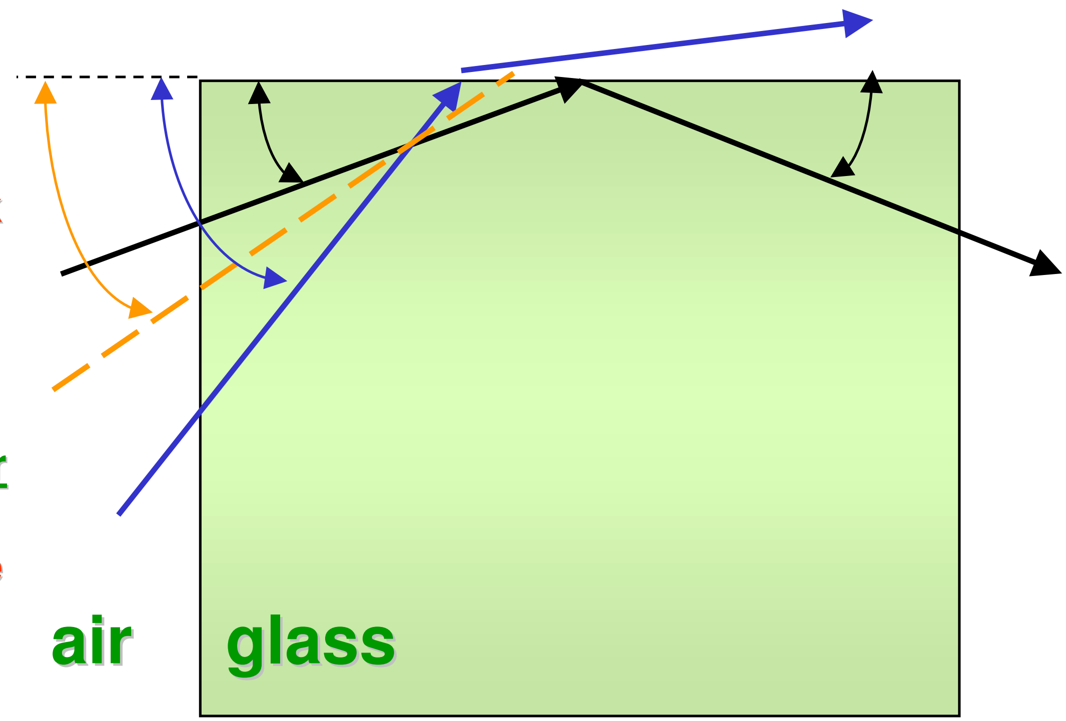


Optical Critical Angle.

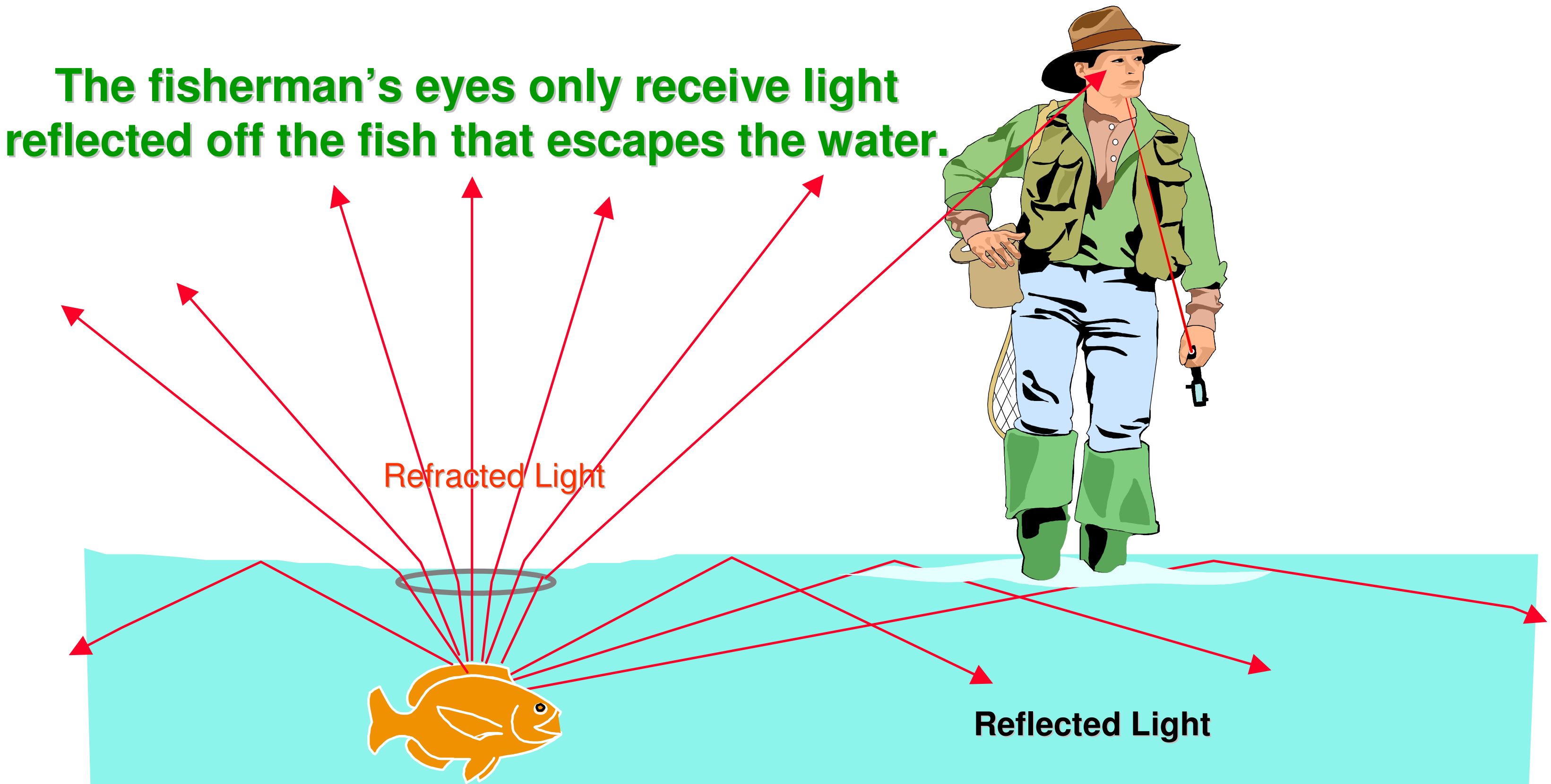
The Critical Angle

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.

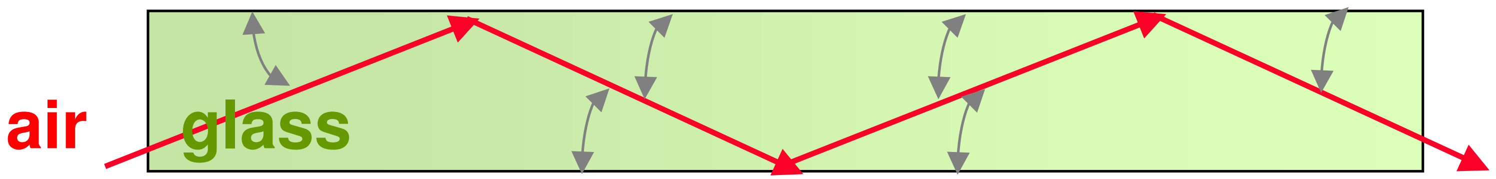


Optical Reflection & Refraction.



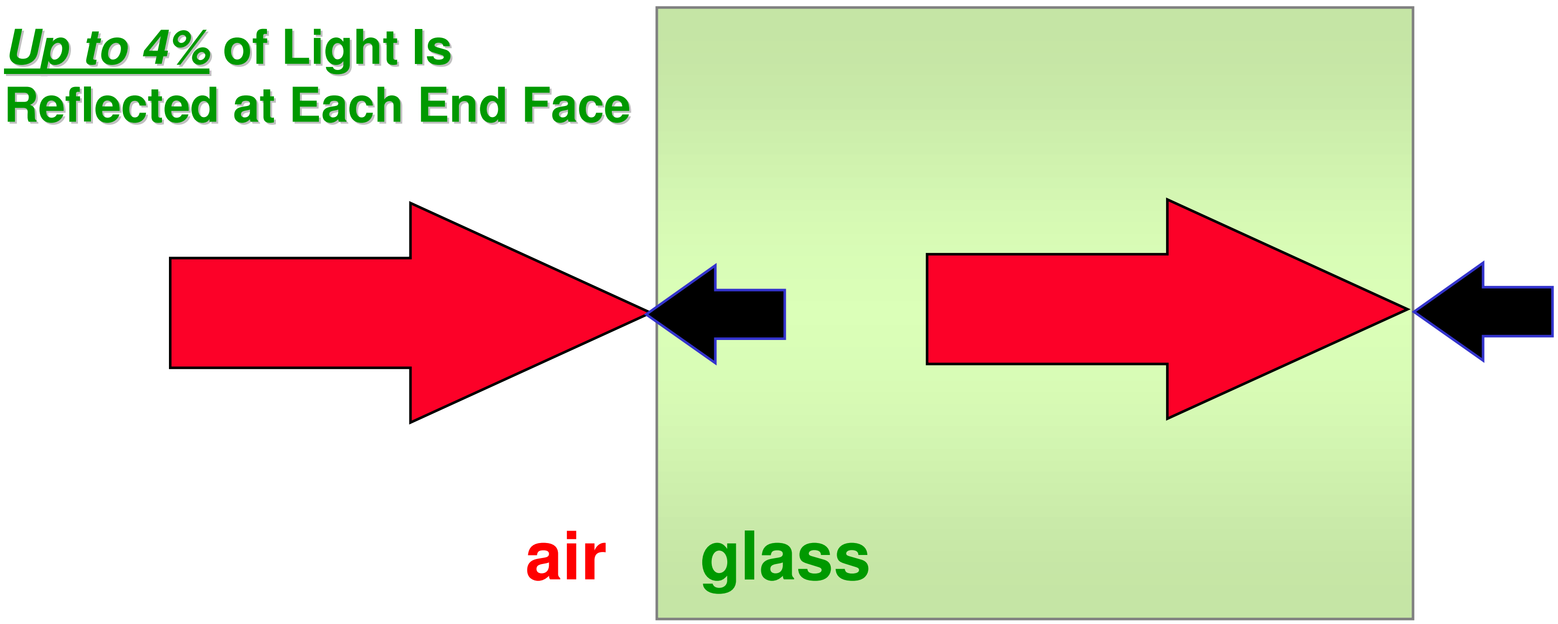
Light rays reflecting off the fish that strike the surface of the water at an angle outside that defined by the circle do not escape but are reflected back into the water.

Optical Reflection & Refraction.

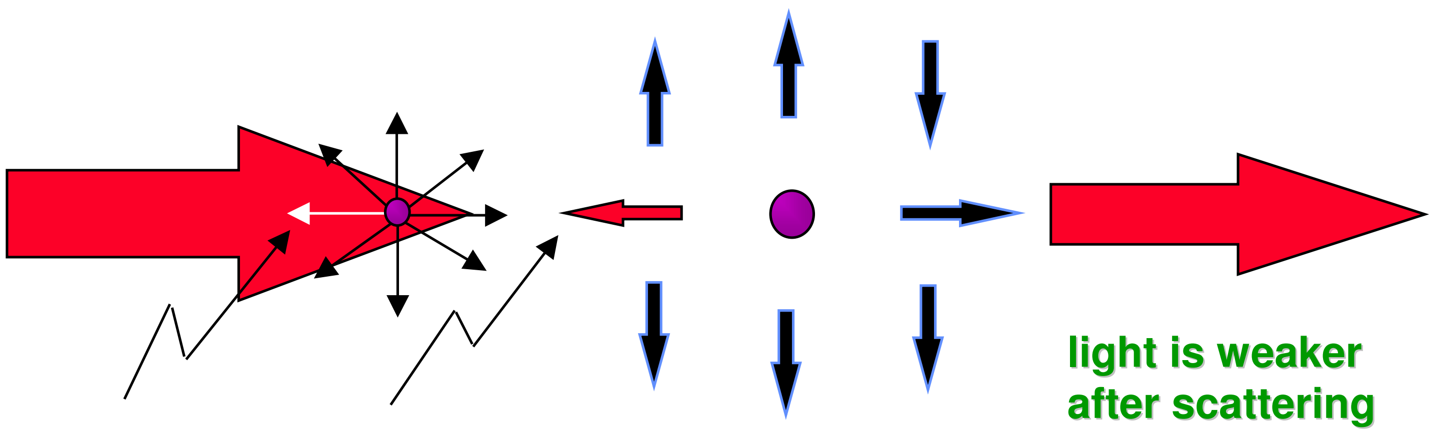


As long as the light ray stays at the Critical Angle or less as it hits the air-glass interface, it will remain in the fiber until it reaches the other end.

Optical Reflection at the Ends of Fiber.



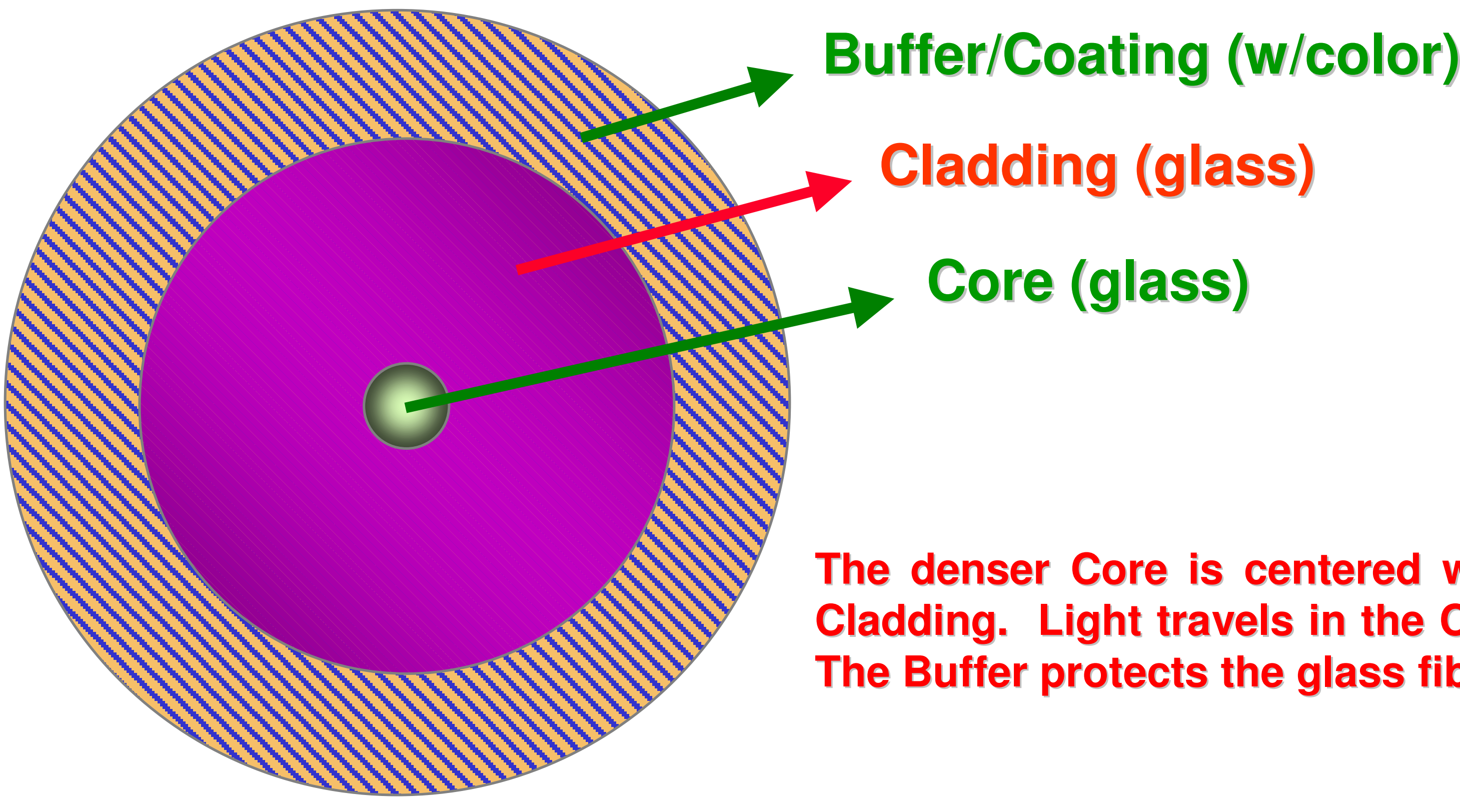
Optical Raleigh Scattering.



Backscatter

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*.

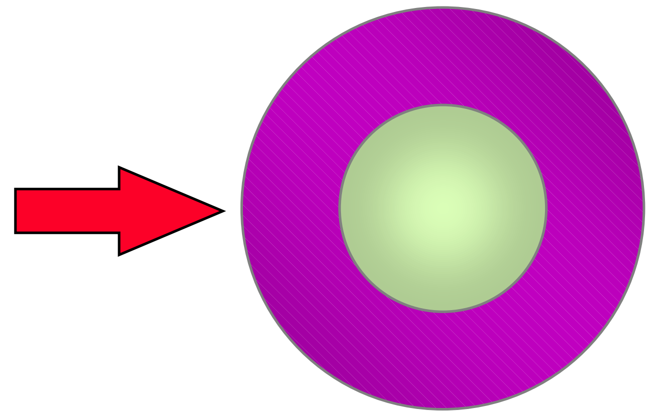
Optical Fiber Parameters.

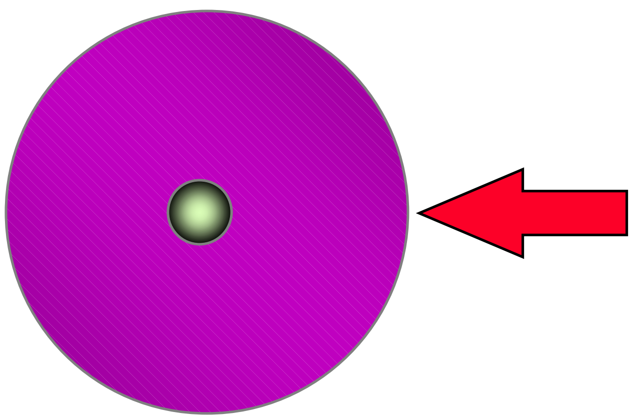


The denser Core is centered within the Cladding. Light travels in the Core only. The Buffer protects the glass fiber.

Optical Fiber Types.

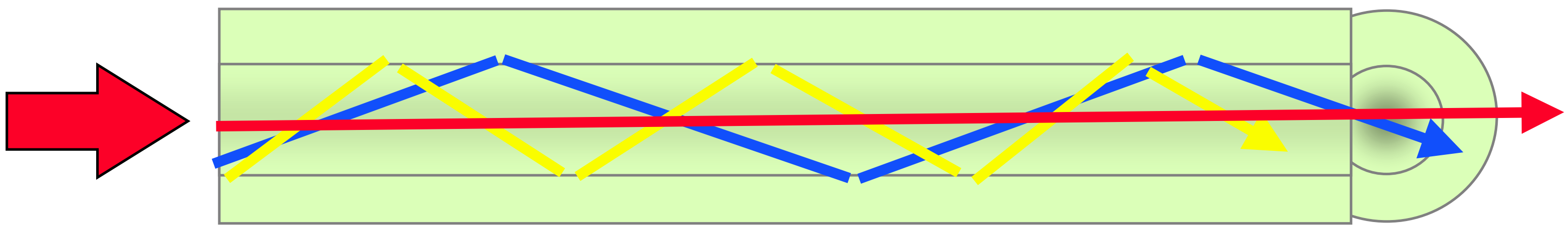
Multimode fiber has a large core relative to the cladding diameter. **50, 62.5, 100 um** are typical core sizes centered in a cladding of 125/ 250 um.



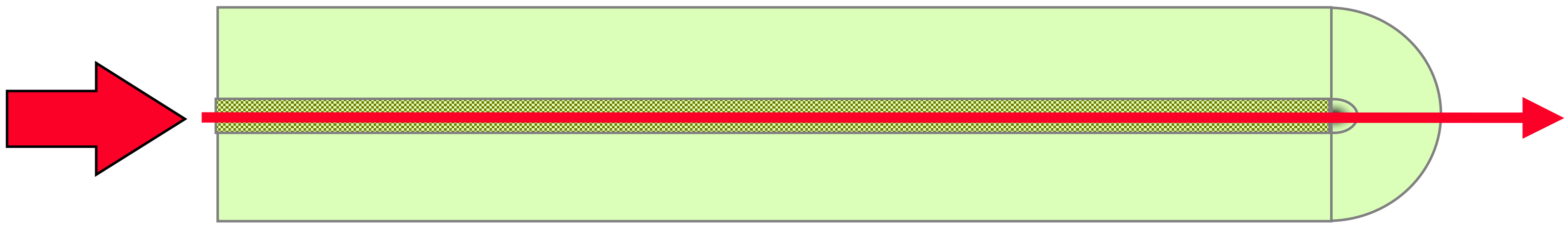


Singlemode fiber has a smaller core relative to the cladding diameter. **8 - 9 um** is a typical core size centered in a cladding of 125 um.

Optical Multimode vs. Singlemode Fiber.



Multimode allows many paths ***("modes")*** for the light

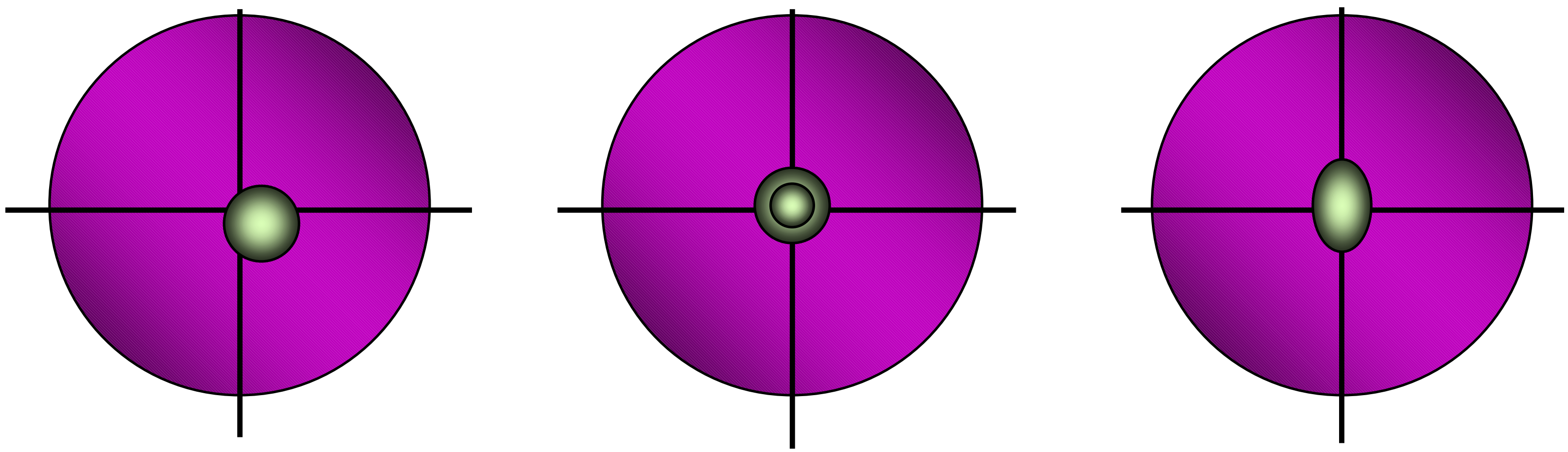


Singlemode allows only one single path for the light

JAAndy hamm   TRISPEC COMMUNICATIONS INC www.trispec.com

Fiber Geometry Problems.

Off Center | **Different Size** | **Non-Circular**



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

Fiber Index of Refraction (n).

- Speed of Light in a Vacuum is: **299,792,460 k/mt per second**.
- Speed of Light in a Vacuum is: **186,287.5 miles per second**.

- In fiber optic the speed of light will be less, it should be around 1.465 of that or: 204,778,157 kmt/sec or 127,158,703 miles/sec.

- Different fiber manufacturers will vary slightly from the above.

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

C (velocity in a vacuum)

V (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")

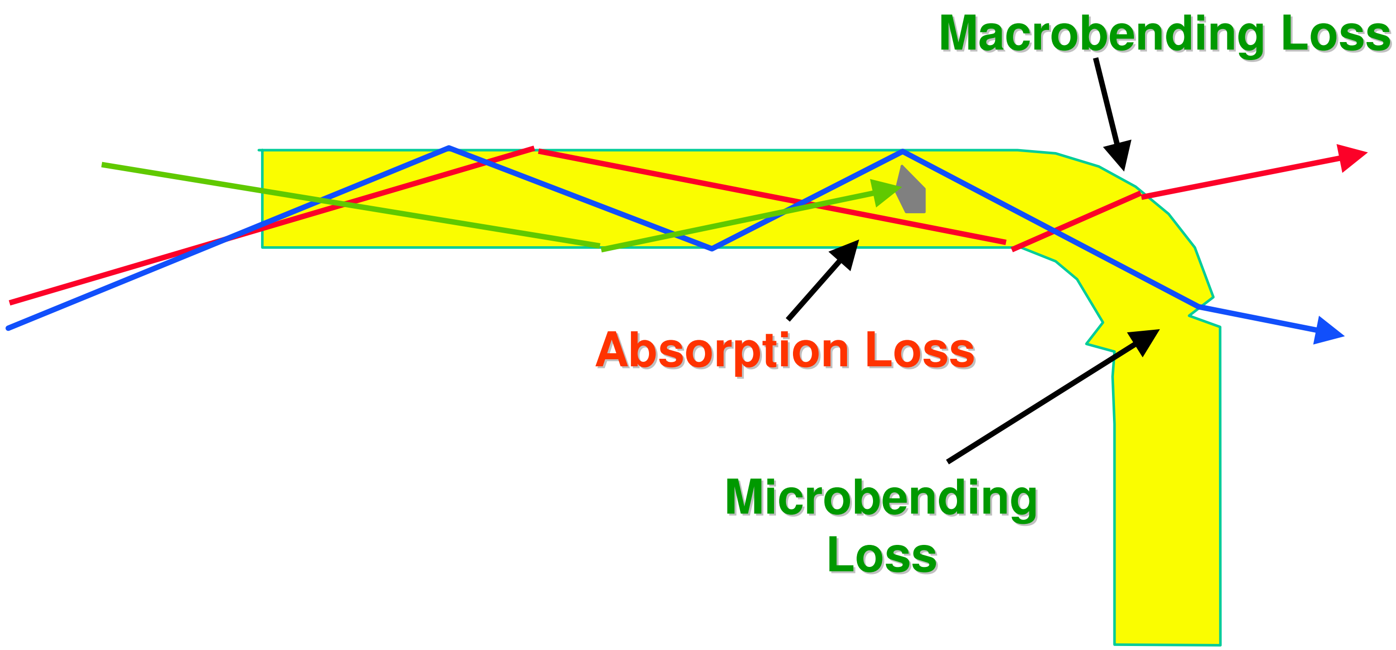
Attenuation in Fiber.

- Rayleigh Scattering
- Macro Bending
- Micro Bending
- Absorption

Raleigh Loss in Fiber.

- 2.50 dB/km at 850 nm — Multimode
- 1.0 dB/km at 1300 nm — Multimode
- 0.33 dB/km at 1310 nm — Singlemode
- 0.19 dB/km at 1550 nm — Singlemode

Attenuation in Fiber.



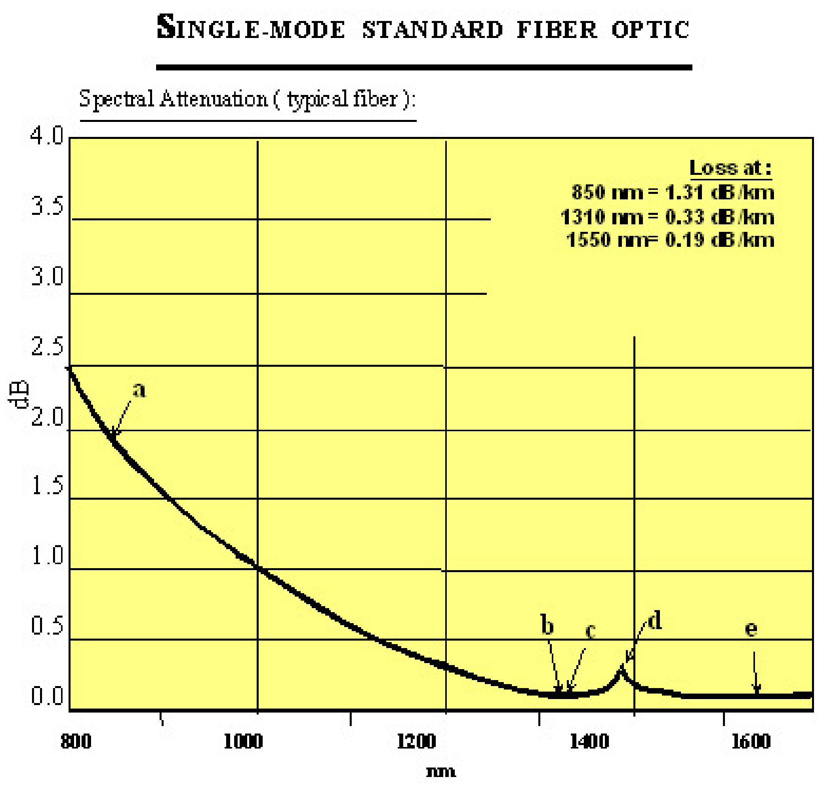
Note: Only the fiber core is shown.

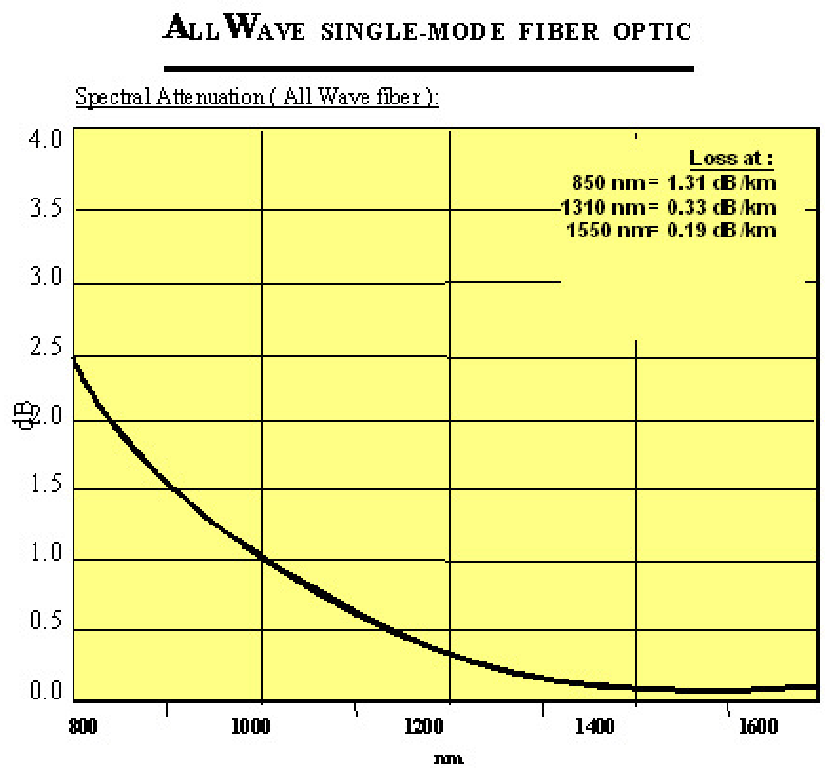
Type of Fiber.

Depressed Cladding Single-Mode Fiber	For long and standard distance, metro access, with a 9.2 um centre.
Matched Cladding Single-Mode Fiber	For long and standard distance, metro access, with a 8.8 um centre.
AllWave® Fiber	Designed for optimum performance with water peak removed at 1400 nm.
TrueWave® RS Fiber	The world first Non-Zero Dispersion optimized for long distance.
TrueWave® SRS Ocean Fiber	The latest innovation, designed for very long transoceanic networks.

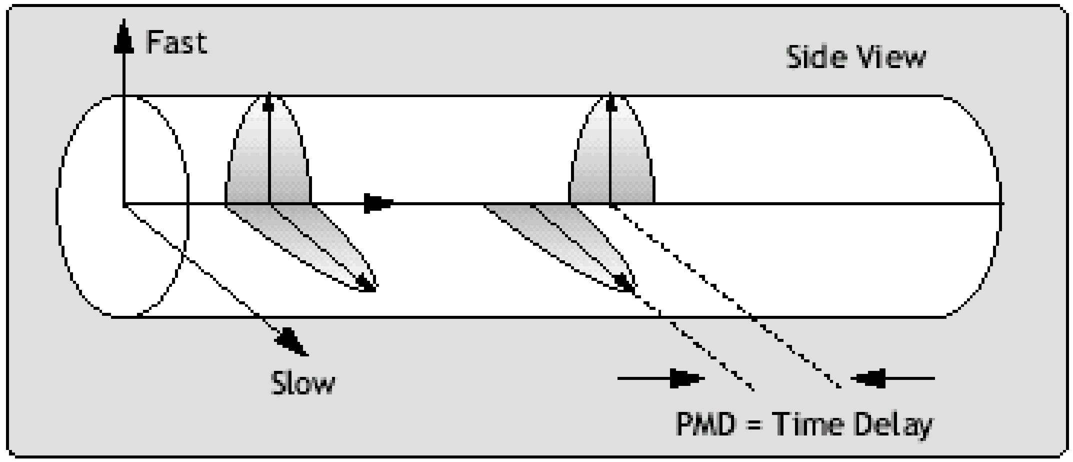
Fiber Specifications.

Performance Characteristics of single mode fiber optic





Polarisation Mode Dispersion in Fiber.

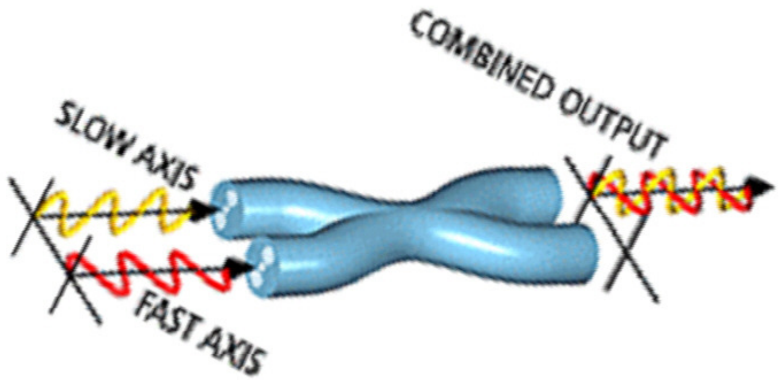


DIFFERENT POLARIZATIONS TRAVEL AT DIFFERENT SPEEDS

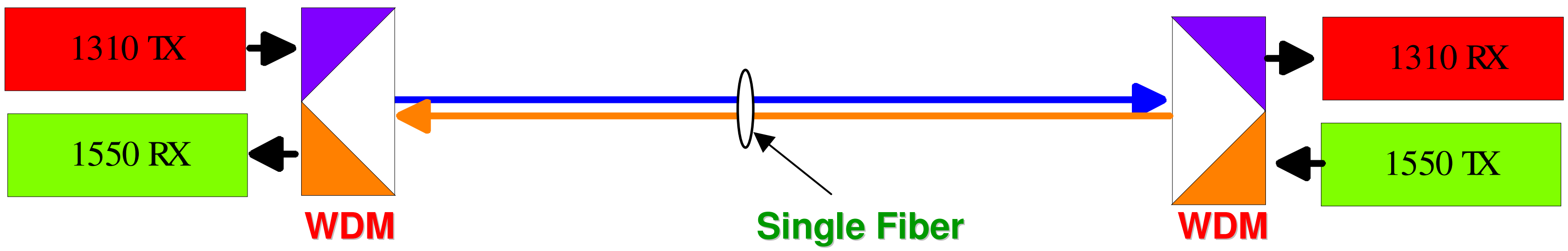
- PMD = Polarization Mode Dispersion
- PMD affects FO transmission by spreading light pulse over a distance
- Digital effects: PMD increases BER and therefore limits system bandwidth
- Analog effects: PMD creates distortion (CSO) and therefore limits the numbers of channels.

Transmitting Two Wavelengths in Fiber.

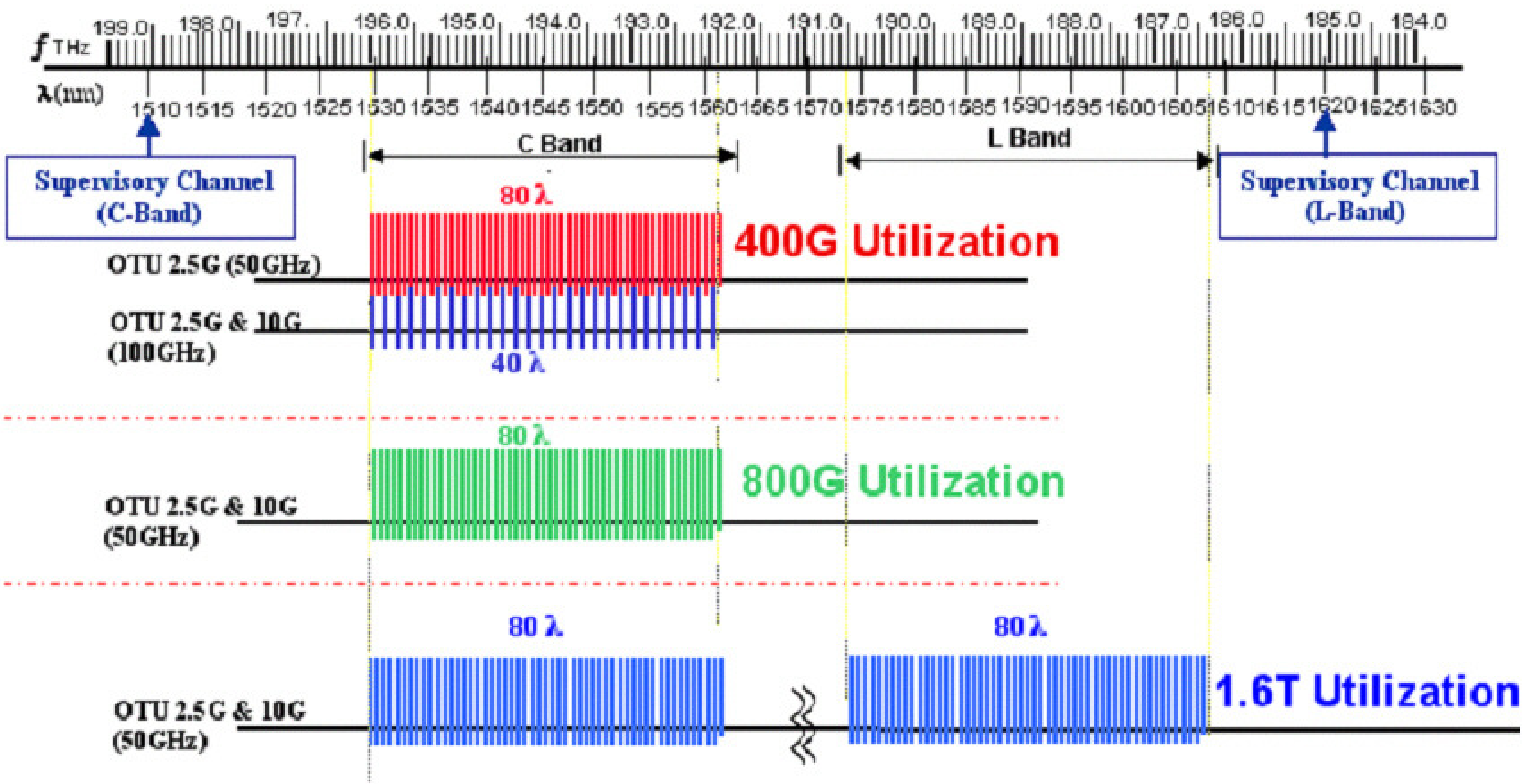
WDM technology



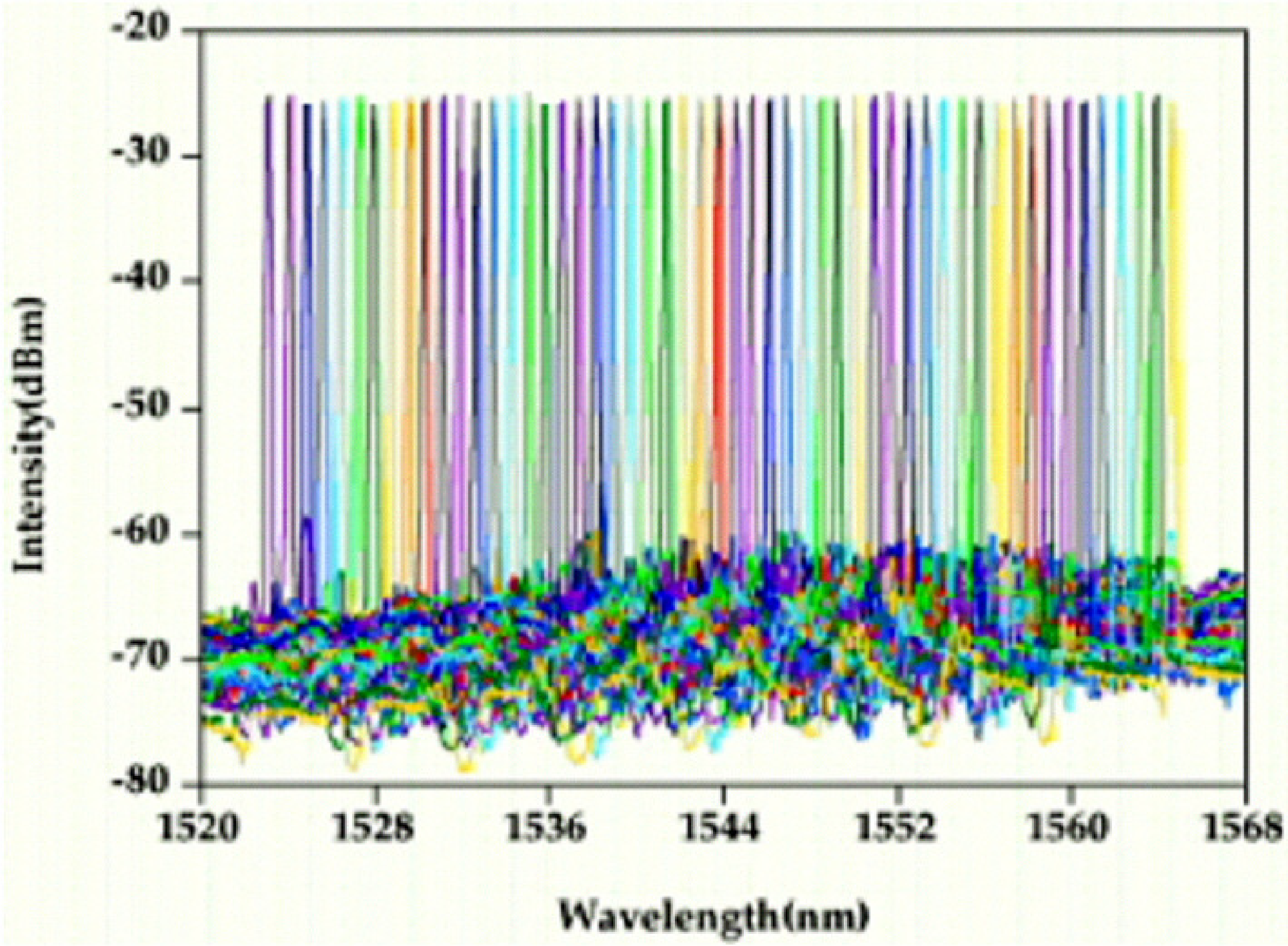
It is possible to transmit Two wavelengths on the same finer, using a WDM at each end.



Using C and L Band in Fiber.



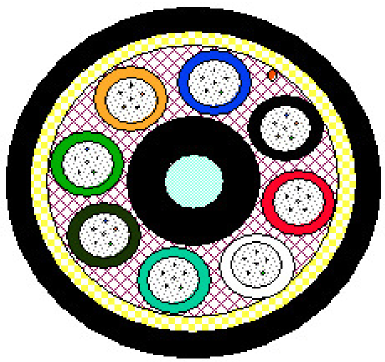
DWDM Technology in Fiber.

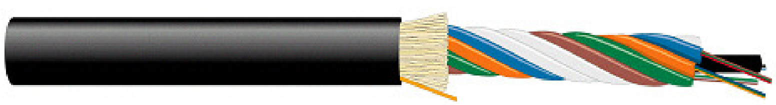


Above is a 32 wavelengths for the DWDM technology.

Type of Fiber Optic Available.

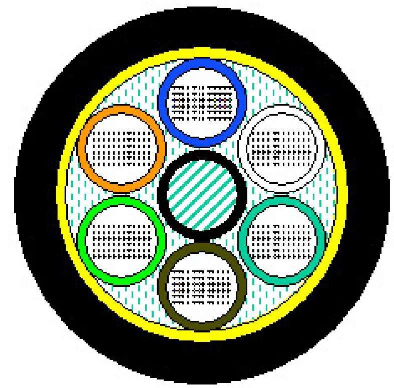
Loose Tube Fiber

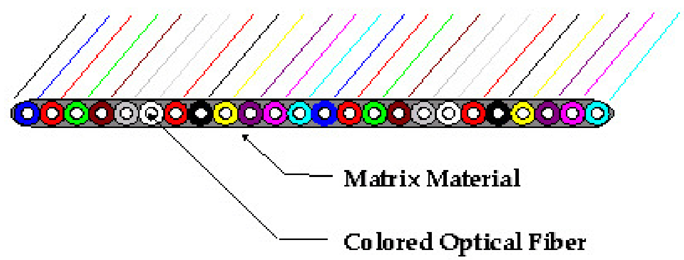




This type of fiber cable is better suited for HFC system, where it is easier to get in the cable again.

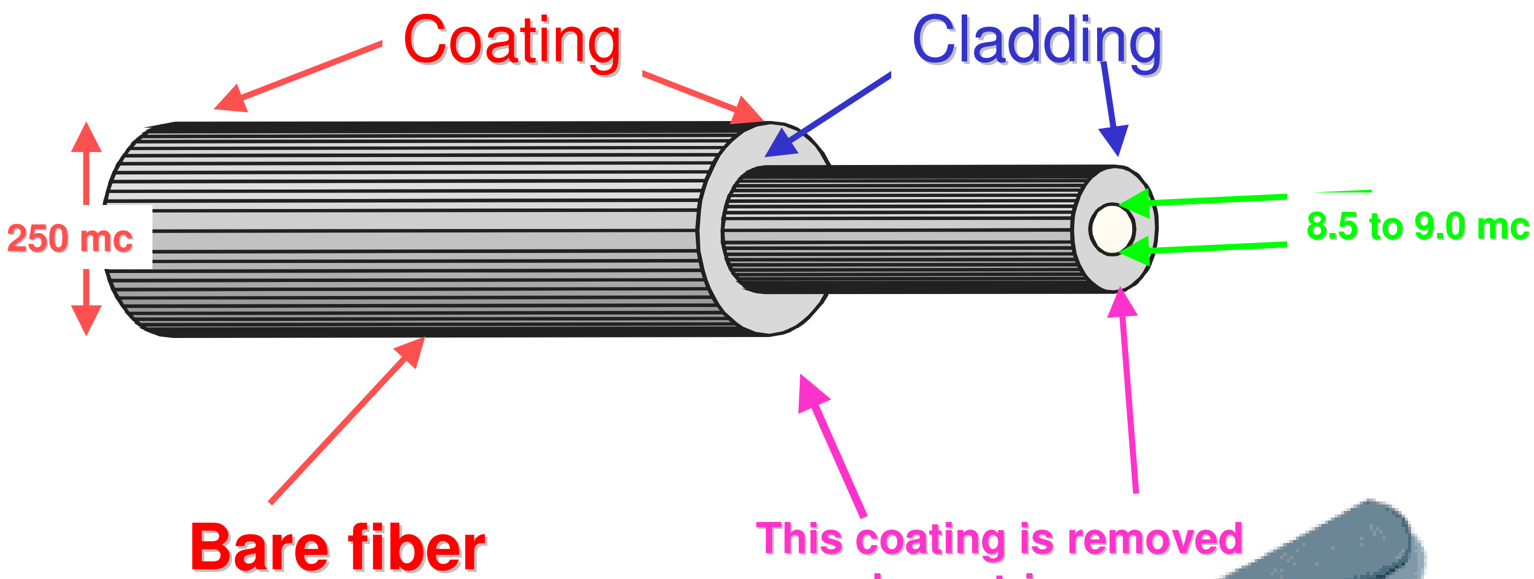
Ribbon Fiber



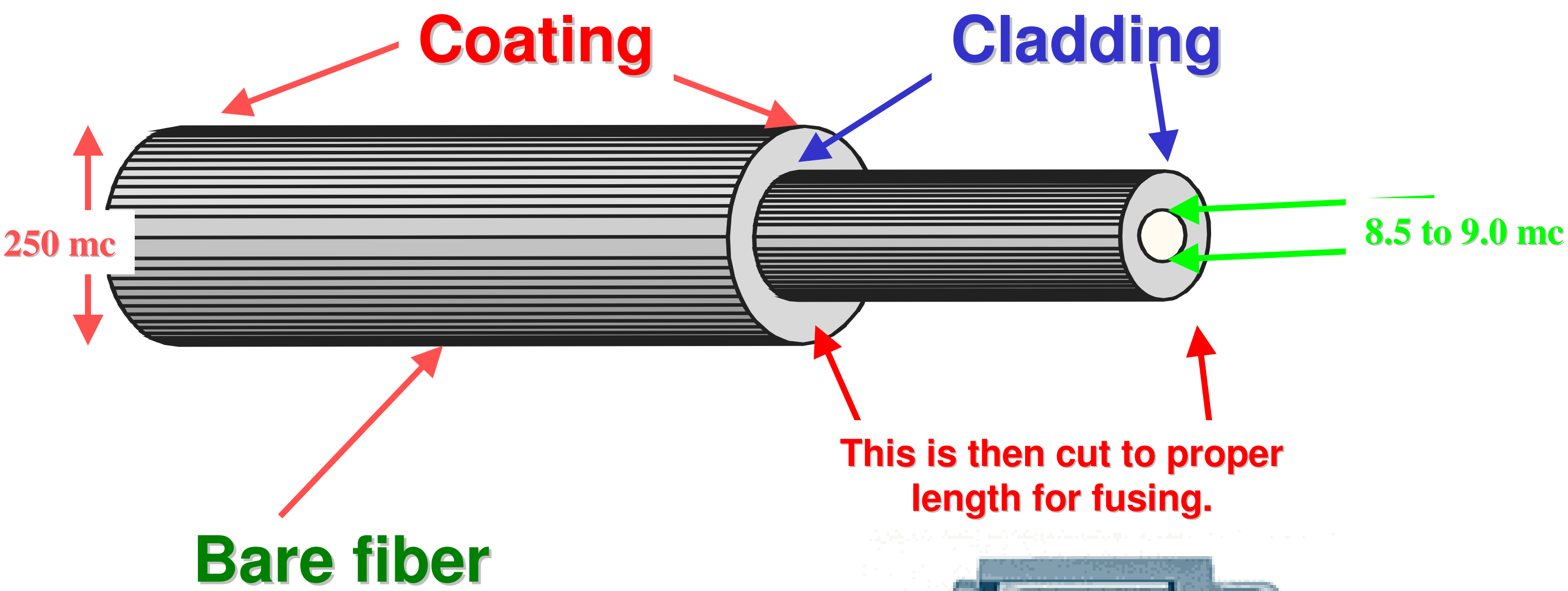


This type of fiber cable is better suited for long distance transport.

Preparation of Single Fiber Optic.

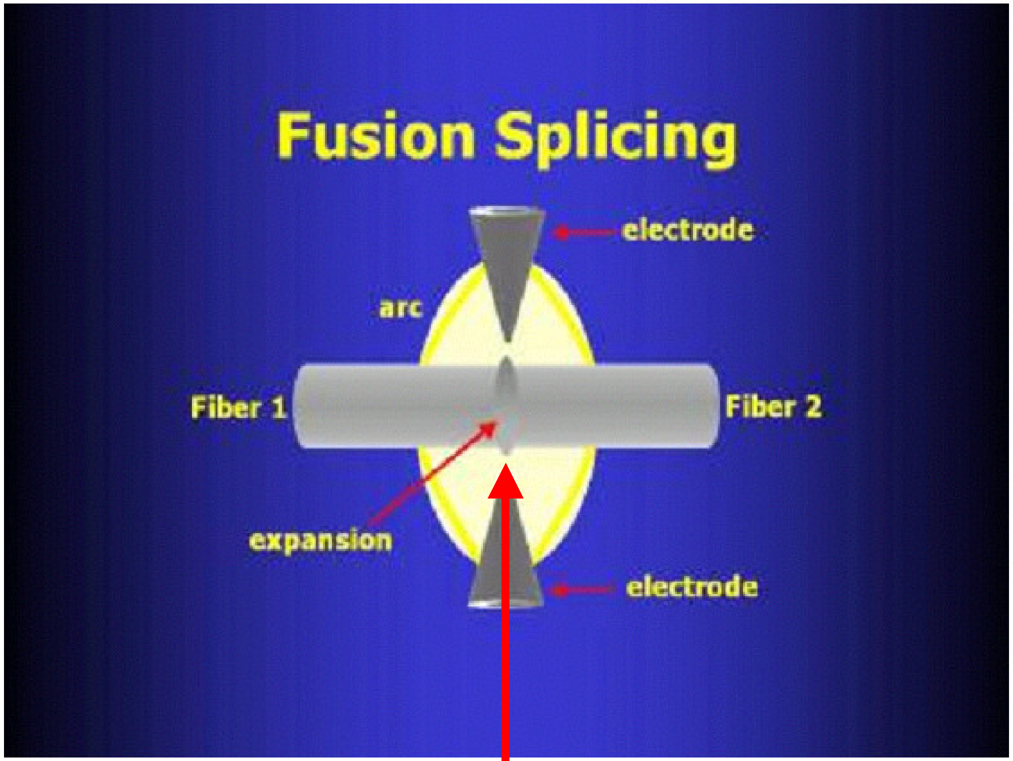


Preparation of Single Fiber Optic.



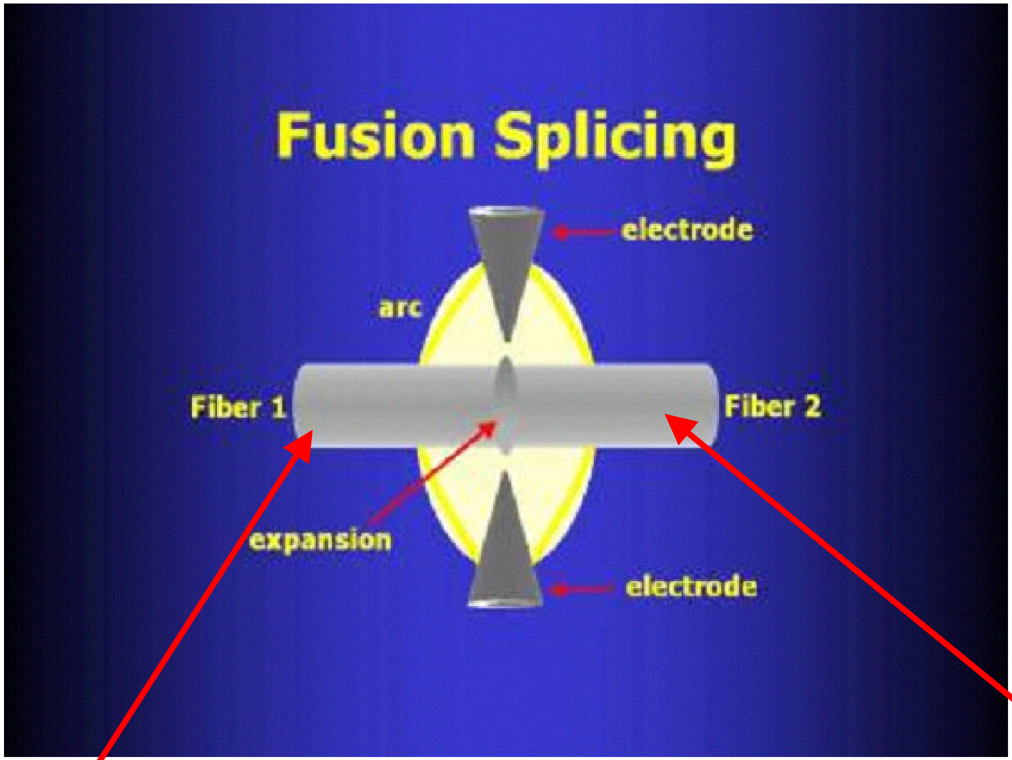
Fusing Single Fiber Optic.

Fusing Single Fiber Optic.



High Electrical Heat Held for a Certain Time by the Fusing Machine.

Fusing Single Fiber Optic.



- Depending on the customer, the signal lost accepted after the fusion can be as much as 0.02 dB and as little as 0.03 dB.
- This measurement can done by the splicing machine.
- This measurement can also can be measured with an OTDR.

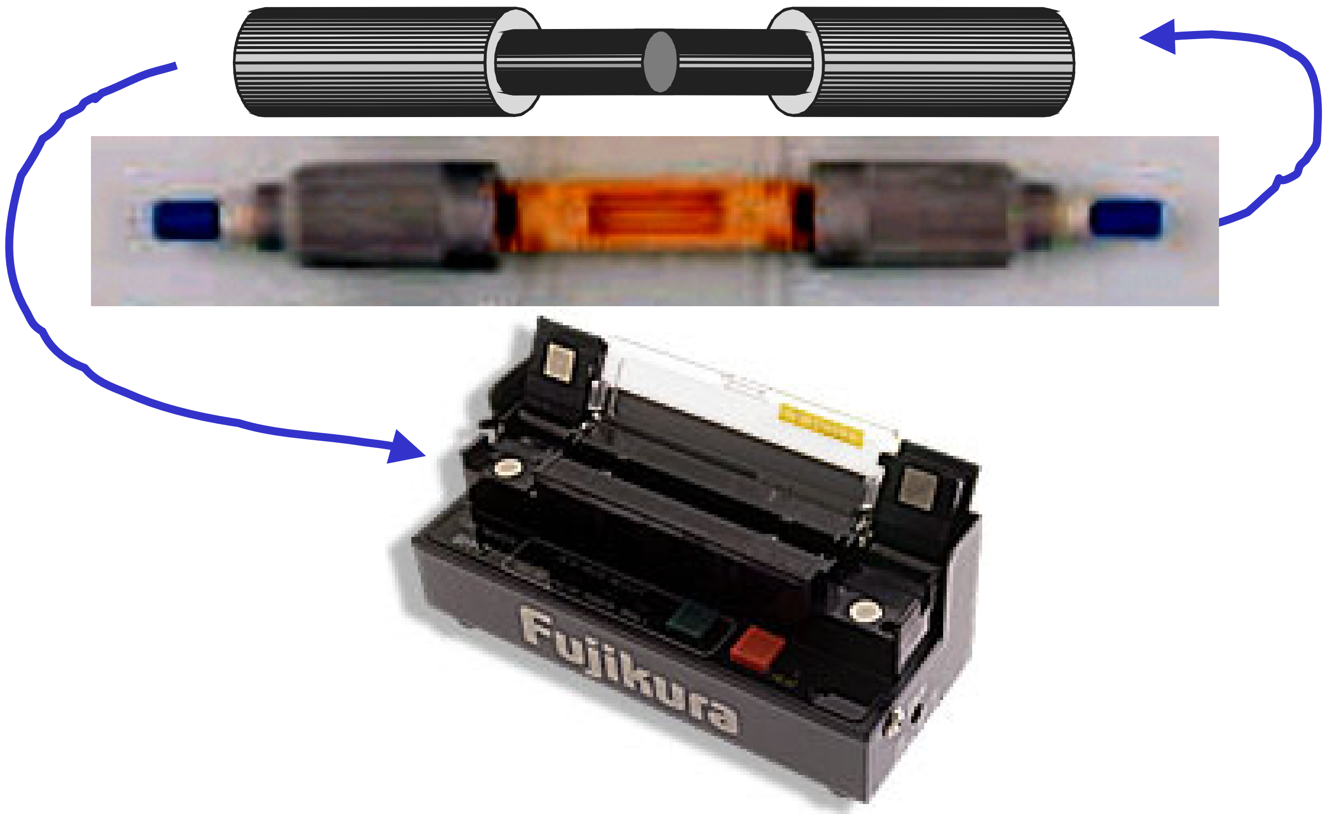
Fusing Single Fiber Optic.

Fiber optic been fused.

Fusing Single Fiber Optic.

Fiber optic been fused.

Fusing Single Fiber Optic.



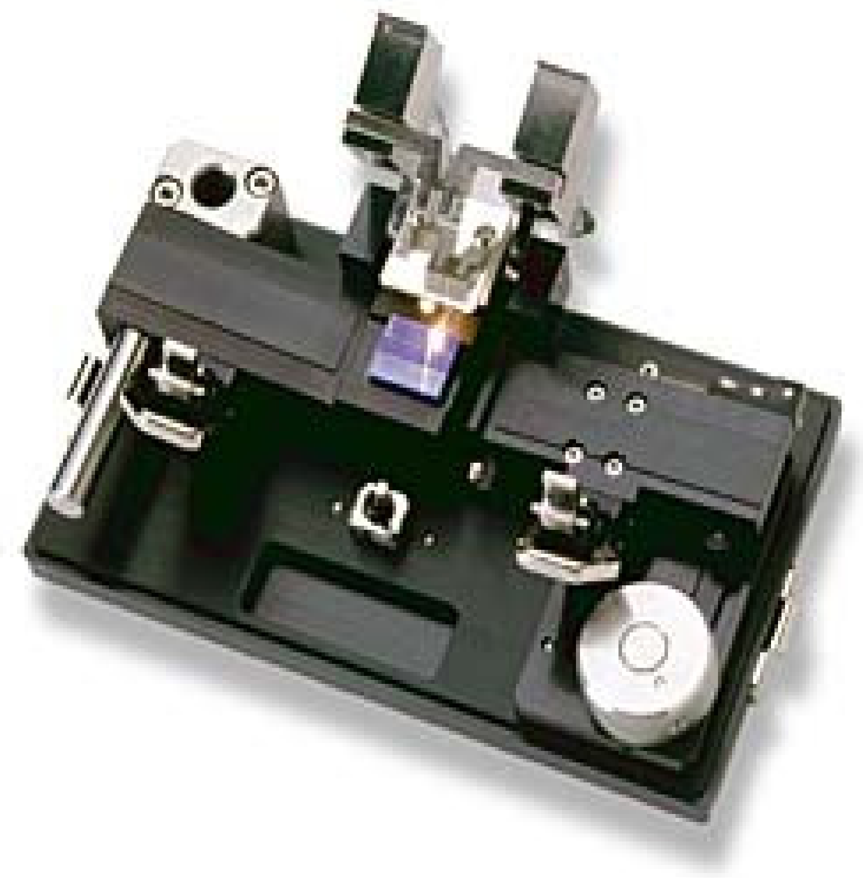
Mechanical splice

Mass Fusing Single Fiber Optic.

Mass Fusing Single Fiber Optic.

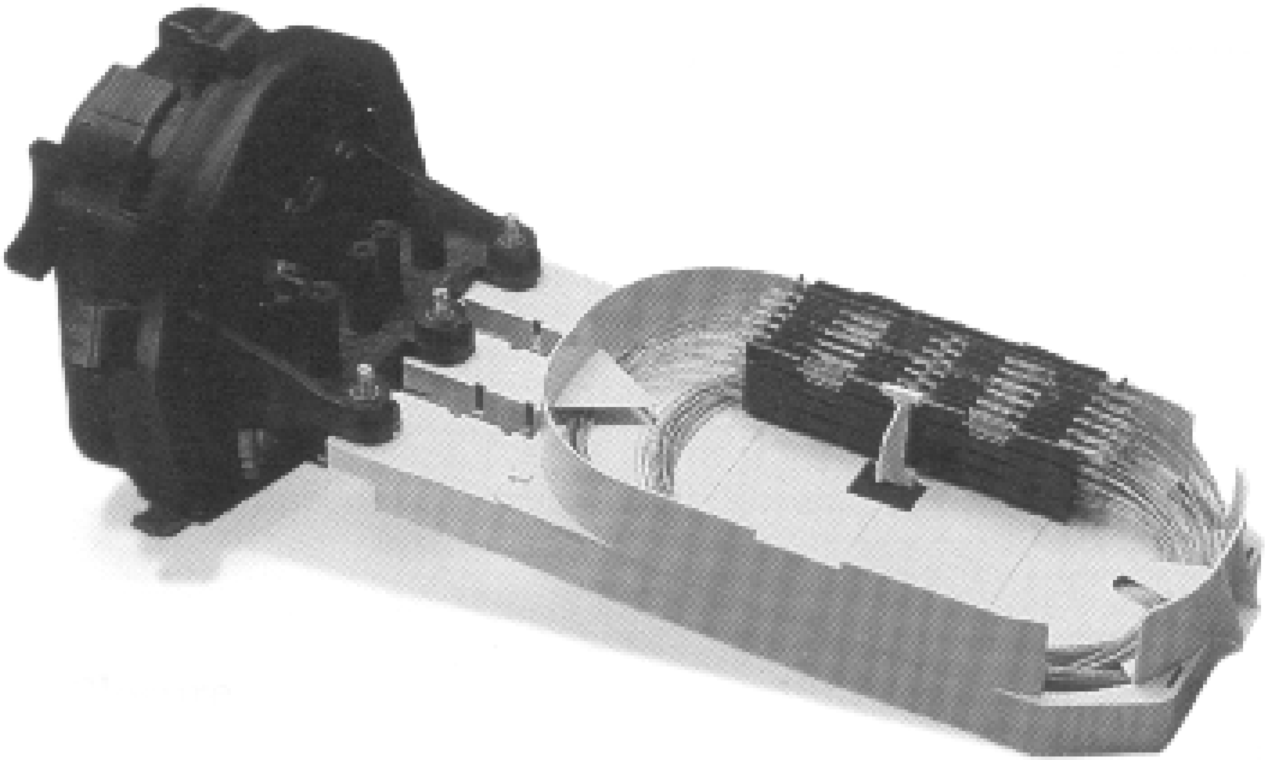
Multi Fiber optic been fused.

Mechanical Splicing Single Fiber Optic.



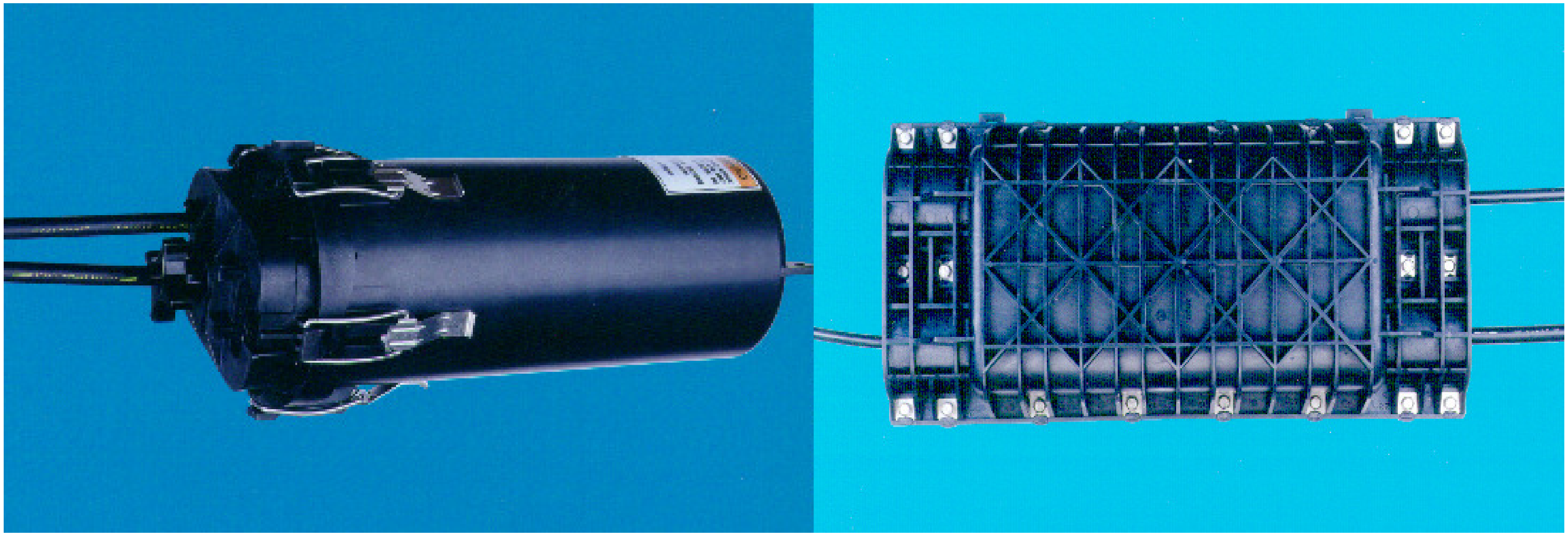
Splicing Closure for Fiber Optic.

Splicing Closures



Protecting the Fiber Optic after the Fusion.

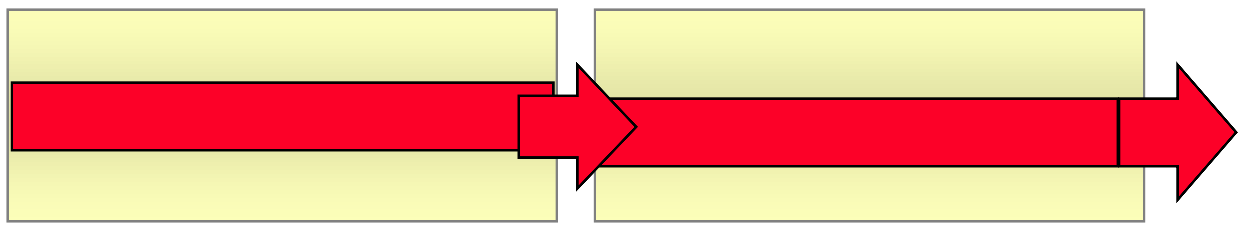
Splicing Closures



Typical Splice Loss Values in Fiber.

- **Fusion: 0.02 to 0.20 dB**
- **Mechanical: 0.10 to 0.50 dB**
- **Splice Loss Depends on:**
  - ***Quality of Fiber***
  - ***Craftsmanship***
  - ***Splicing Device Quality***

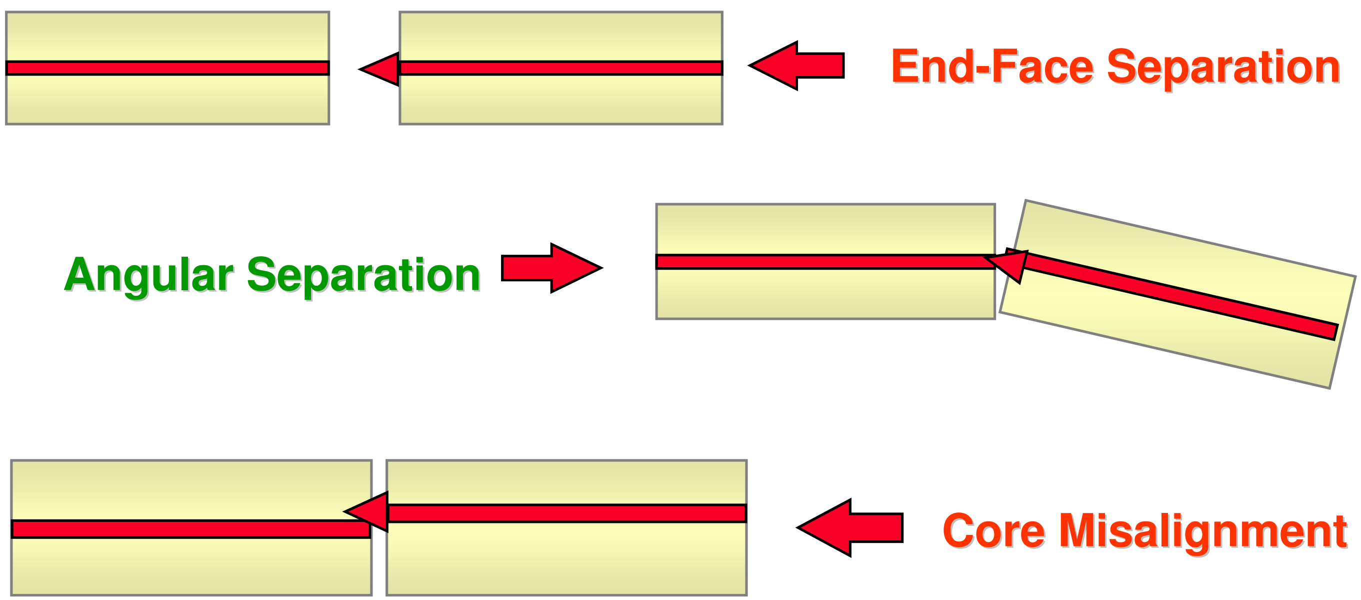
Splice Loss Due to Core Mismatch in Fiber.



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.

Cause of Connectors Loss in Fiber.

Typical Loss = 0.15 to 0.25 dB



Testing Fiber – Why?.

- Verify specs
- Check handling
- Measure work
- Record best condition
- Detect defects
- Locates 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

Reel of Fiber Optic Birth Certificate.

FITEL | Lucent Technologies
a joint venture company

Cable Test Report

Reel # 181162002023
Serial # S05-001283

Customer:	TRISPEC COMMUNICATIONS	Ordered Length	5000 M	OSE marking	40432 M
Ship to:	TRISPEC COMMUNICATION INC.	Ship Length:	5033 M	ISE marking:	35399 M
Date:	5/6/01				
Cable Part	AT-3BMNCD6-012-2	Customer Part #:	QB1-0083		
Design #:	F00-114-018	Customer Item #	16302		
Description	12 Fiber Singlemode LooseTube Cable	Customer Reel #			

0.35/0.25 dB/km @ 1310/1550 nm
DCM Single Armor: 2 PE Jackets 1 Steel Tape
DryBlock Core
1 x 22 AWG Copper Pair

Remarks

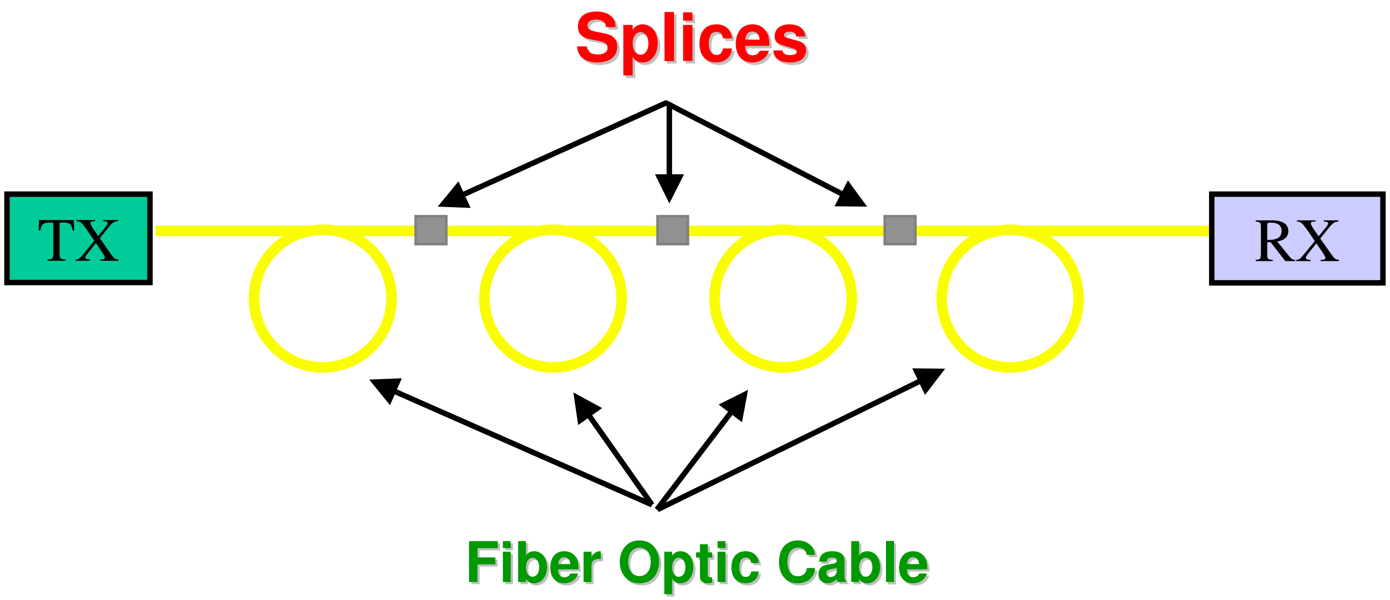
Pc Tul Fiber Attenuation dB/km (1310nm/1550nm singlemode, 850nm/1300nm multimode)

	BL	OR	GR	BR	SL	WH
BL	0.33/0.19	0.33/0.19	0.32/0.19	0.33/0.19	0.33/0.19	0.33/0.19
OR	0.33/0.19	0.33/0.19	0.33/0.19	0.33/0.19	0.32/0.19	0.33/0.19

Testing Fiber – How?.

- Optical Power Meter
- Optical Source
- OTDR

Basic Fiber Optic Link.

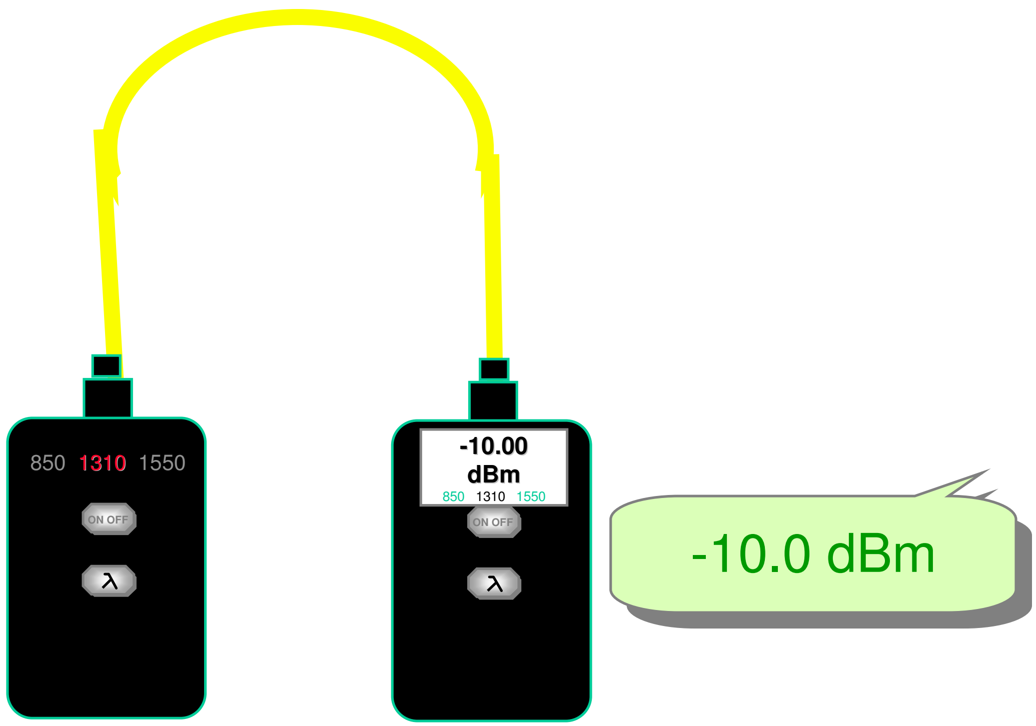


Optical Power Meter Applications.

- Measure TX Output
- Measure Fiber Loss
- Optimize Splices
- ID Active Fibers

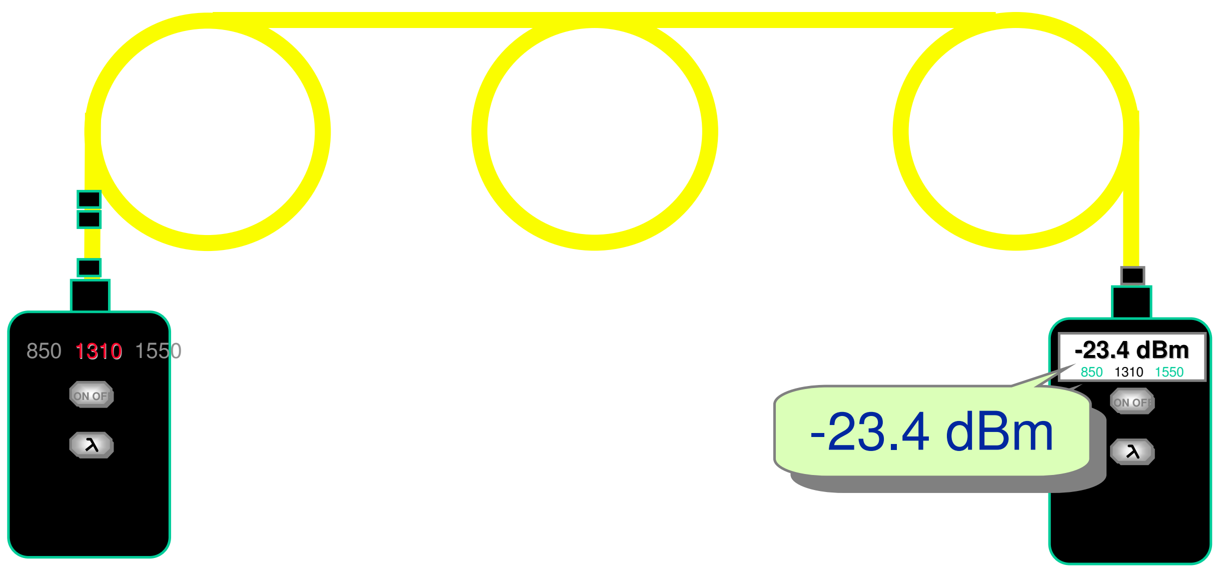
Optical Power Calculations.

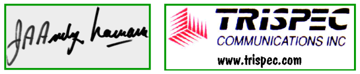
Step 1 - Take Reference (P1)



Optical Power Calculations.

Step 2 - Read Fiber Output (P2)





Optical Power Calculations.

Step 3 - Calculate Loss

$$\text{End-End Loss} = P_1 - P_2$$

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

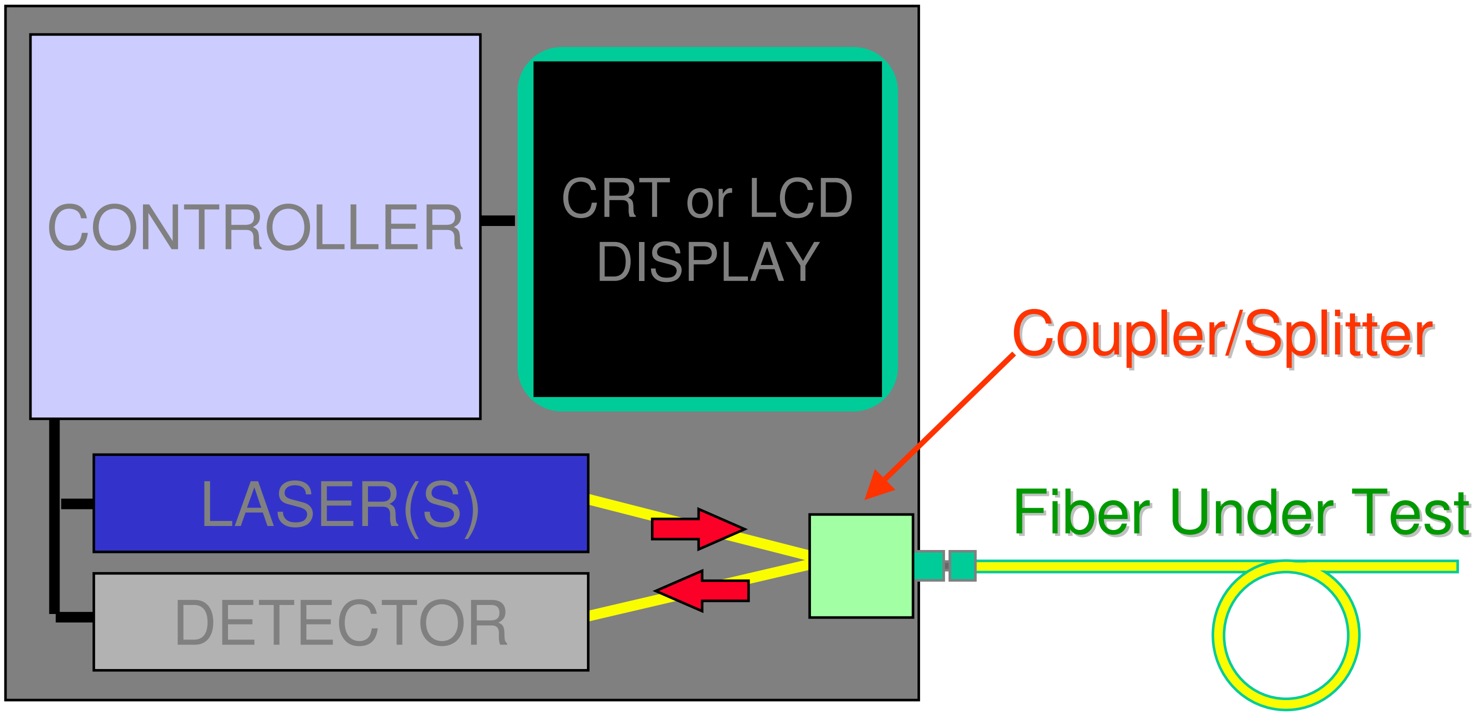
The OTDR.

- **Creates a graph of *<u>DISTANCE vs. RETURN SIGNAL LEVEL</u>* along fiber.**
- **Produces *<u>"Trace"</u>* or profile of signal level loss throughout the fiber.**
- **Uses radar principle to measure faults, return loss and distance.**

The 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

The OTDR.


CONTROLLER
CRT or LCD DISPLAY
LASER(S)
DETECTOR
Coupler/Splitter
Fiber Under Test

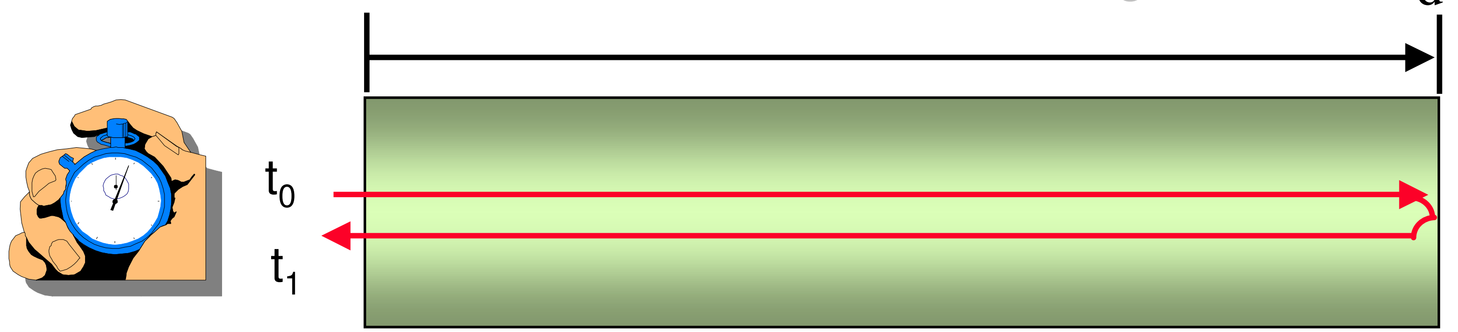
The OTDR.

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

"C" = speed of light

"n" = Index

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



"t" = $t_1 - t_0$

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

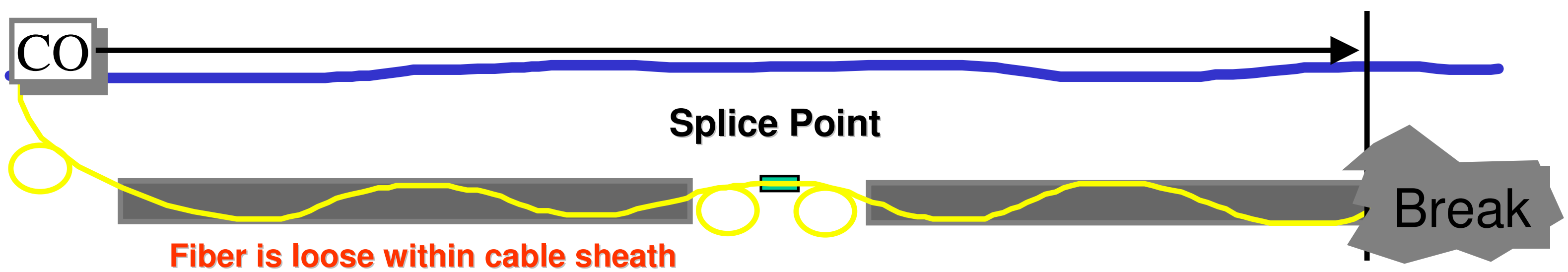
Speed of Light in a Vacuum is: 186,287.5 miles per second.

The 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

The OTDR Distance Measurements.

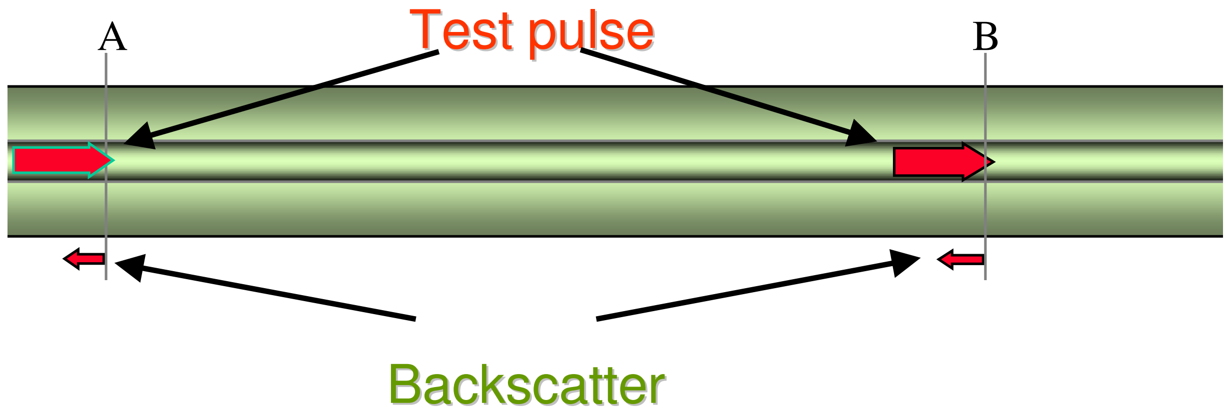
- Index of Refraction set correctly for fiber being tested
- Fiber length versus sheath length (approx. 2%) - Helix factor
- Sheath length versus ground distance
  need to compensate for loops & slack in fiber & cable
- Measure from closest known event on fiber to break
- Set OTDR's resolution as high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



The 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.

The 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.

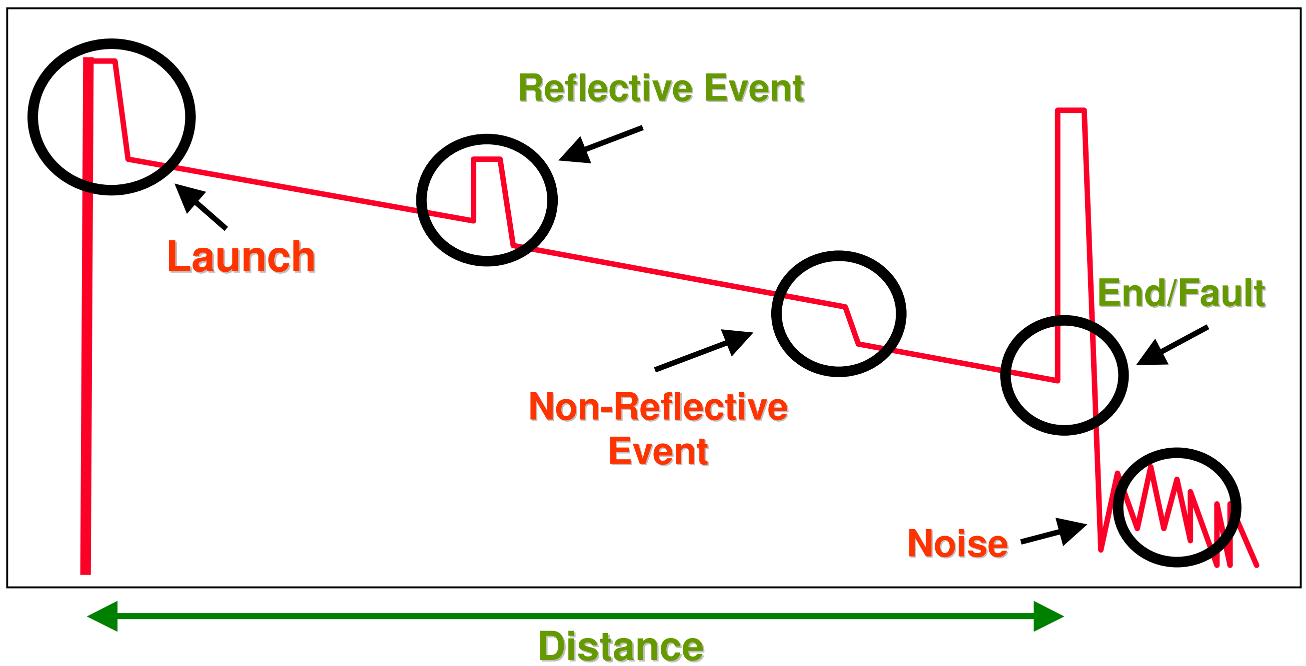
Gathering Data on a OTDR.

- Connect Fiber to Test Port
- Press TEST or REAL TIME K

or

- Press FAULT LOCATE Key

OTDR Traces Basics.



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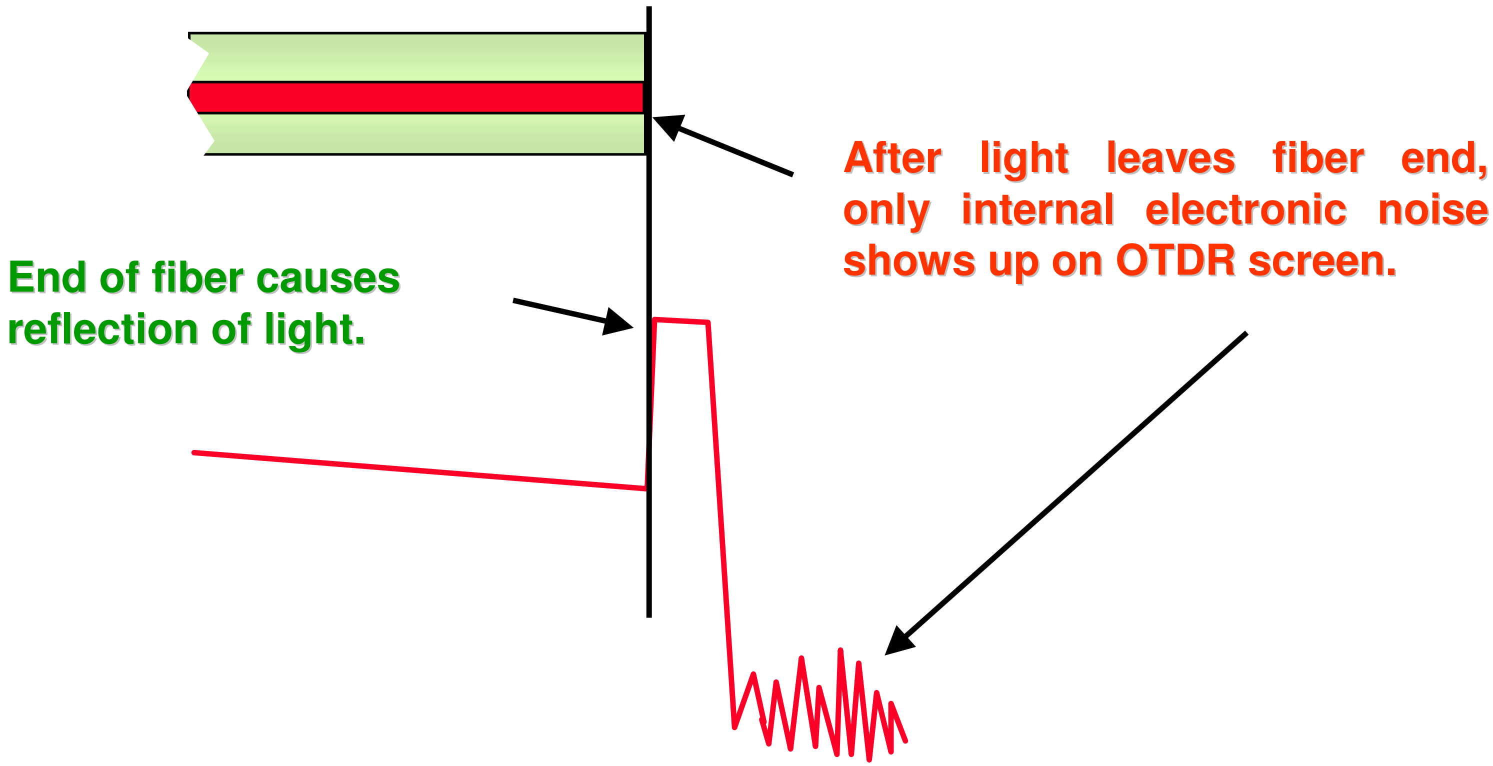
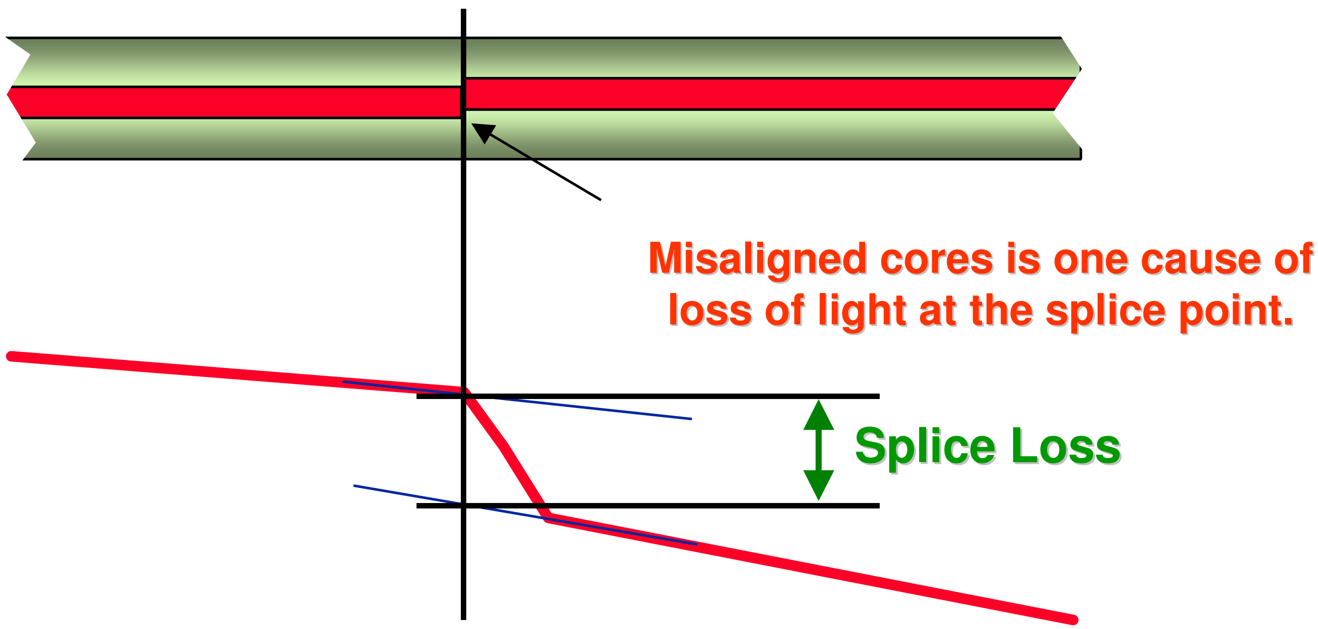
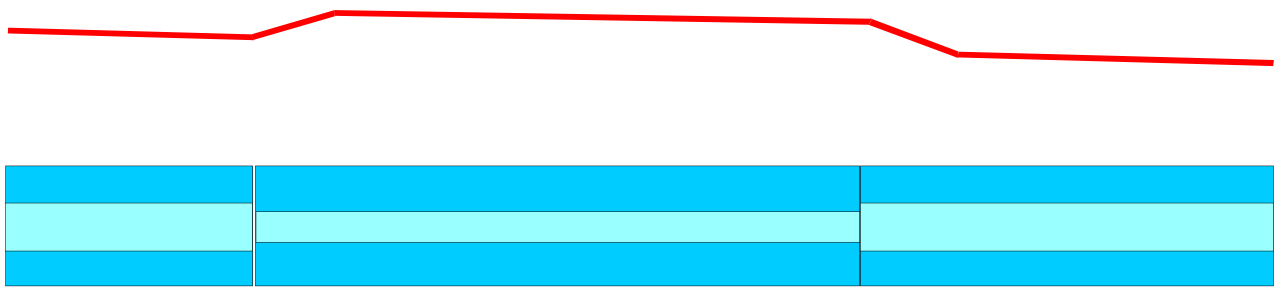
OTDR Locating the End of Fiber.



OTDR Locating & Measuring Non-Reflective Even.



OTDR Gainers & Losers.



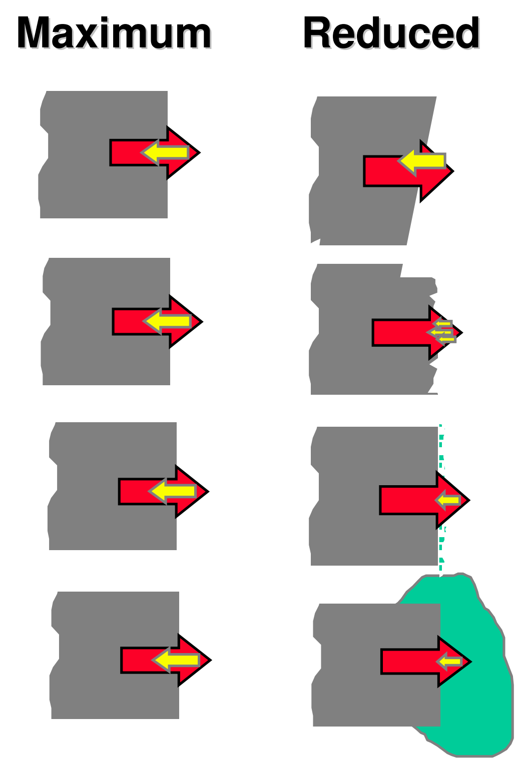
$$\text{Total Backscatter} = -10 \log \left(\frac{W1}{W2} \right)^2 \text{dB}$$

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

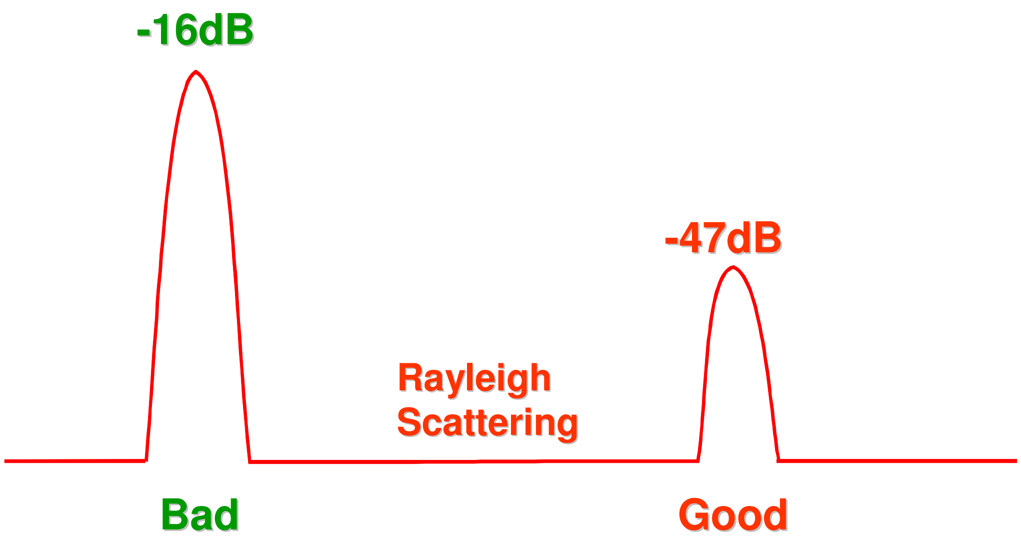
OTDR Reflection Magnitude Factors

What Creates a Big Reflection.

- **90^{o} 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



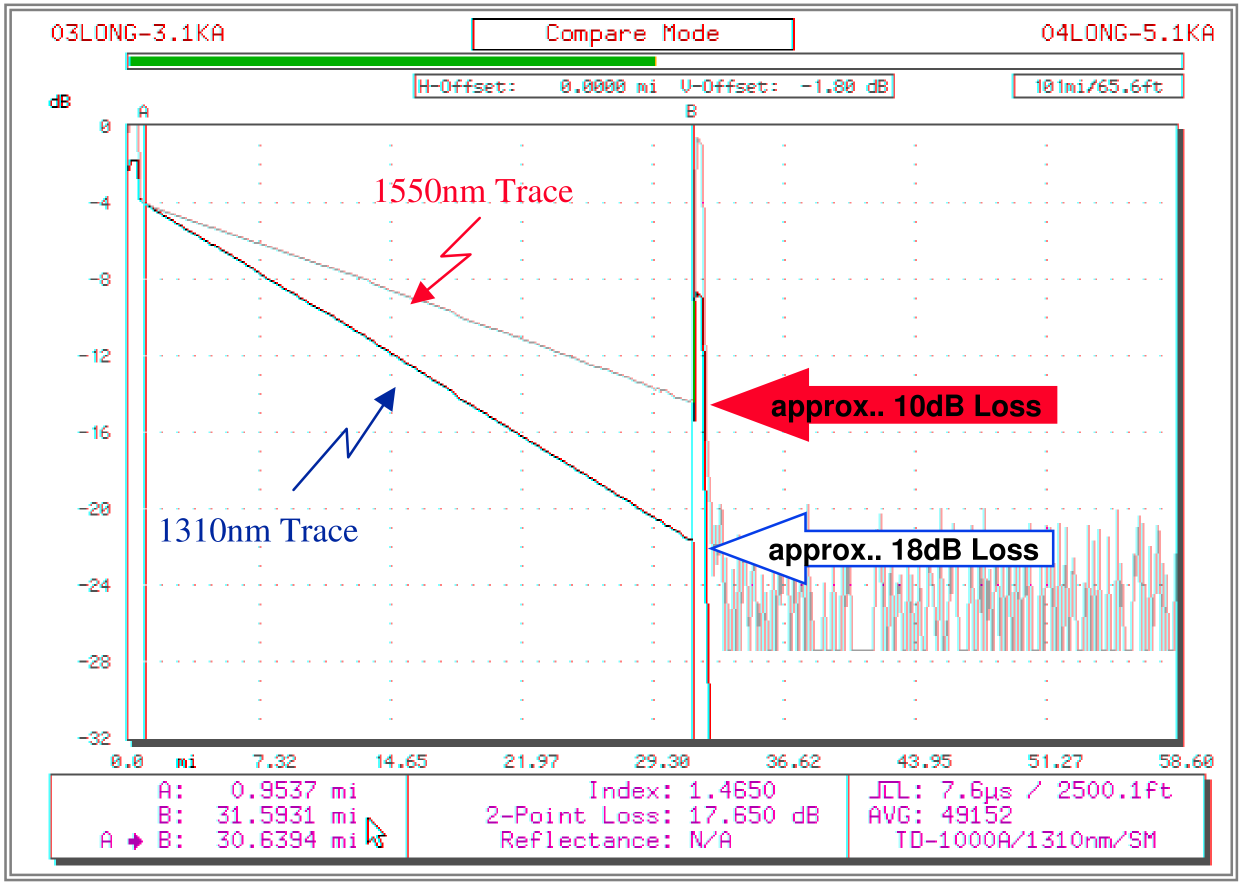
OTDR Reflection Are Negative.



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

OTDR Views.

Scattering Loss Difference

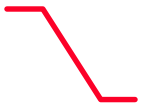


OTDR Dynamic Range.

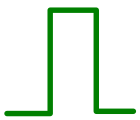
- Measured in dB. Typical range is between 30 – 40 dB
- Describes how much loss an OTDR can measure in a fiber, which in turn describes how long of a fiber can be measured
- Directly related to Pulse Width: larger pulse widths provide larger dynamic range
- Increase by using longer PW and by decreasing noise through averaging

OTDR Fiber Analysis Software - Operations.

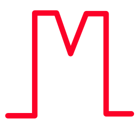
Event Types



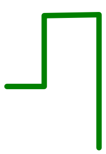
•Non-Reflective = fusion splice, defect, or macrobend in fiber



•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"*.

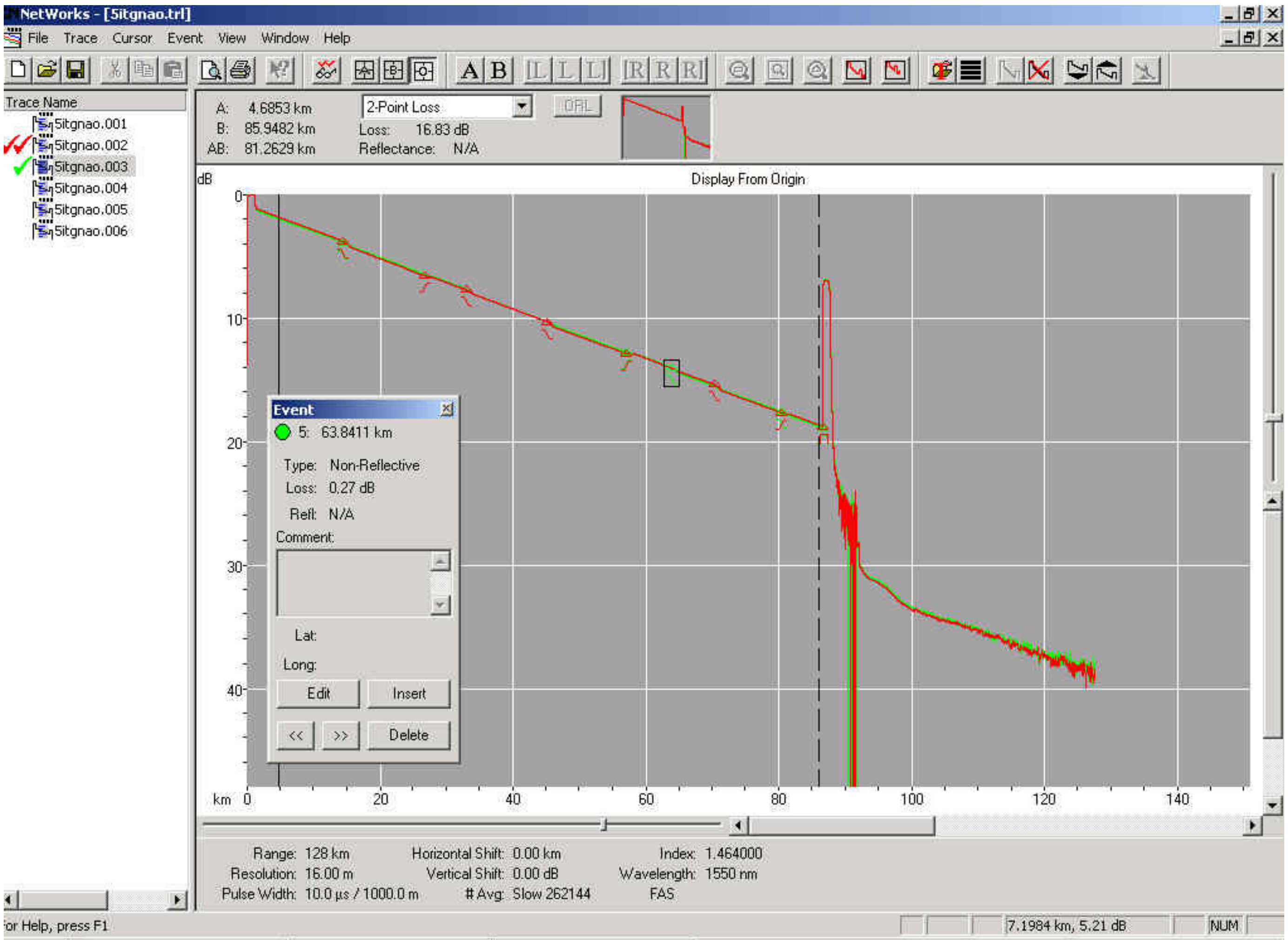
NetTest OTDR CMA 4000.

- The world's fastest OTDR
- Shortest Deadzones
- 50 dB Optics
- Quad Wavelengths
- Color Display
- Built-in Keyboard
- 1 Meg RAM
- 540 MB Hard Drive

NetTest OTDR CMA 40 FiberHawk.

- Light Weight and Portable
- Fast - Locates a fiber break typically in less than 60 seconds.
- 1310nm, 1550nm and dual 1310/1550nm singlemode models.
- 110km fault locate distance range at 1550 nm.
- Available floppy drive for storing fiber trace data.

NetTest OTDR CMA 4000.



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Test!

- What are the two optical frequencies used in a HFC system?

- What is the main component used in fiber optic glass?

- What is a figure-8 fiber optic cable?

- What do we measure a break with in a fiber optic link?

- What does a optical source do?

- What is the proper light level required at a NODE?

- What does backscatter do in fiber optic transmission?

The end of this session.