# FIBER OPTICS 101

# Movie Time

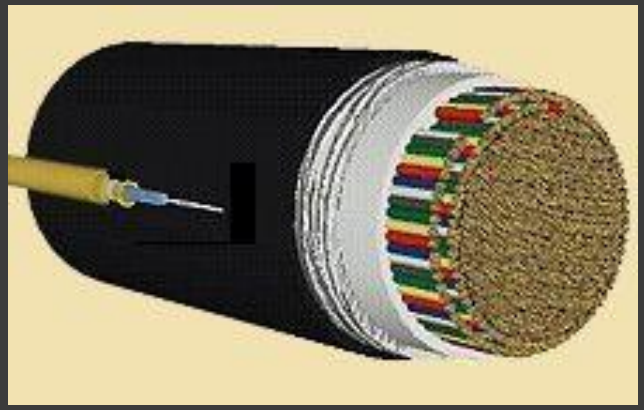
http://www.youtube.com/watch?v=u1DRrAhQJtM&feature=related

# Applications

- Medical
- Communications
  - Telephone
  - Internet
  - CATV
- Data Storage
- Networking
- Military / Aerospace
- Industrial / Security

# Benefits of Fiber Optics

- Bandwidth
- Security
- Size and Weight
- Emissions
- Distance
- Safety



# Refractive Index

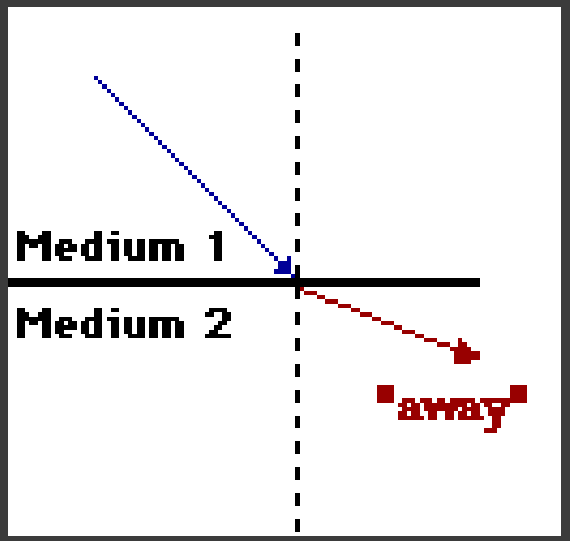
- Speed of Light 299,792,458 meters/sec
- Refractive Index
  - Light in a Vacuum (1.0) is the base refractive index
  - Light slows as it travels in different media
- Wavelength dependant

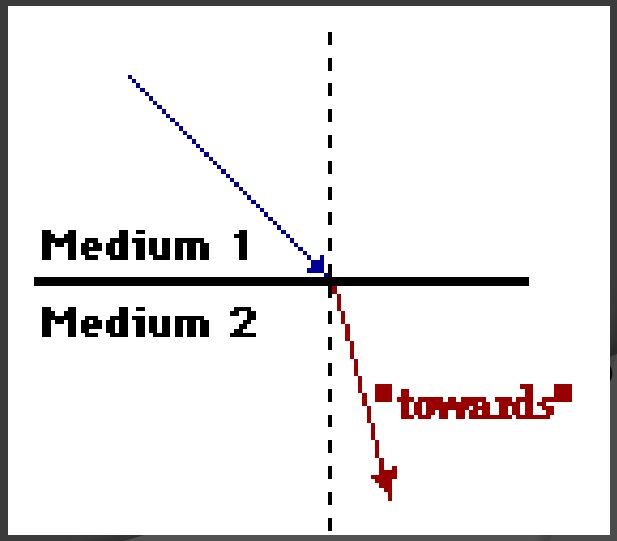
| Material | R. Index |
|---|---|
| Air | 1.0027 |
| Water | 1.333 |
| Alcohol | 1.361 |
| Silica (pure) | 1.458 |
| NaCl | 1.50 |
| Diamond | 2.419 |


Near and Far Infrared

# Refraction

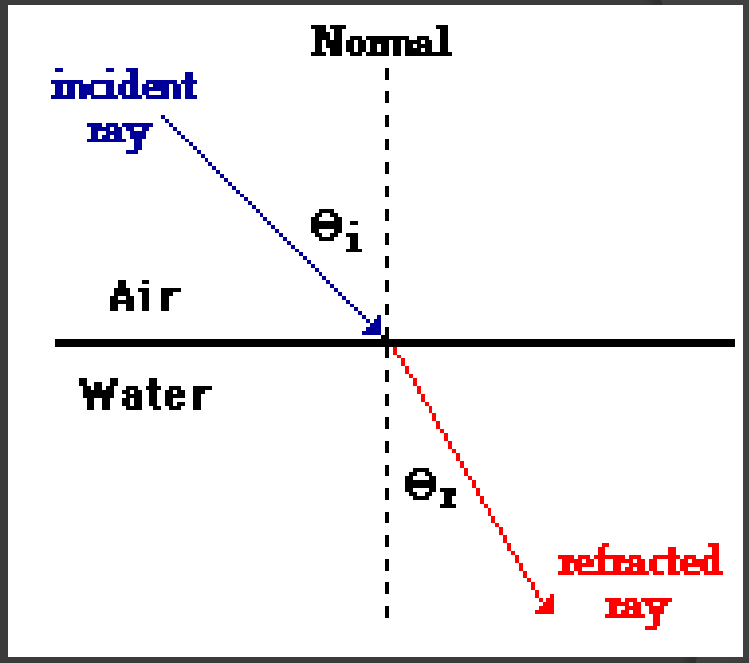
- Definition of Refraction
  - “Bending of light due to slowing of light as it moves between to different Indexes of Refraction”
  - Bends “towards” lower Index of Refraction materials or “away” from higher



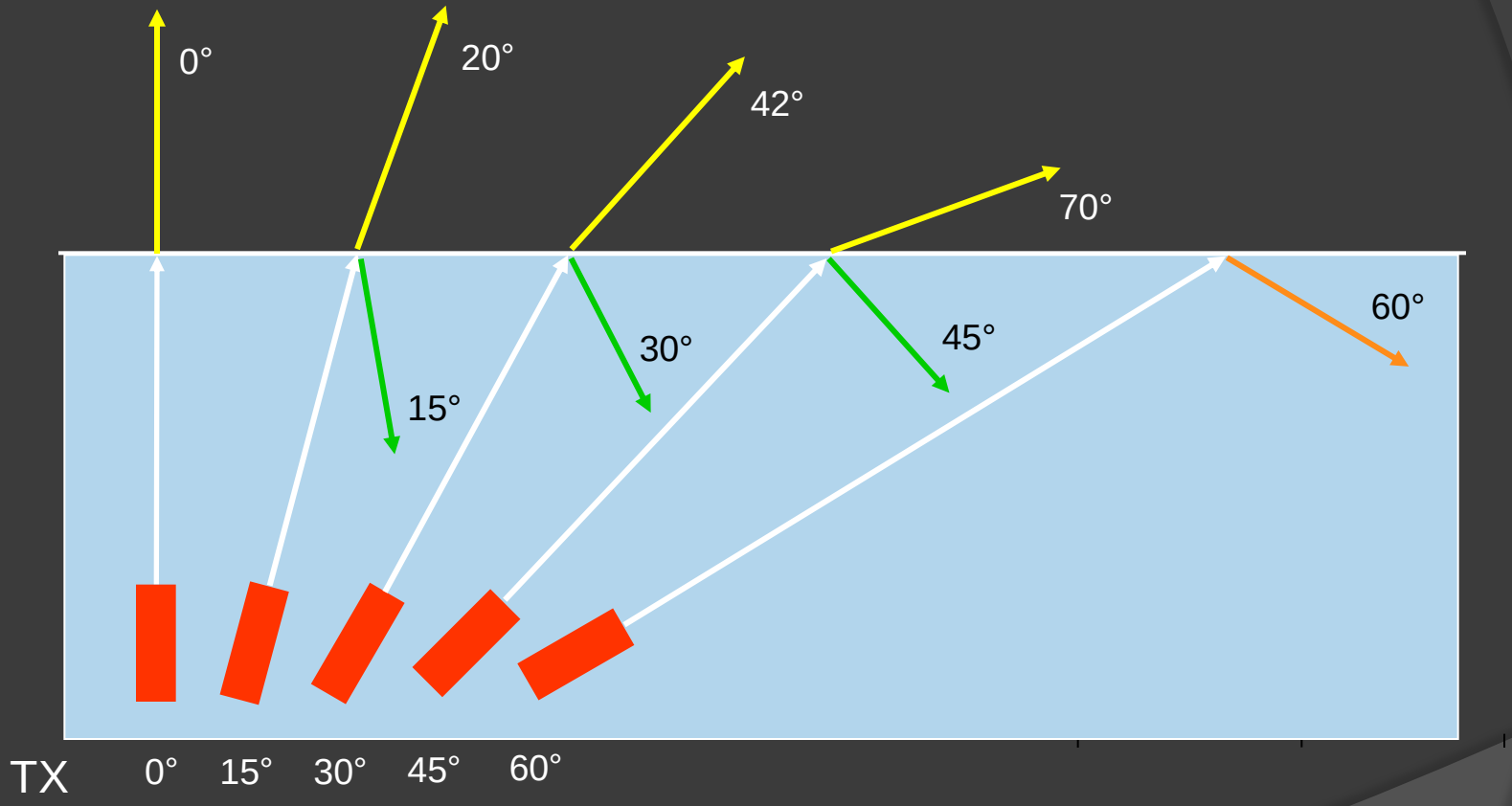



# Total Internal Reflection

- Angle of Incidence – The angles which the indident ray of light makes when traveling unaffected.
- Angle of Refraction – Angle of the light ray after it has been altered
- Critical Angle – Angle of Incidence in which light goes from reflecting to passing through.

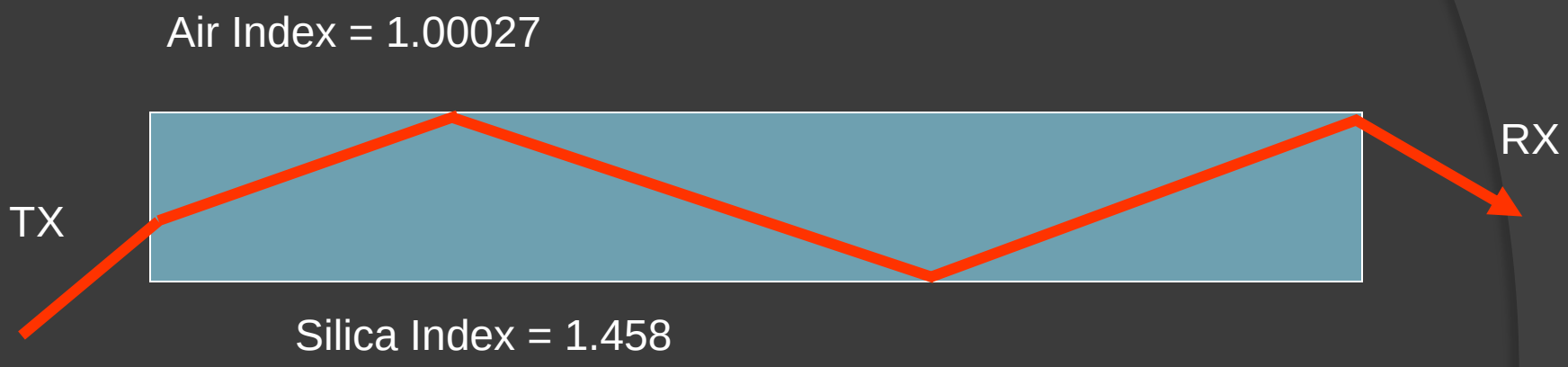


# Total Internal Reflection



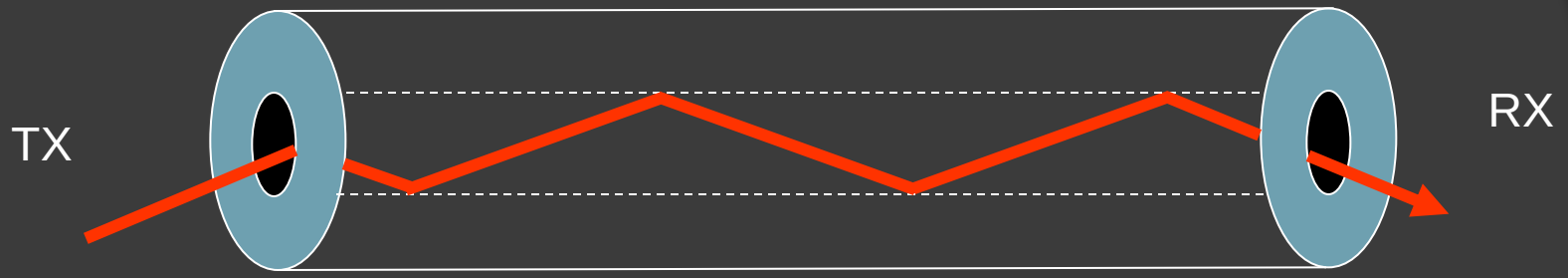

TIR – When all incident light is reflected at the boundary

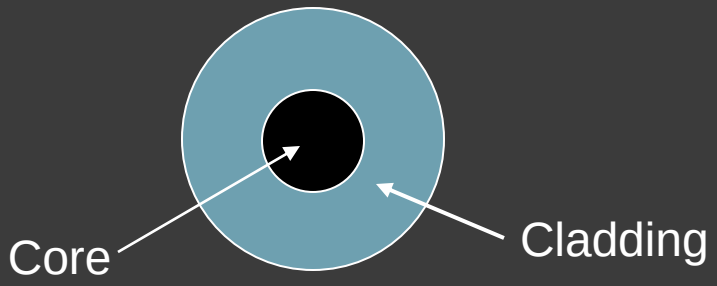
# TIR at Work




Light reflects away from the lower index of refraction material (air) and continues to bounce down the object.

# Reflection at Work



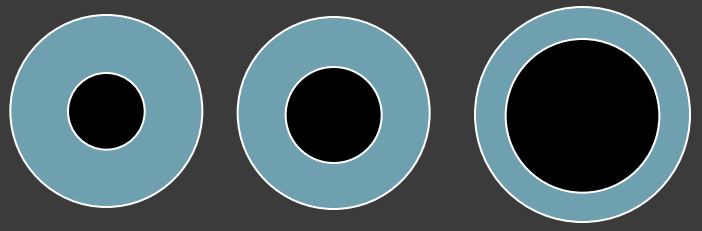

| Optical Glass Index of Refraction |
| --- |
| Core = 1.458 |
| Cladding = 1.440 |

# Common Optical Fiber

| Geometry | Core Diameter | Cladding Diameter | Aspect Ratio | Aperture |
|---|---|---|---|---|
| 9 / 125 | 9 um | 125 um | .064 | .11 |
| 50 / 125 | 50 um | 125 um | .40 | .20 |
| 62.5 / 125 | 62.5 um | 125 um | .50 | .275 |
| 100 / 140 | 100 um | 140 um | .71 | .29 |

Single Mode

1310 nm
1550 nm
1625 nm



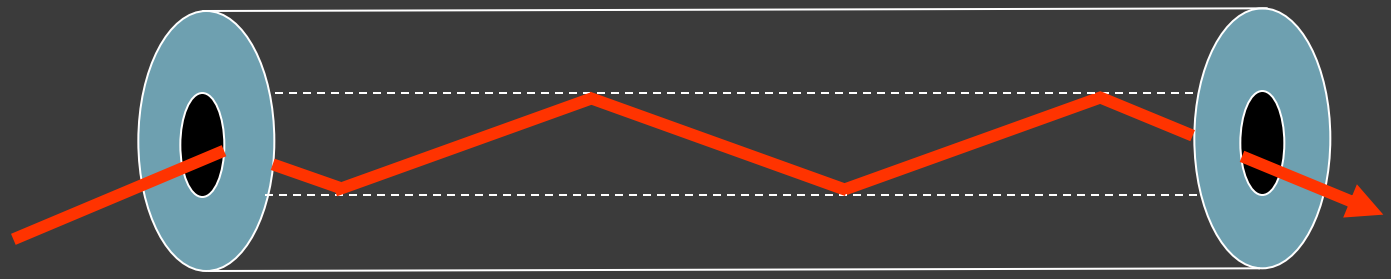
Multimode

850 nm
1310 nm

Aspect Ratio = Core Diameter / Cladding Diameter

Aperture = Area of the core which will accept light entry,
also known as light acceptance

# In a Nutshell

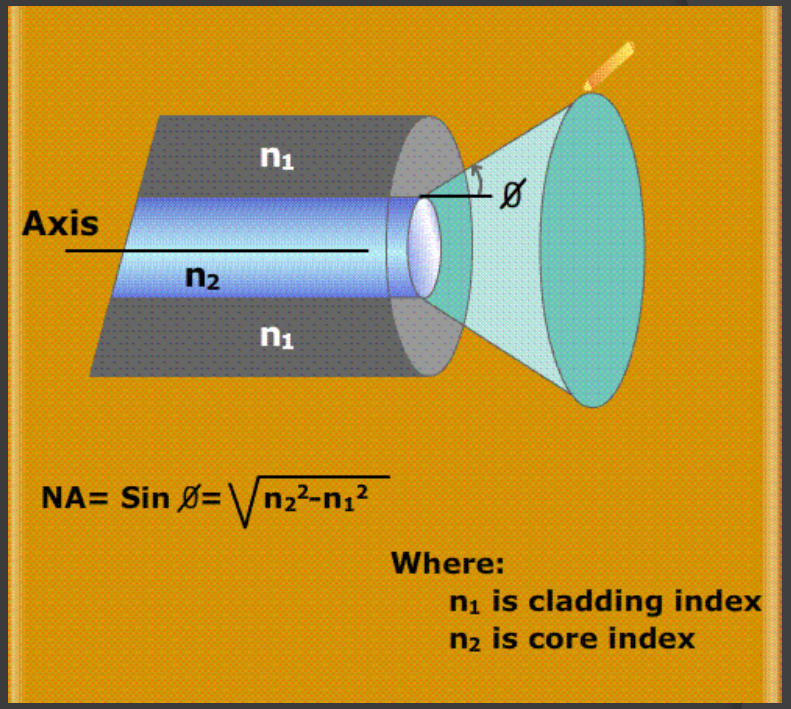



LOSS
**B**

**A – B = C**

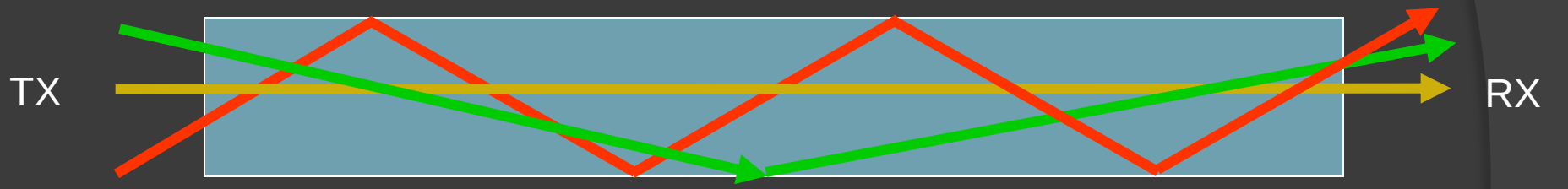
# Light Acceptance

- Light Acceptance
  - All about how much light can get into the fiber for transmission.
  - Effected by design of laser and coupling method.
  - Designated as TX



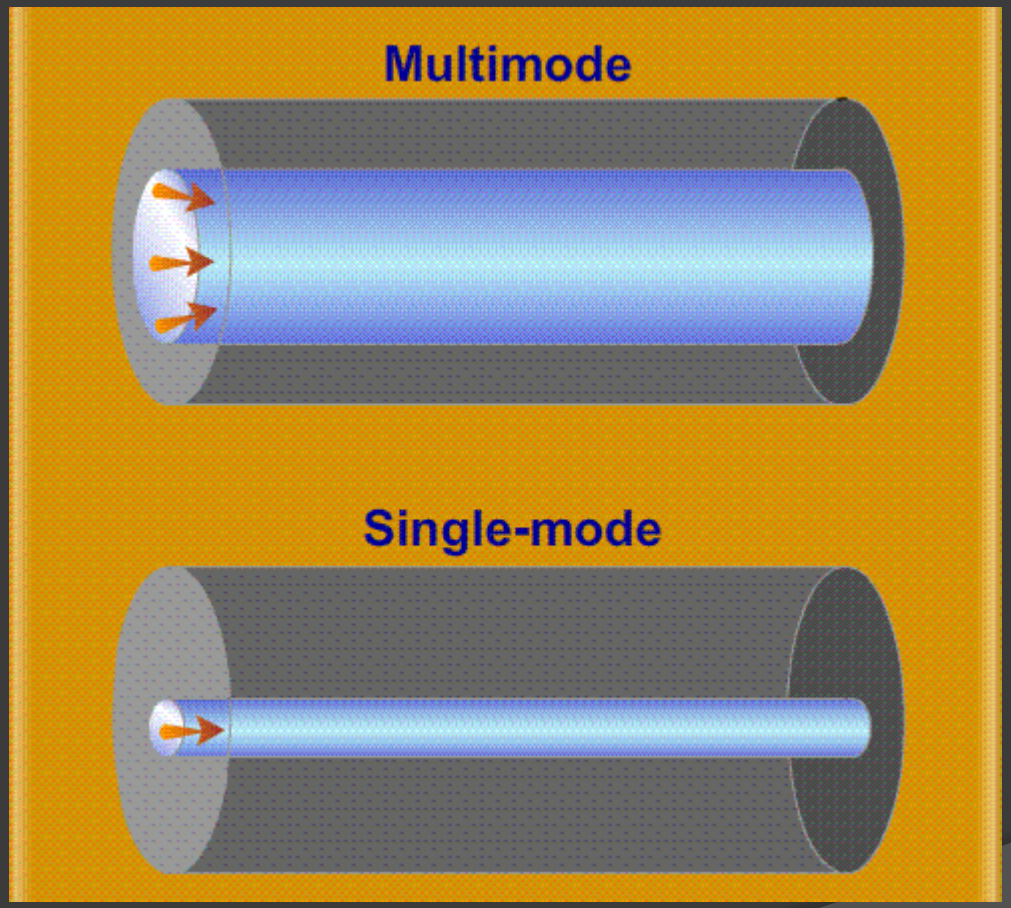
# Modes

- Light can take many “paths” along the optical core as it travels. These are called modes.




**Zero Order Mode** – Perfect direct path for light (very unlikely)
**Highest Order Mode** – “Longest path”
**Lowest Order Mode** – “Realistic Shortest path”

# Modes



# Types of Loss

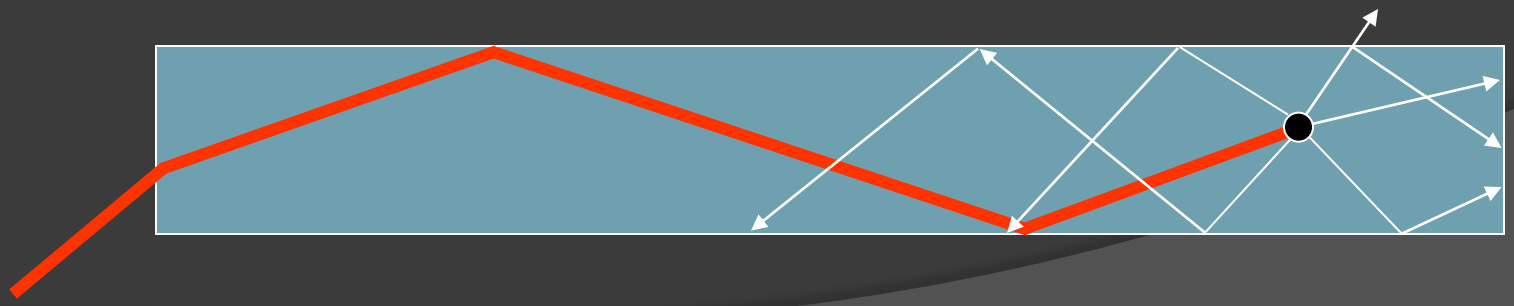
- Loss (Attenuation)
  - Not all light that enters a fiber is going to make it to the far end.
  - Common types of loss include:
    - Intrinsic Loss
      - Material Absorption
      - Scattering
    - Extrinsic Loss
      - Micro Bending
      - Macro Bending

# Intrinsic Loss

- Absorption – Removal of light by non-reradiating collisions with the atomic structure of the optical core.

  Caused by:
  - Impure molecules due to processing issues.
  - Pure molecules that are rare.
  - Impurity that is intentionally introduced during processing (doping).

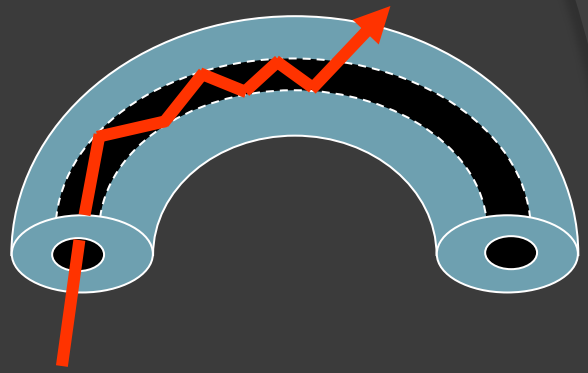
- Scattering – Removal of light due to light being “scattered” after colliding with a variation in the atomic structure.



# Extrinsic Loss

- Macrobending – Light lost from the optical core due to macroscopic effects such as bending and crushing.

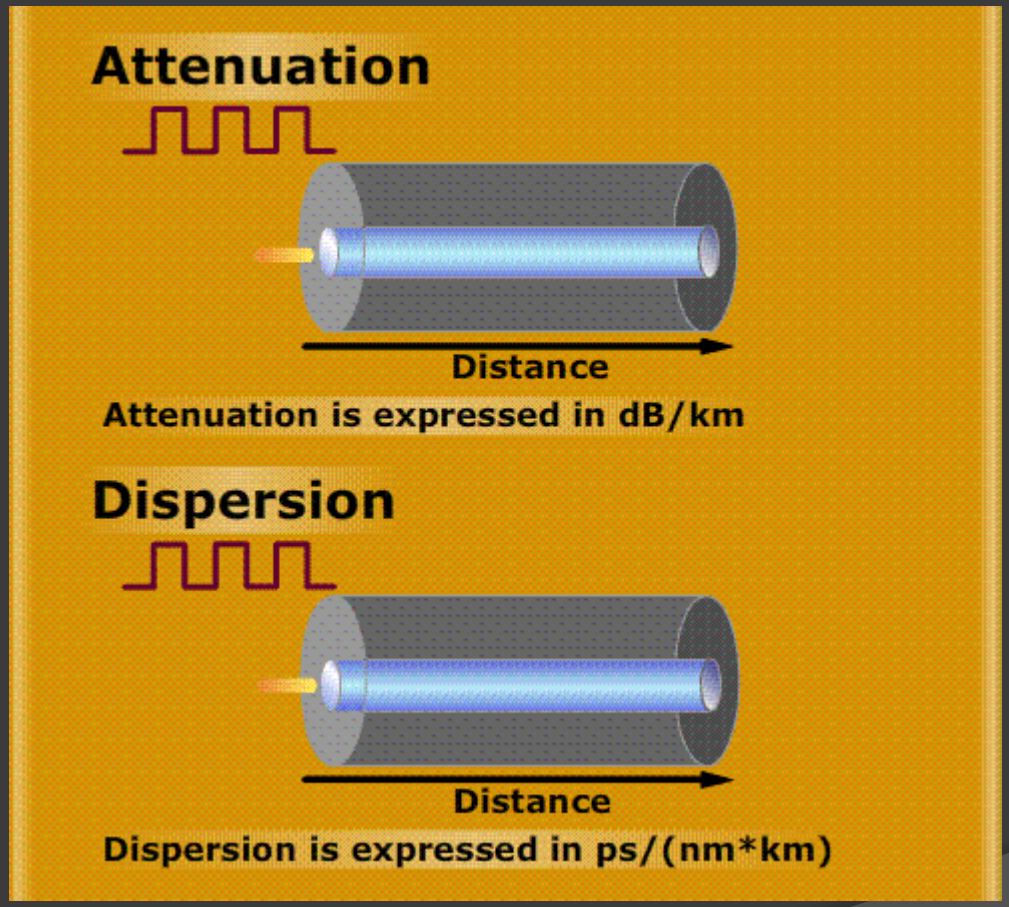
  Caused by:
  - Poor handling of fiber
  - Tight bend radius installation



- Microbending – Light lost from the optical core due to microscopic effects resulting from deformation and damage to the core in manufacturing.

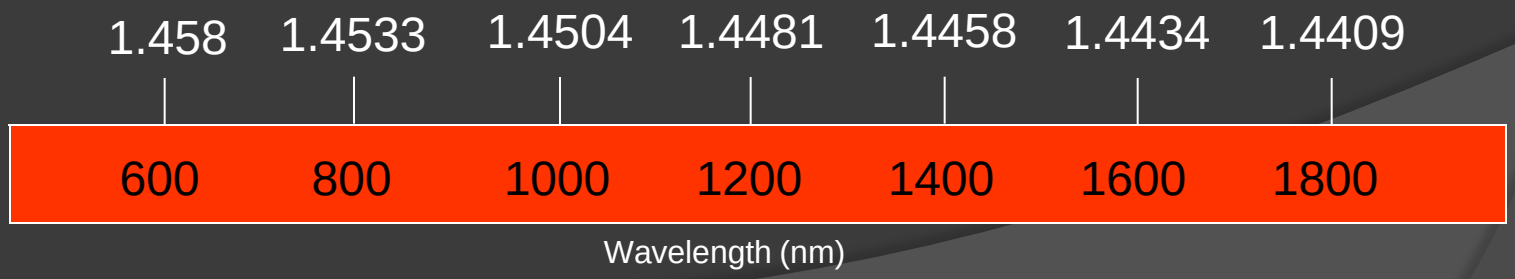
**THIS IS QA ISSUE AND CAN BE VERY BAD NEWS!!!**

# Examples of Loss



# Bandwidth

- Arguably the most important benefits of fiber
- Bandwidth - Amount of Information that can be sent and received in correct order.
- End of Bandwidth – Defined by data arriving out of order in regards to its time domain.
- Two factors mess with fiber Bandwidth
  - Intermodal Dispersion – Time or arrival differences of signal between zero order and highest order modes.
  - Intramodal Dispersion – Differences of Index of Refraction by wavelength



# Laser vs. LED

- LED – Light Emitting Diodes
  - Low Cost (Multimode Systems)
  - Slow ON/OFF
  - Use Overfilled Launch and many many modes

- Laser
  - High Cost (In the beginning Single mode then later Multimode systems)
  - Faster modulation and more power

# Types of Lasers

**Multimode**

**850 nm**
**1310 nm**

LED – Light Emitting Diode

VSCEL - Vertical Cavity Surface Emitting Laser

**Single Mode**

**1310 nm**
**1550 nm**
**1625 nm**

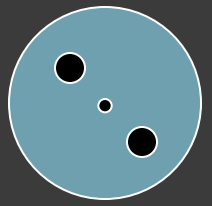
DFB – Distributed Feedback

FP - Fabry-Perot

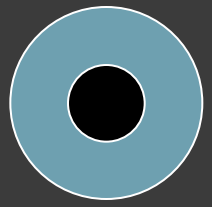
# Common Types of Fiber

- Single Mode
  - SMF-28
  - PM / Polarization Maintaining
- Multimode
  - Step Index
  - Graded Index
  - Laser Optimized

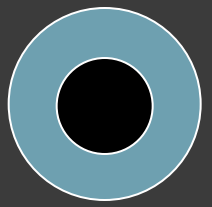
9/125



9/125



50/125

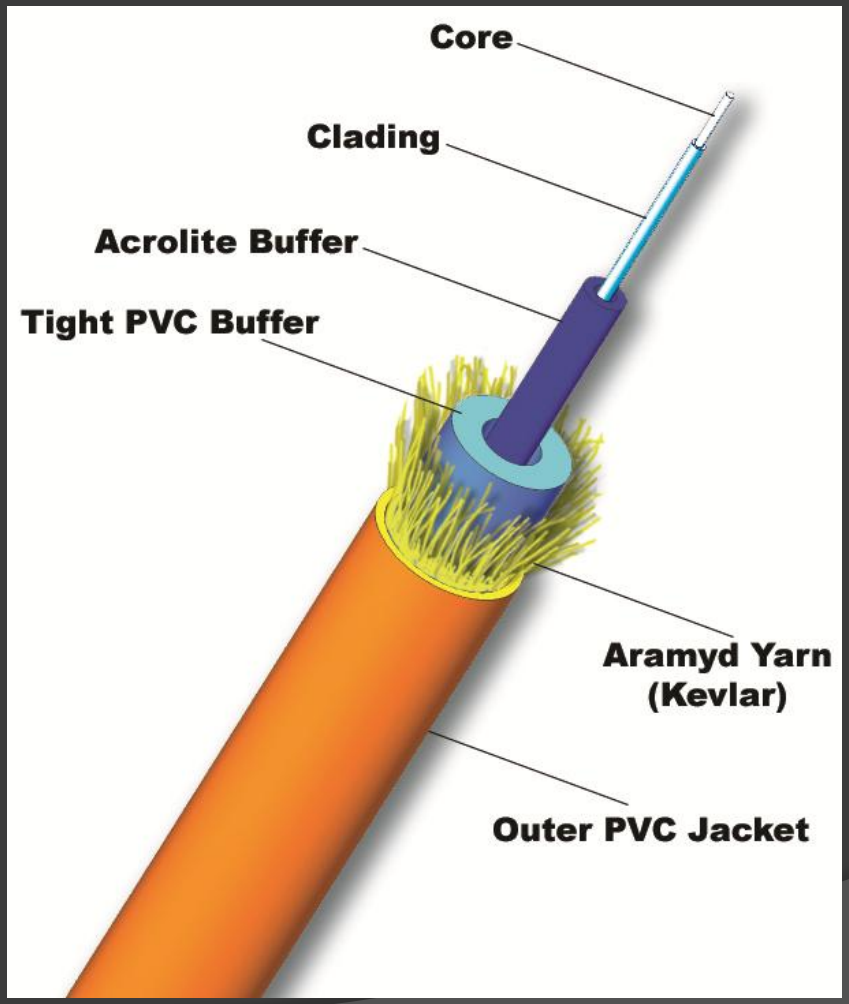


62.5/125


Step Index


Graded Index

# Parts of Single Fiber Cable



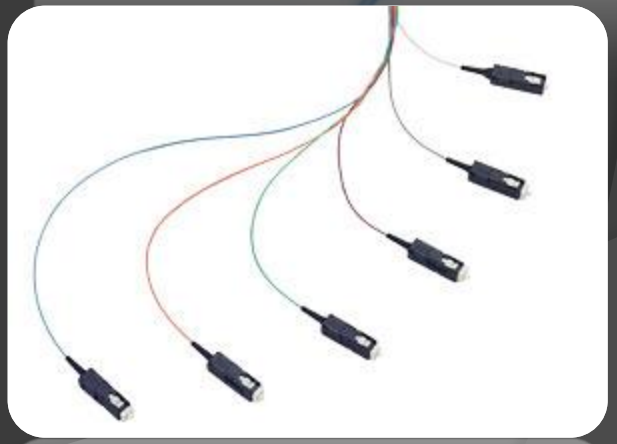
# Styles of Fiber Optic Cable

Style – Outer appearance, materials, use, and features and benefits

- Bare Fiber
- 900um
- Patch Cord
- Break Out
- Distribution
- Ribbon

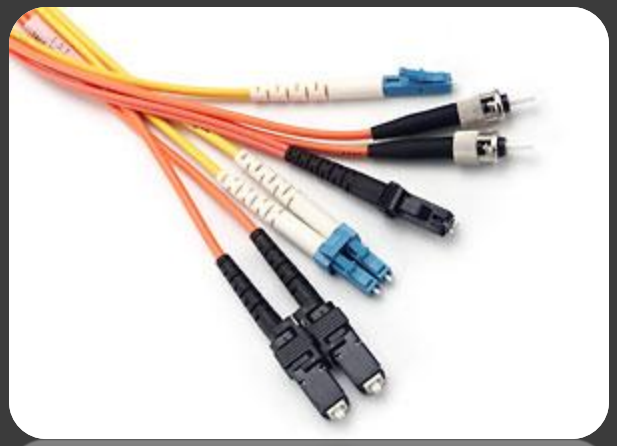
# Bare / 900um Fiber

- Bare
  - Not really bare
  - Usually Spooled
  - 25km spool
  - 250 to 400um acrolite buffer / polyimide
  - PM Light Sensitive
- 900um
  - PVC or Plenum Jacketed
  - Many colors that mean very little
  - Used mostly in internal applications
  - Loopback Guts



# Patchcord Fiber

- Simplex
  - SM / MM
  - Pig tailing
  - OD 1.6, 2.0, 3.0mm
- Duplex
  - SM / MM / LOMM
  - Zipcord
  - OD 1.6, 2.0, 3.0mm
- Dulan
  - SM / MM
  - Not Common – MTRJ
  - 3.0mm



**SM**
**9/125**

**MM**

**50/125 and 62.5/125**

**MM**

**MM**
**Laser Optimized**

# Breakout Cable

- Both MM and SM
- Indoor / Outdoor
- 1.6, 2.0. 3.0mm sub units
- 2, 4, 6, 8, 12, 24, 48, 72 or greater fiber counts
- Outer Jacket can be of a variety of materials
- Terminated with all styles of connectors
- Often field terminated

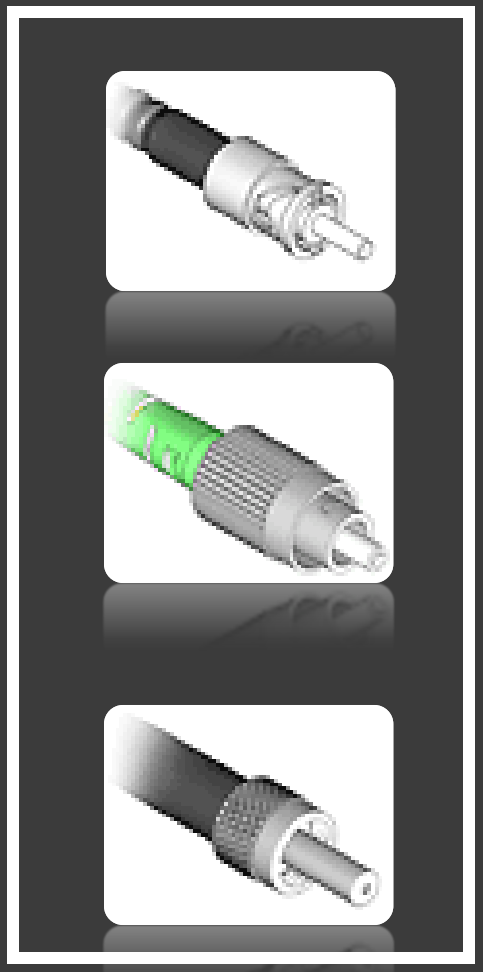
# Distribution Cable

- Both MM and SM
- Indoor / Outdoor
- 900um sub units
- 2, 4, 6, 8, 12, 24, 48, 72, 144 or greater fiber counts
- Outer Jacket can be of a variety of materials
- Usually longer runs
- Messenger Cable
- Can be terminated with almost any style of connector

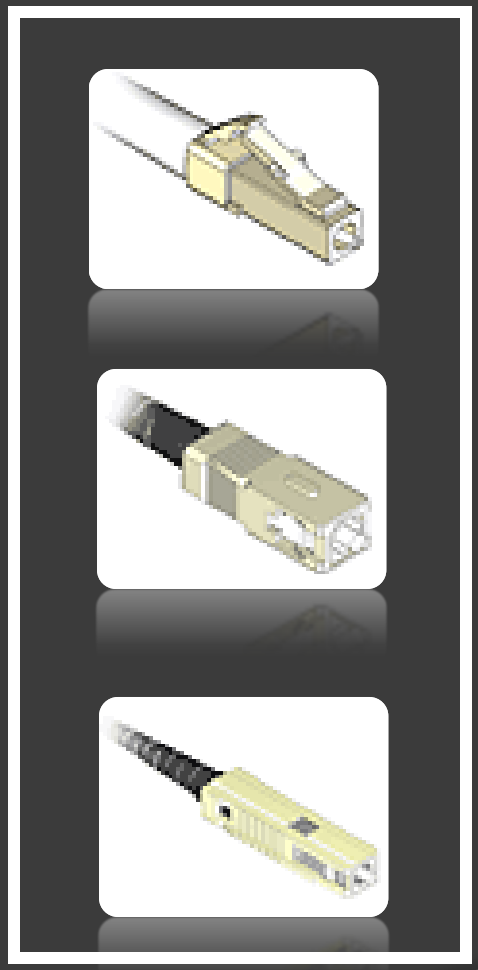
# Ribbon Fiber

- Fibers Count – 4, 6, 8, 12, 24, 48, 72
- Color Coded
- Jacket Styles
  - Bare
  - Jacketed
  - Distribution

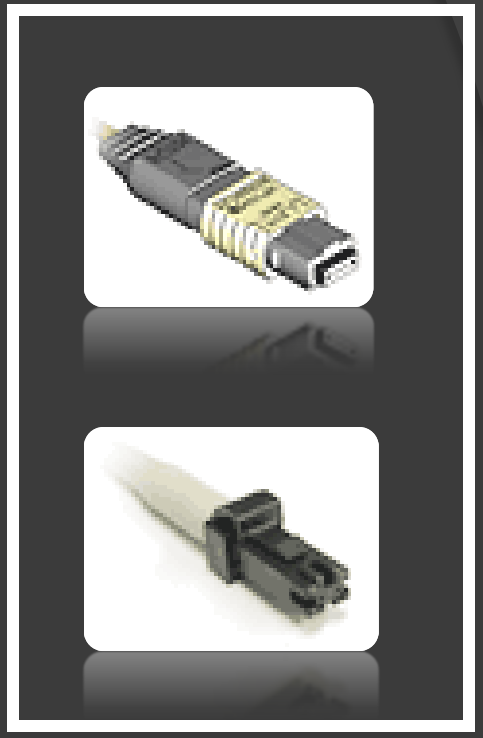
# Connectors



Simplex



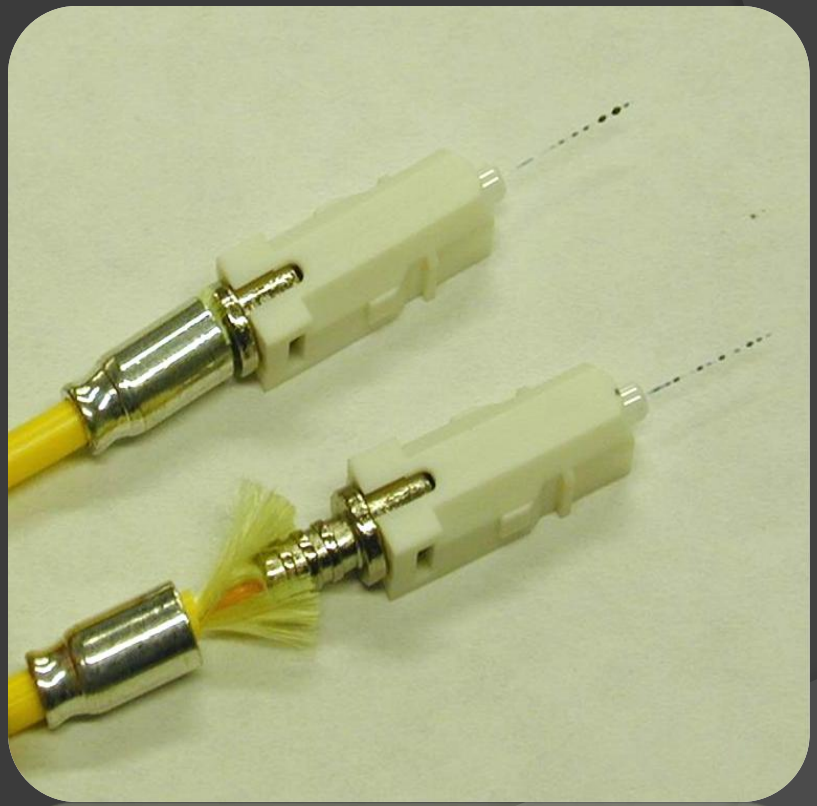
Simplex or Duplex



Ribbon

# Parts of a Connector

- Ferrule
  - Stainless, Composite, Ceramic
  - 1.25, 1.5, and 2.5mm
- Body
  - Steel or Plastic
- Crimp Ring
  - Steel
  - Connects Kevlar to post
- Boot
  - Maintains bend radis
  - Sizes and Shapes



# ST Connector

ST stands for Straight Tip- a quick release bayonet style connector developed by AT&T. STs were predominant in the late 80s and early 90s.

ST connectors are among the most commonly used fiber optic connectors in networking applications. They are cylindrical with twist lock coupling, 2.5mm keyed ferrule. ST connectors are used both short distance applications and long line systems. The ST connector has a bayonet mount and a long cylindrical ferrule to hold the fiber.

# FC Connector

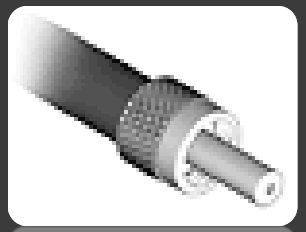
FC stands for Fixed Connection. It is fixed by way of a threaded barrel housing. FC connectors are typical in test environments and for singlemode applications.

FC is the fiber optic connector standard for Nippon Telephone & Telegraph (NTT) installations, developed with Nippon Electric Co. (NEC).

TIP: The FC screws on firmly, but make sure you have the key aligned in the slot properly before tightening.

# SMA Connector

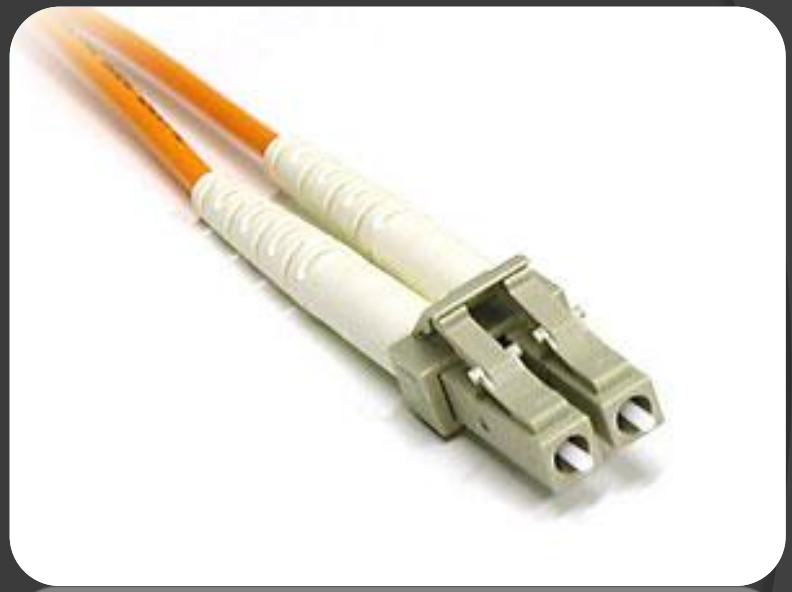
SMA is a fiber optic connector developed and manufactured by Amphenol Fiber Optic Products; it stands for Sub Miniature Version A. SMA connectors use a threaded plug and socket.



# LC Connector

LC stands for Lucent Connector. The LC is a small form-factor fiber optic connector.

The LC connector uses a 1.25 mm ferrule, half the size of the ST / SC. Otherwise, it is a standard ceramic ferrule connector. The LC has good performance and is highly favored for both multimode and single mode applications.



# SC Connector

SC stands for Subscriber Connector- a general purpose push/pull style connector developed by NTT. SC has an advantage in keyed duplexibility to support send/receive channels.

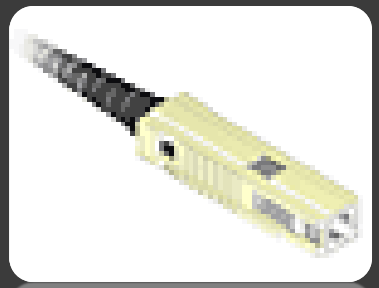
SC Connectors are frequently used for newer network applications. The connector is square and keyed with push-pull mating, 2.5mm ferrule and molded housing for protection.

The SC is a snap-in connector that is widely used in singlemode systems for its performance. The snap-in connector latches with a simple push-pull motion.

# MU Connector

MU is a small form factor SC. It has the same push/pull style, but can fit 2 channels in the same footprint of a single SC. MU was developed by NTT.

The MU connector looks a miniature SC with a 1.25 mm ferrule. It is a popular connector type in Japan.



# MT / MPO

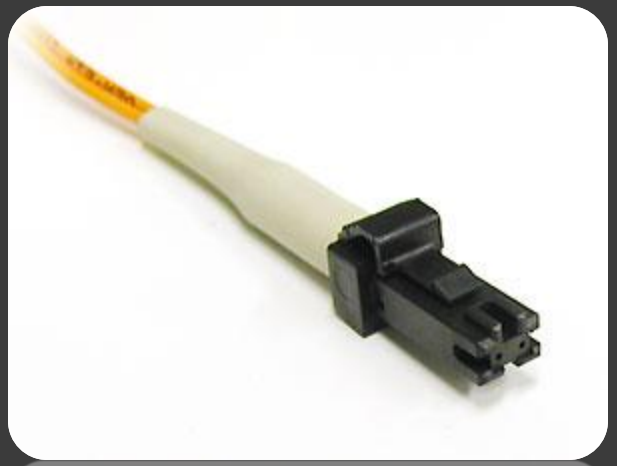
Multi-fiber ribbon connector housing up to 72 fibers in a single ferrule.

The MT is also referred to as MTP® - manufactured by US Connec Ltd. or the MPO by other non-US Conec companies.

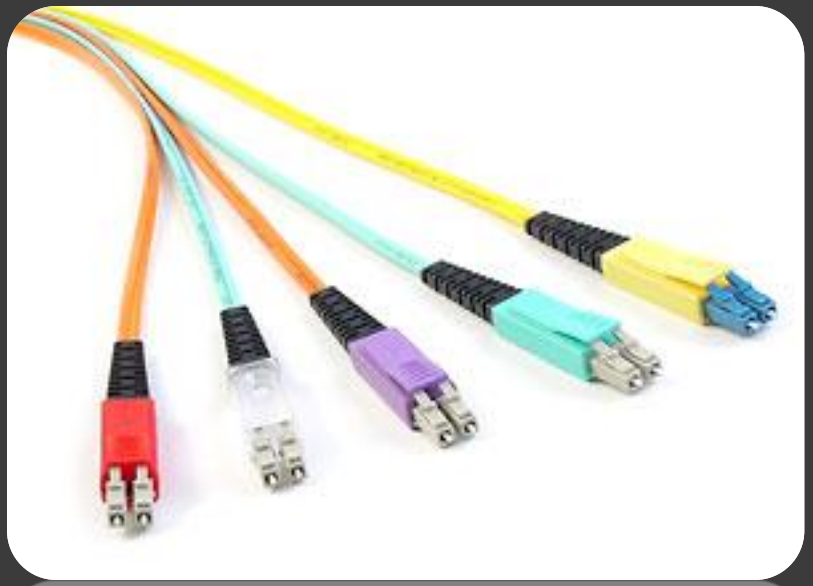
# MTRJ Connector

MT-RJ stands for Mechanical Transfer Registered Jack. MT-RJ is a fiber-optic cable connector that is very popular for small form factor devices due to its small size. Housing two fibers and mating together with locating pins on the

The MT-RJ is commonly used for networking applications. Its size is slightly smaller than a standard phone jack and just as easy to connect and disconnect. It's half the size of the SC connector it was designed to replace.



# Timbercon Armadillo



# Questions?