WOMEN IN FIBER

presents

# EmpowerHour

An Hour of Education and Empowerment

Fiber Broadband ASSOCIATION

Women in Fiber Monthly Committee Meeting

WOMEN IN FIBER
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Committee Chair
KGP


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Graybar


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Last Mile Broadband, LLC


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Vetro


**Teresa McGaughey**
Calix


**Michaela O'Brien**
Calix

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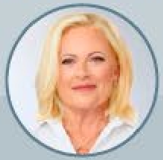
**Taylor Trewyn**
Broadband
Technology Group


**Madison Carroll**
Dura-Line

## Professional Development/Webinars


**Tanna Hanna**
Allo


Martha Galley
Calix

## Stem & Partnership


**Libby Pawlick**
TDS Telecom


**Kelly Weismann**
Clearfield, Inc

Fiber Broadband
ASSOCIATION

## Recognition Spotlight/Welcome


**Lori Ransbottom**
LYNN


**Yvonne Lambeth**
Fujitsu


**Lauren Allen**
NSI Network
Infrastructure

## Social Media


**Kendal Ingraham**
Okanogan PUD


**Diane Garcia**

www.fiberbroadband.org

WOMEN IN FIBER

Fiber Broadband Association believes the world is a better place when women's voices are heard. We believe companies are more successful when women are encouraged and rewarded to reach their full potential. We believe it is up to us to help identify, develop, and promote women in the Fiber Broadband industry as well as technology, telecommunications, construction and manufacturing. We pledge to use this forum to help women succeed in the Fiber Broadband industry.

# Women in Fiber updates:

- New format for WIF monthly meetings
- Get involved - Contact Candy Riem (candy.riem@teammidwest.com) for any questions or how to reach anyone below.
- FBA membership - contact Danielle Lawrence
- Contact needed for a STEM org in Nashville - contact Libby Pawlick
- Love to read? Unofficial launch of book summary group trial start -contact Alexa Edens
- Where are you headed next? Interested in hosting an event - contact Taylor Trewyn or Madison Carroll or fill out this form: https://bit.ly/41mtyh2
- Celebrate amazing women - contact Lori Ransbottom
- Join the conversation - LinkedIn (www.linkedin.com/groups/12262312/) & FBA Community (www.community.fiberbroadband.org/)

WOMEN IN FIBER

# Women in Fiber Update

## Recognition Spotlight

[Submit a nomination now](#)

WOMEN IN FIBER

# Spotlight

January 2025

Ashley has been an absolute heaven send ! She has brought a wealth of Knowledge to KGPCo with hands on experience in government and state spending for broadband infrastructure
She is sharing her knowledge amongst all of us at KGPCo, ensuring that we are prepared to maximize our growth as a company, build solid relationships with partners and serve our customers with outstanding support! Thank you Ashley!

Nominated by:

- Rasjah Tolliver, *Program Manager, KGPCo*

**Ashley Travers**
*Vice President Strategic Partnerships*

KGPCo.

Fiber Broadband ASSOCIATION

*Do you have an outstanding woman to nominate for the Spotlight? Contact Lori Ransbottom, lransbottom@thinklynn.com*

Libby Pawlick
TDS Telecom

Kelly Weismann
Clearfield, Inc

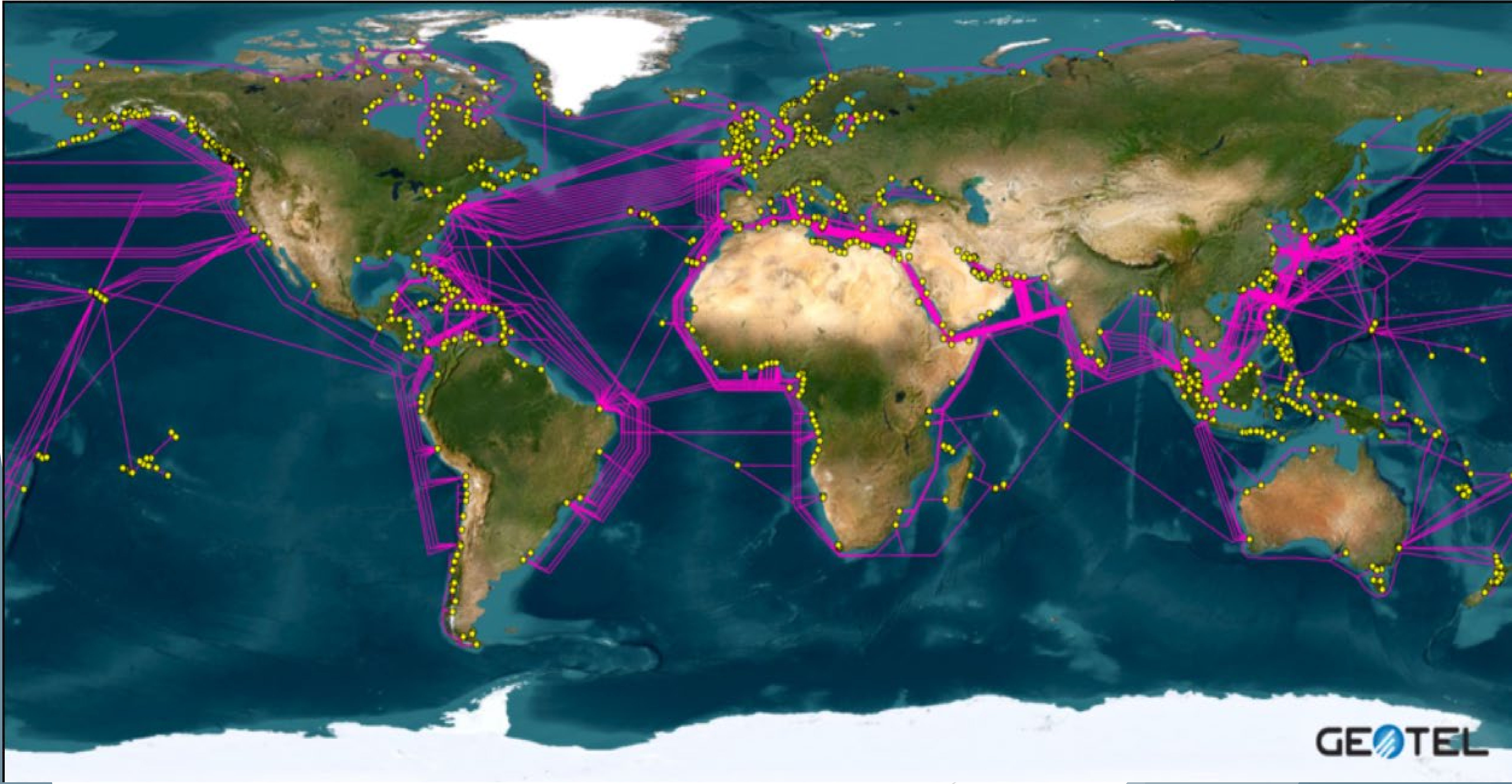
# Stem & Partnership

presents

## Fiber 101

## Fiber Network ins & outs

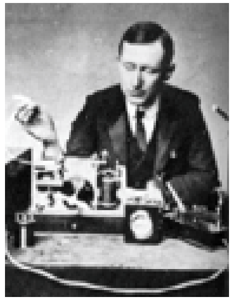
WOMEN IN FIBER



# Modern Communications

Morse, Telegraph
1830s-40s

Bell, Telephone
1876



Marconi, Wireless
1901

Charles Kao, STL
1965

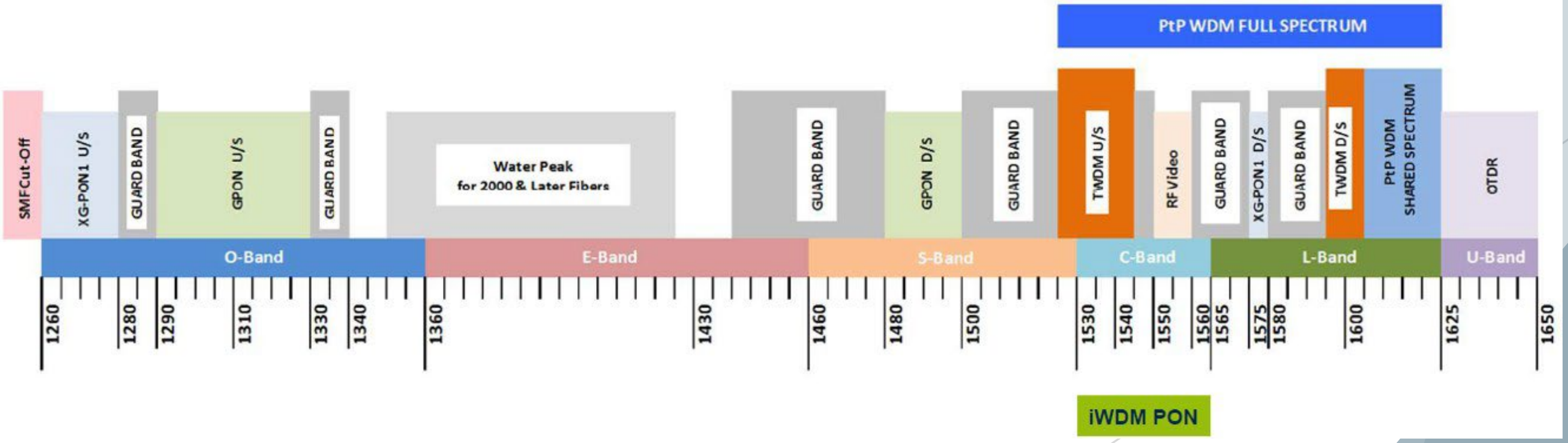
The staff at Bell Labs
Lasers, Cables, Systems

Donald Keck, Robert Maurer
& Peter Schultz
Corning, 1970

The famous inventors

# FIBER TRANSITIONS THROUGH HISTORY

- **1970** — Multimode fiber
- **1980** — Single-mode fiber
- **1990** — DWDM
- **2000** — FTTx
- **2020** — Solving bandwidth demands



# SAFETY FIRST!


- Safety glasses are a MUST!
- Dispose of all scraps properly (most common danger when working with fiber
- NO food or drink in work space
- Follow instructions for various chemicals/cleaners. Alcohol is flammable.

NEVER
look into a fiber unless you know NO light (Laser or LED) is present

❖ It can focus the infrared light directly into your eye! Use a power meter to check it.

The adoption of any technology depends on having workable standards to ensure product compatibility.

# Standards, Codes and Regulations

- **ANSI** – American National Standards Institute
- **EIA/TIA** – Electronic Industries Alliance/Telecommunications Industry Association
- **NIST** – US National Institute of Standards and Technology
- **NEBS** – Network Equipment Building Systems (Telcordia/Bellcore standard)
- **TELCORDIA** (Bellcore)

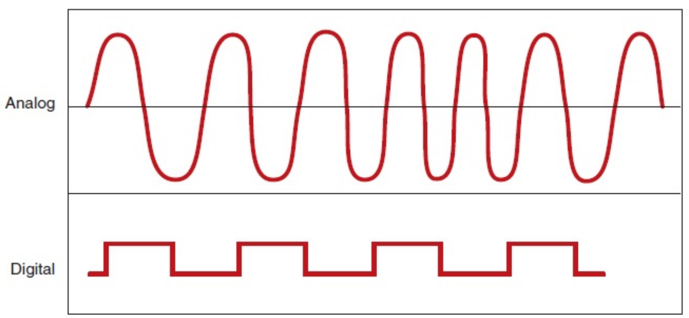
- **NEMA** – National Electrical Manufacturer Association
- **IEEE –** Institute of Electrical and Electronics Engineers
- **SCTE –** Society of Cable Telecommunications Engineers
- **NEC** – National Electric Code – Electrical and fire safety

- *****Check and follow your local government/codes for any regulations** as they take precedence*

# What is “Fiber Optics”?


- Transmitting communications signals in the form of modulated light guided over hair-thin strands of glass or plastic.
- Signals, voice, data or video can be analog or digital form.

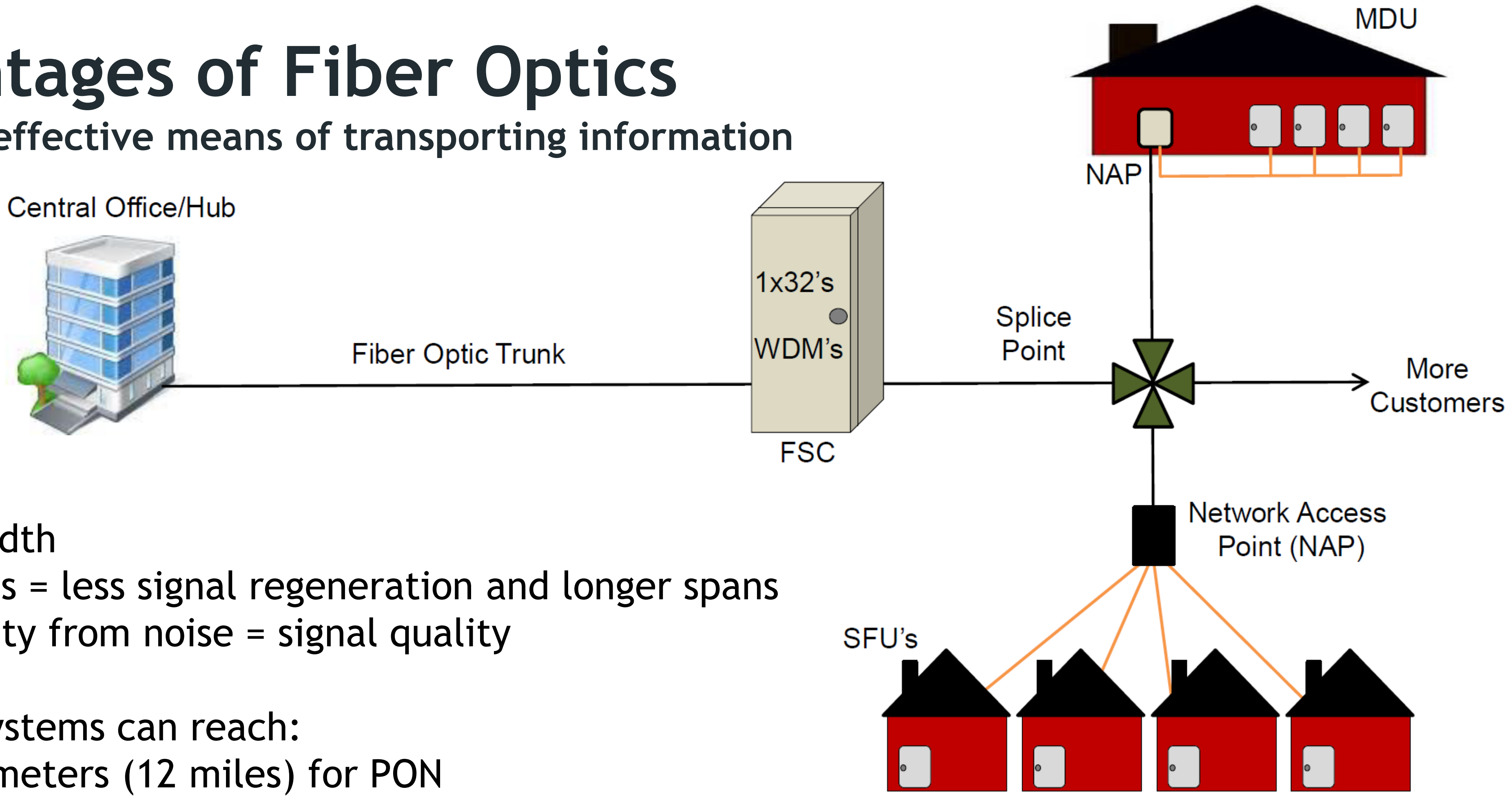
Used in communications, lighting, medicine, optical inspections and to make sensors.




We will concentrate on Communications.

# Advantages of Fiber Optics

**Most cost-effective means of transporting information**



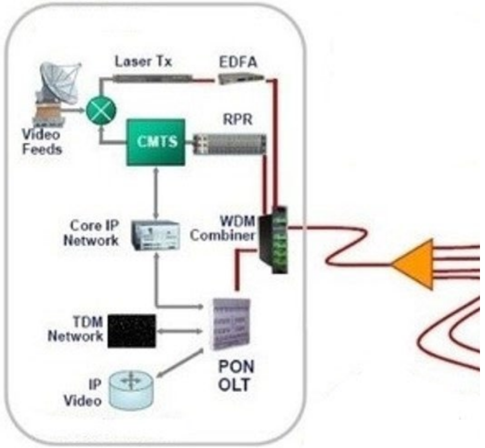

Bandwidth
Low loss = less signal regeneration and longer spans
Immunity from noise = signal quality

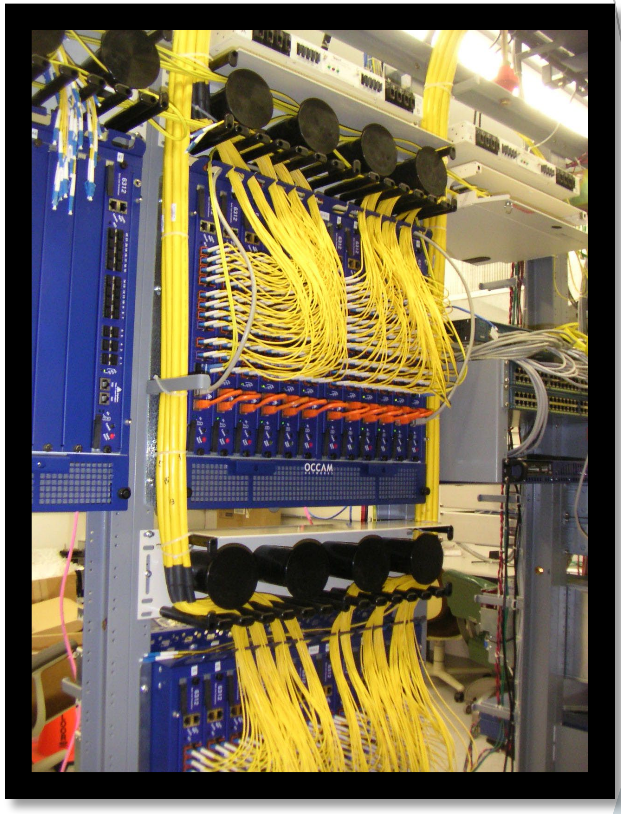
FTTx systems can reach:
20 kilometers (12 miles) for PON
60 kilometers (37 miles) for Active Ethernet

Low latency (time delay) is essential for high speed, long distance and interactive applications including
Stock markets, Medical and Gaming

# INSIDE PLANT (ISP)

**Central Office or HeadEnd**
**"The TRANSMITTER"**



# Fiber Optic Sources

**LEDs** (Light Emitting Diode) for multimode fiber links (<250 MHz)  OM1 & OM2 (62.5/125)

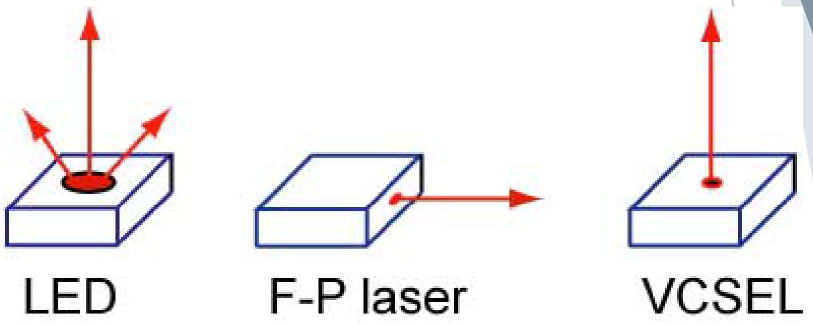
**VCSELs** (Vertical Cavity Surface Emitting Laser)for > 1 GHz multimode links OM3 & newer fibers

**The restricted launch of the VCSEL provides greater power for more distance and bandwidth capabilities than LEDs**

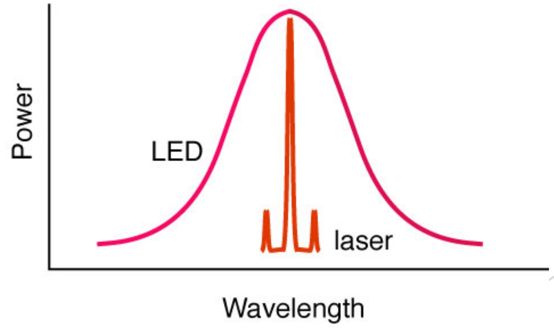
**Fabry-Perot lasers** (Light Amplification from the Stimulated Emission of Radiation) for singlemode links

**DFB lasers** for analog (CATV-RFOG) or DWDM singlemode

| Class | Min Optical Link Budget | Max Optical Link Budget |
|---|---|---|
| A | 5dB | 20dB |
| B | 10dB | 25db |
| B+ | 13dB | 28dB |
| C | 15dB | 30dB |
| C+ | 17dB | 32dB |



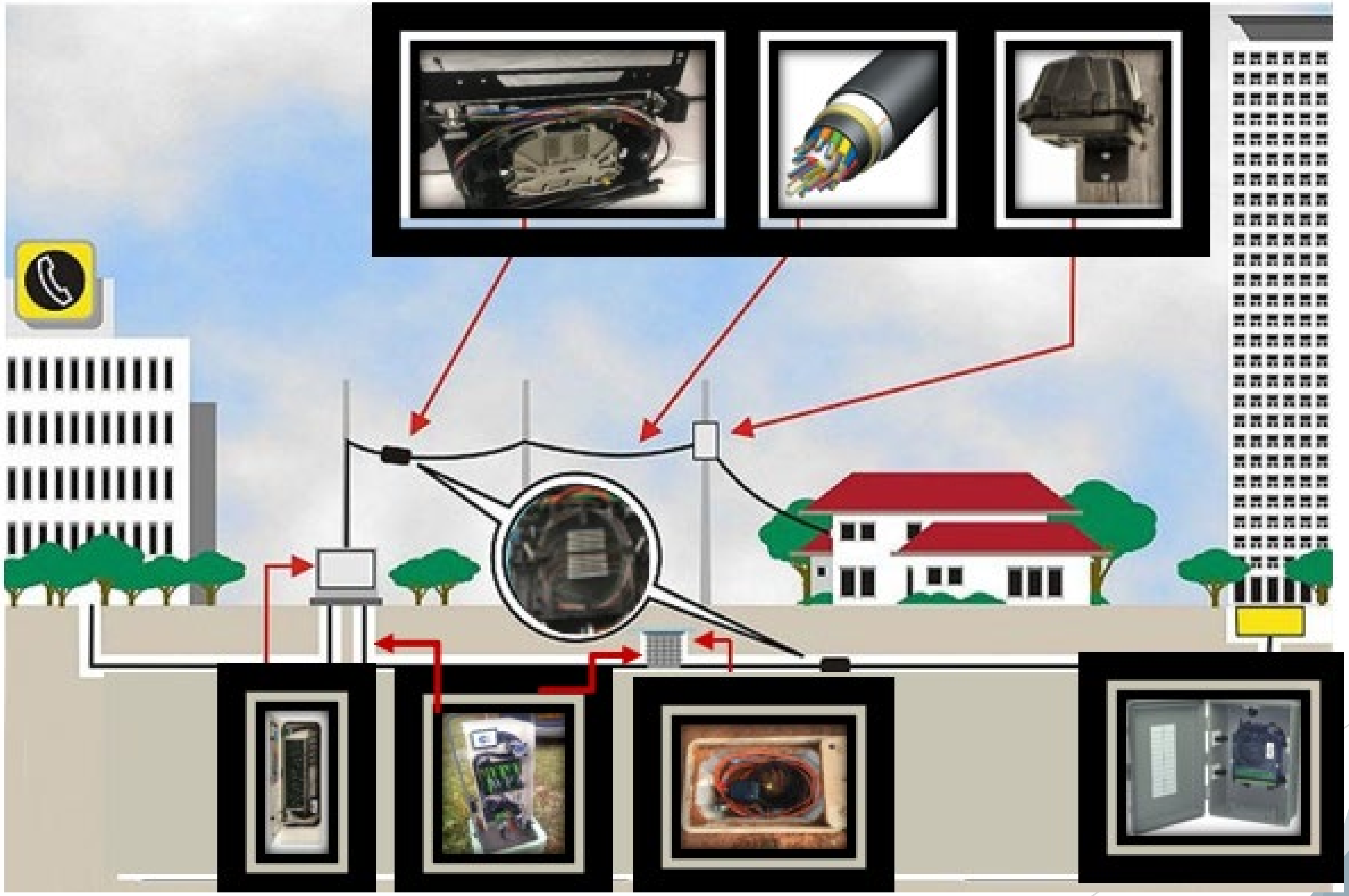

Spectral Output



# INSIDE PLANT (ISP)
## ….Moving out into the network

Active Cabinets

# OUTSIDE PLANT (OSP)



# PREMISE – MDU/MTU and Single-Family Units ~ *Access Plant*

MDU – Multi-Dwelling Units (residential~ Single-Mode

MTU – Multi-Tenant Units (business) ~ Single-Mode
**Multi-Mode can/is used in structured cabling*

Both MDU/MTU could be combined

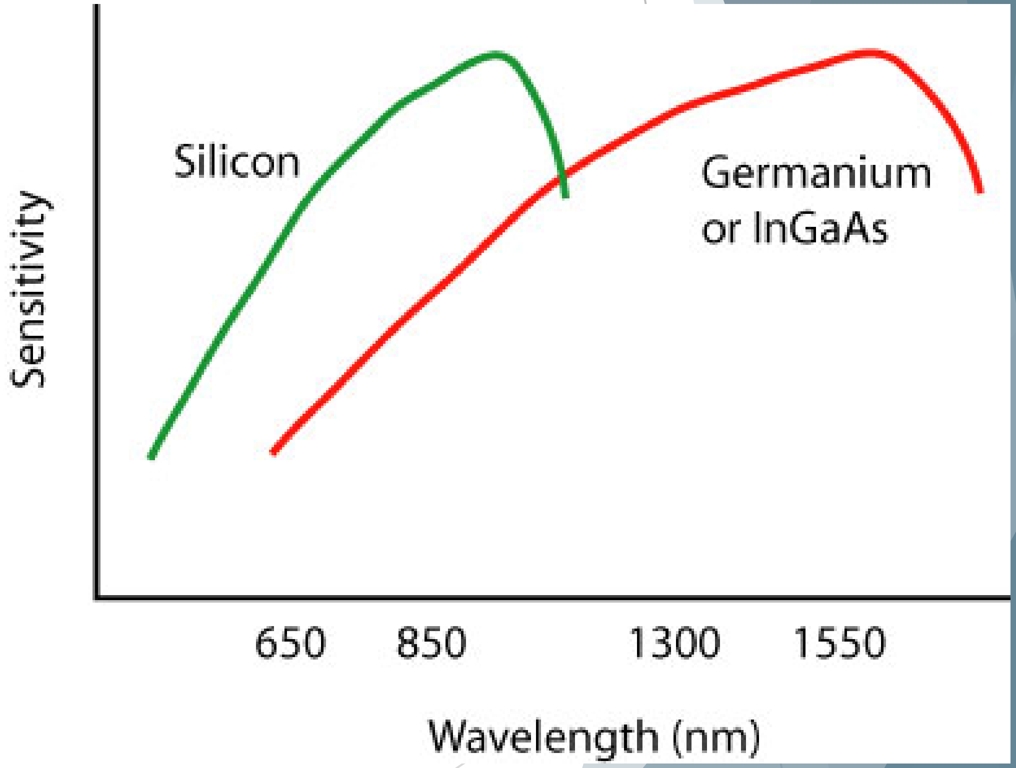
The drop to the home/bus and premise install is the most time consuming and expensive portion to construct

# Fiber Optic Detectors

- **Silicon (Si)** detectors for short wavelength links at 650 or 850 nm. Response issues after 900nm.
- **Germanium (Ge)** Good response from 700nm to 1550nm. Tends to be noisier than Gallium Arsenide types and responsitivity falls off close to 1550nm window
- **Indium Gallium Arsenide Phosphide (InGaAsP)** Operates well at longer wavelengths from 900nm to 1700nm
- **Avalanche (APDs)** photodetectors have higher gain and bandwidth than PIN Diodes.

**Receiver/PhotoDetector**

**2 Types: PIN Diodes and Avalanche Photodiodes**

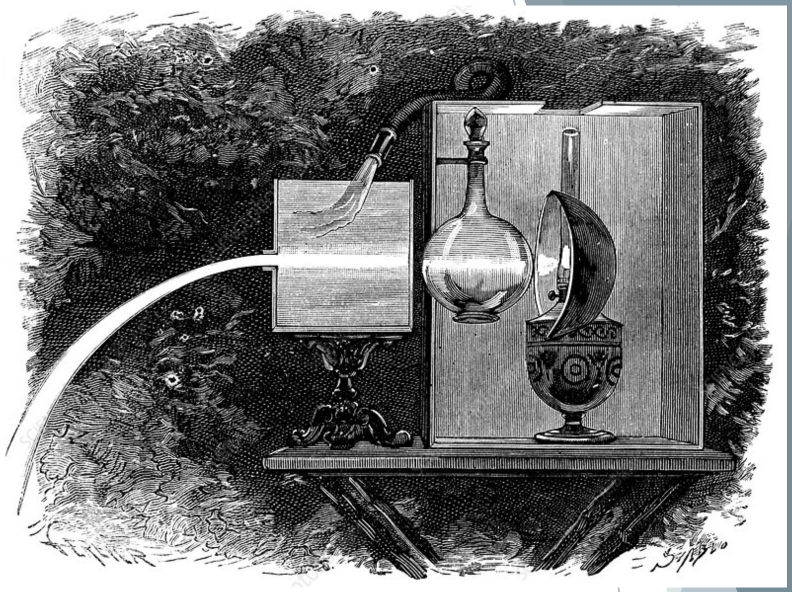


# Basic Fiber Theory

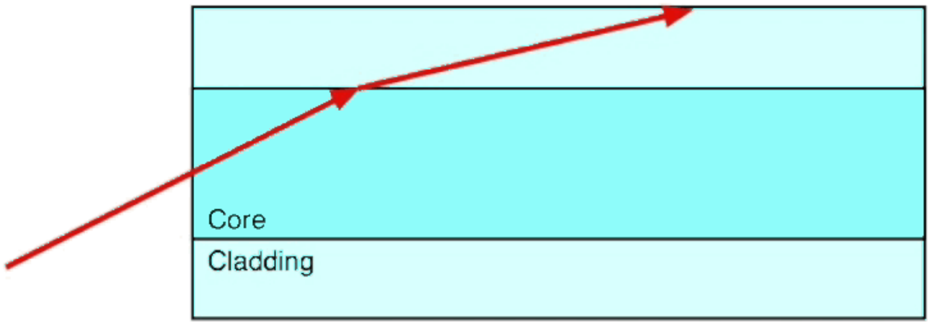
- **Key terms to understand:**
  - Total Internal Reflection
  - Attenuation
    - Absorption and Scattering
  - Bandwidth
  - Dispersion
  - Numerical Aperture (NA)
  - Wavelength
  - Reflections

https://youtu.be/jZOg39v73c4?si=Rhx79ZRcVes4W0bW

# Total Internal Reflection

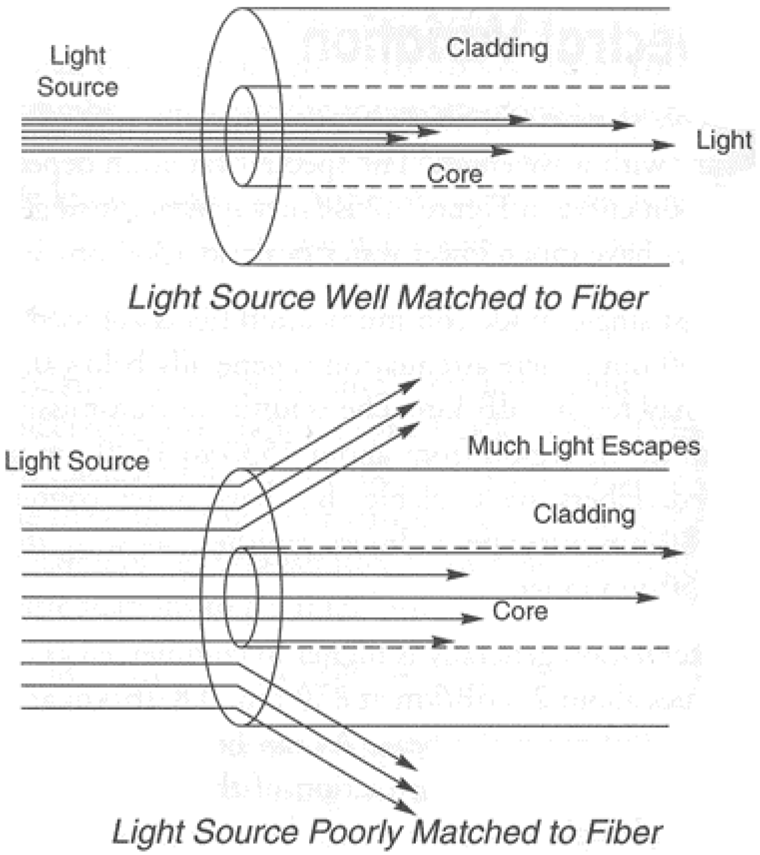


In 1841, Daniel Colladon, a professor at the University of Geneva, first demonstrated “light guiding” by focusing sunlight into a thin stream of water flowing through a hole in a water tank.  When the light hit the forward edge of the water flow, he observed that the light rays were trapped in the water stream.  This is now known as total internal reflection




- occurs when a core with a higher index of refraction is encapsulated by a cladding of a lower refractive index

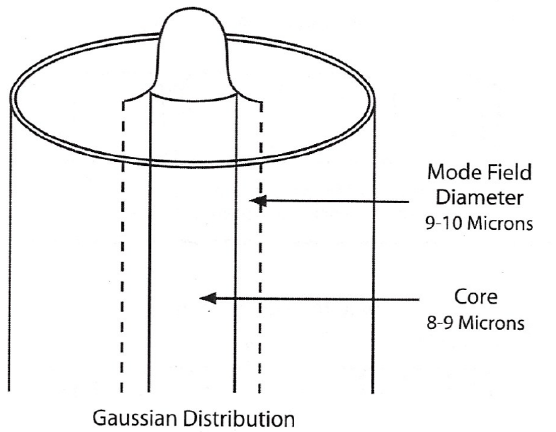
# Fiber's capability to collect light and transmit it along the fiber




**Core Size**

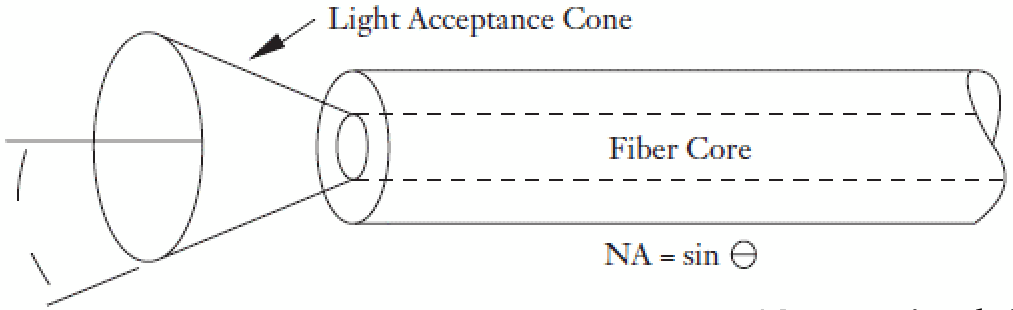
**Important Factors**

- Core Size
- Mode Field Diameter
- Numerical Aperture




**Mode Field Diameter**

| Specification | Wavelength | Mode Field Diameter |
|---|---|---|
| ITU-T G.652 | 1310 nm | 8.6–9.5 ±.7 $\mu$m |
| ITU-T G.655 | 1550 nm | 8-11 ±.7 $\mu$m |

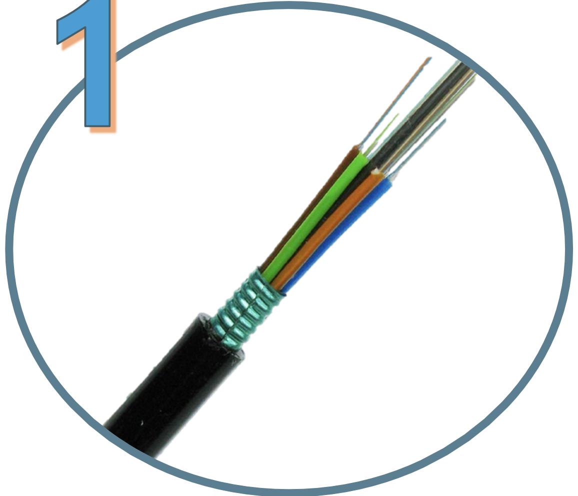



MM 0.20-0.275
SM 0.13

**Numerical Aperture**

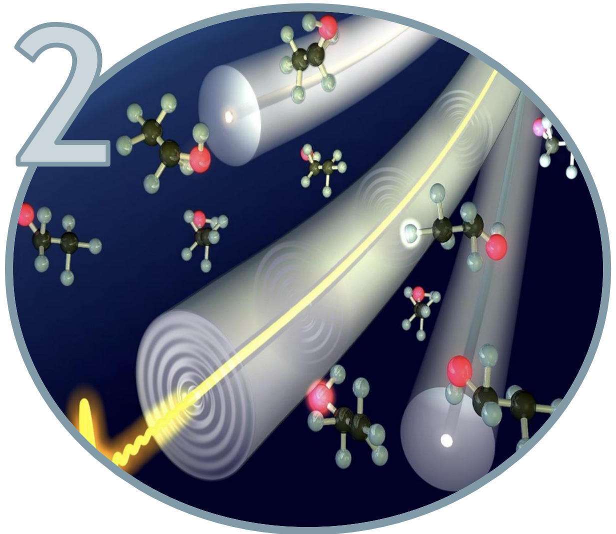
# Architectural Components

1



Fiber Optic Cable

2

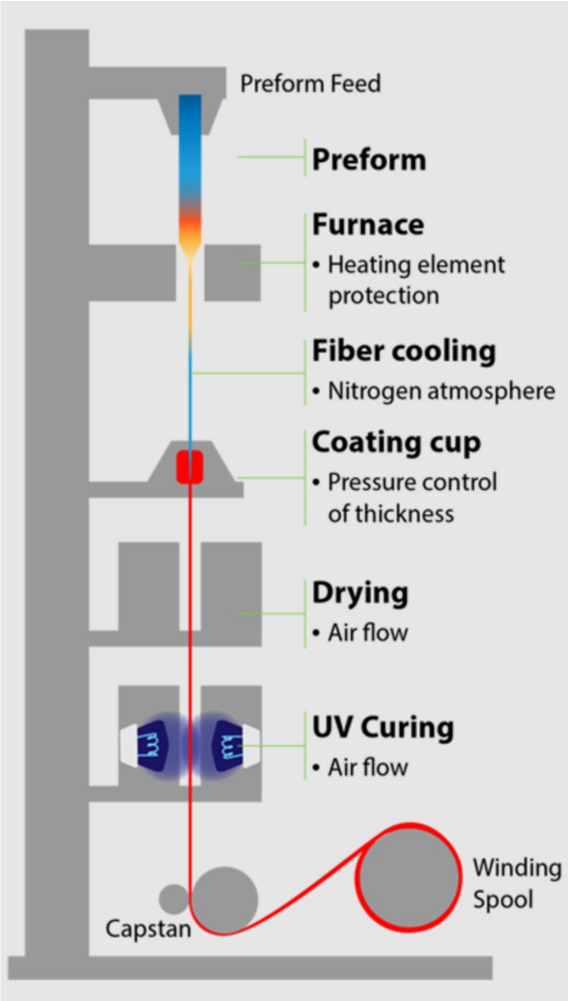


Class of Optics

3

Optical Components

# Fiber Manufacturing




- Core diameter
- Mode field diameter
- Cladding diameter
- Coating diameter
- Attenuation
- Dispersion
- Rayleigh backscatter

**Preform manufacturing**

- Vapor-Phase Axial Deposition (VAD) – OFS
- Outside Vapor Deposition (OVD) – Corning and Prysmian/Draka
- Plasma Chemical Vapor Deposition (PCVD) – Prysmian/Draka

A variety of fiber parameters are affected during the Depostion process., including attenuation uniformity

**Sintering**
**Attenuation is “locked” in**

**Draw**
Effects fiber geometry, cut-off wavelength, fiber curl, PMD performance, reliability and coating strippability

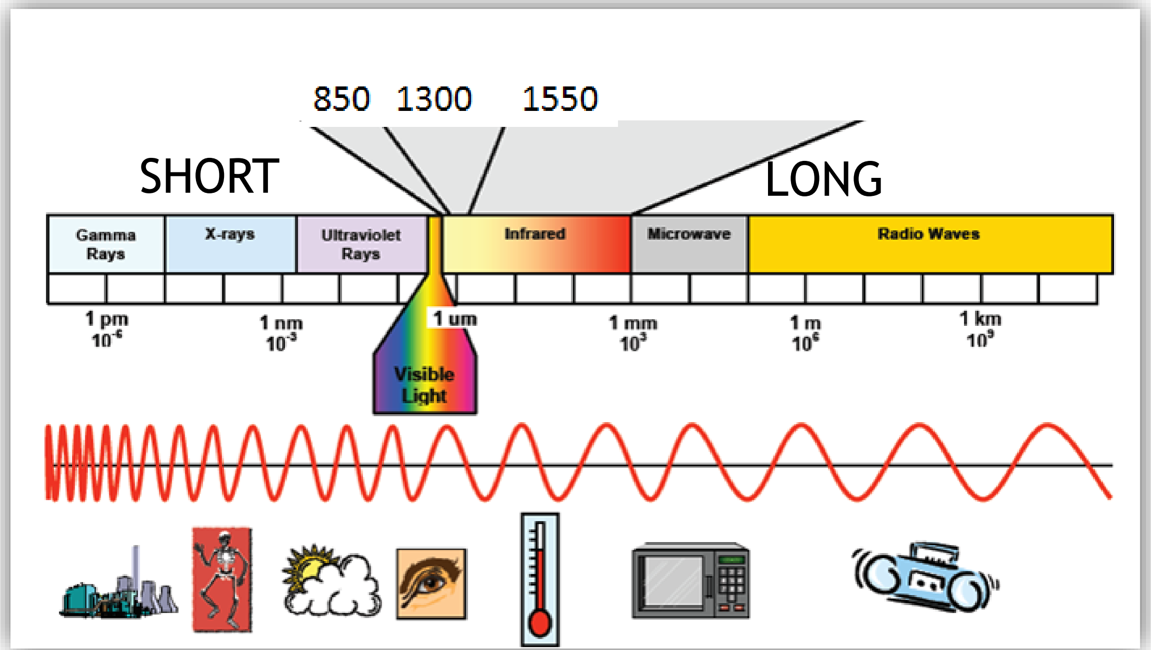
**Test & Measurements**
Proof test, OTDR, Optical, Geometry and visual

https://youtu.be/XvBk2l2h5Zw?si=eJwbisYgTmAxsV4z

# Fiber Optic Spectrum

## How light is defined

**Light is defined as "wavelength" that is measured in nanometers (billionth of a meter).**




**Cut-Off Wavelength**
**λ = 1260nm**

Fiber optics utilize wavelengths in the infrared region where absorption and scattering losses are lowest.

Utilizes the infrared region – 800nm to 1670nm
Multimode: 850nm and 1300nm
Singlemode: 1310nm and 1550nm

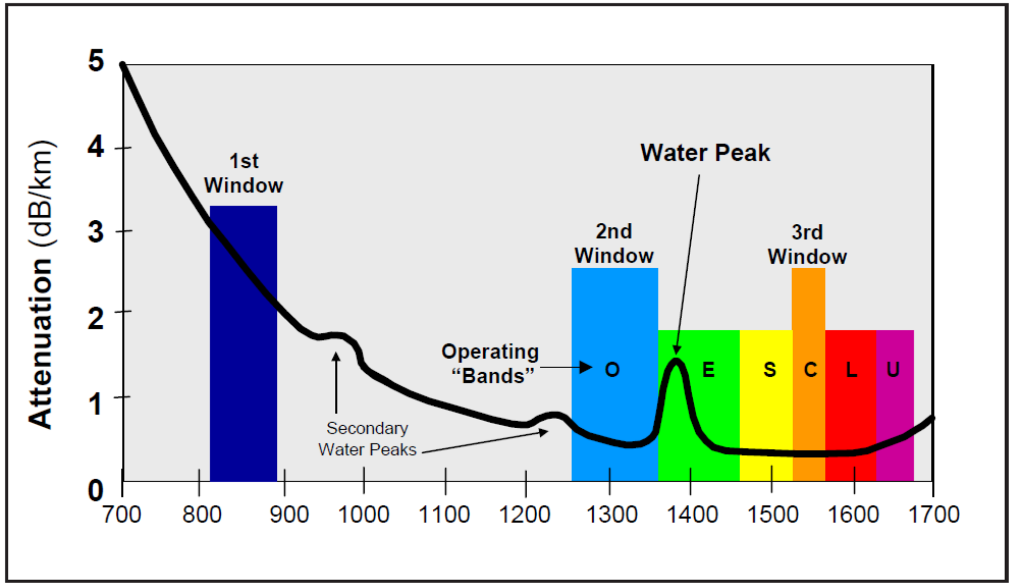
*Wavelength is often used interchangeably with lambda (λ) and color

# Fiber Optic Spectrum

## How light is defined

G.652
G.652C
G.652D

**Windows - *i.e.*, *Bands***




Windows 1, 2 and 3 are original windows chosen for lowest attenuation

Today we use the entire spectrum

| Wavelength Band | Wavelength Range (nm) | Definition |
|---|---|---|
| O-band | 1260-1360 | Original band, PON upstream |
| E-band | 1360-1460 | Water peak band |
| S-band | 1460-1530 | PON downstream |
| C-band | 1530-1565 | Lowest attenuation, original DWDM band, compatible with EDFA fiber amplifiers, AM CATV |
| L-band | 1565-1625 | Low attenuation, expanded DWDM band |
| U-band | 1625-1675 | Ultra long wavelengths |

# How do we Define Fibers?

- The term single-mode tells us the fiber transmits one light path (mode) through a fiber.  FTTx uses only single-mode fibers due to their low attenuation and high bandwidth.

- The term multimode tells us the fiber transmits in many modes (500+), with all info in all modes and arrive basically at the same time.  The smaller the core, the more bandwidth capable.

- Fibers physical dimensions are made in micrometers (microns)

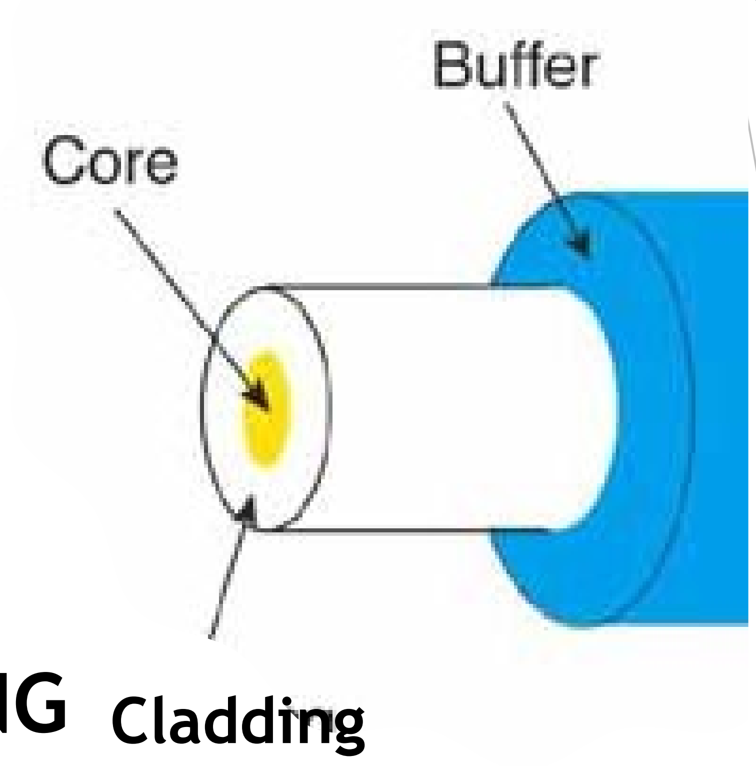
- FTTx fiber specifications are defined through International Telecommunications Union (ITU) standards

- There are many types of single-mode fibers (SMF) available and each has optical or physical attributes for different applications as you will learn

# The Structure of an Optical Fiber - Glass is stronger than steel!

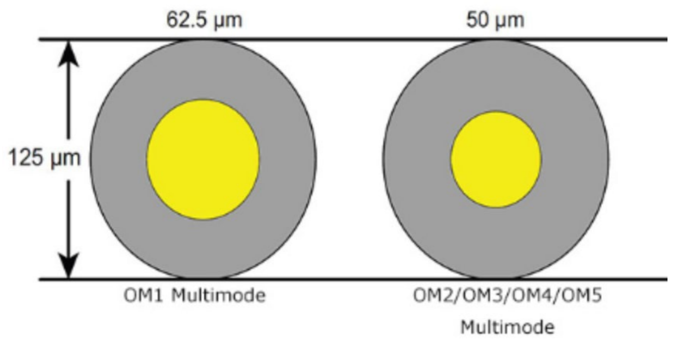
Typical optical fibers are composed of:

- **CORE**
- **CLADDING**
- **PRIMARY BUFFER COATING**
  - **Removed prior to termination**



# Defining Multimode Fibers

- 5 Grades
  - Legacy OM1 and OM2 – 62.5µm using LEDs
  - OM2, OM3, OM4 and OM5 - 50µm using VCSELs @850nm
    - OM3 & OM4 are preferred/common
    - OM5 intended for data centers/high speed applications that require shortwave division multiplexing (SWDM)
- 3dB/km loss @850nm




| | | Bandwidth (MHZ*KM) | | DISTANCE LIMITATIONS | | |
|---|---|---|---|---|---|---|
| Fiber Type | Core/Cladding (µ) | Overfilled Launch LED source 850nm | Effective Modal Bandwidth LASER source 850nm | 10GBASE-SR | 40GBASE-SR4 | 100GBASE-SR10 |
| OM1 | 62.5/125 | 200 | N/A | 33m/ 108ft | | |
| OM2 | 50/125 | 500 | N/A | 82m/ 269ft | | |
| OM3 | 50/125 | 1500 | 2000 | 300m/ 984ft | 100m/ 328ft | 70m/ 230ft |
| OM4 | 50/125 | 3500 | 4700 | 400m/ 1312ft | 150m/ 492ft | 100m/ 328ft |
| OM5 | 50/125 | 3500 | 4700 | 550m/ 1804ft | 150m/ 492ft | 100m/ 328ft |

# Defining Single-Mode Fiber Theoretically, infinite bandwidth

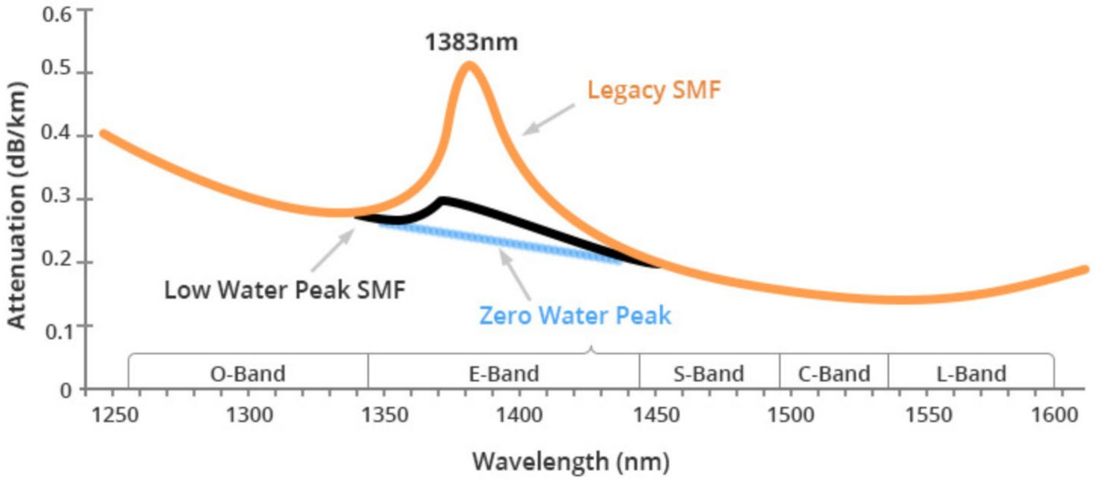
Small core 8-10µm
only allows one mode of light

- Single-mode of light eliminates “modal dispersion” enabling ultra high bandwidth over long distances
- Low attenuation enables very long-distance support (typically< 0.2-0.3 dB/km @1550 nm)
- Many types for different applications
  - Chromatic dispersion
  - Polarization Mode dispersion

| Description | IEC Type | ITU Spec | TIA |
|---|---|---|---|
| **Standard SM fiber** | **B1.1** | **G.652** | **OS1** |
| Cutoff-shifted fiber | B1.2 | G.654 | |
| **Low water peak fiber** | **B1.3** | **G.652** | **OS2** |
| Dispersion-shifted fiber | B2 | G.653 | |
| Non-zero dispersion shifted fiber | B4 | G.655 | |
| Bend-insensitive fiber | | G.657 | |

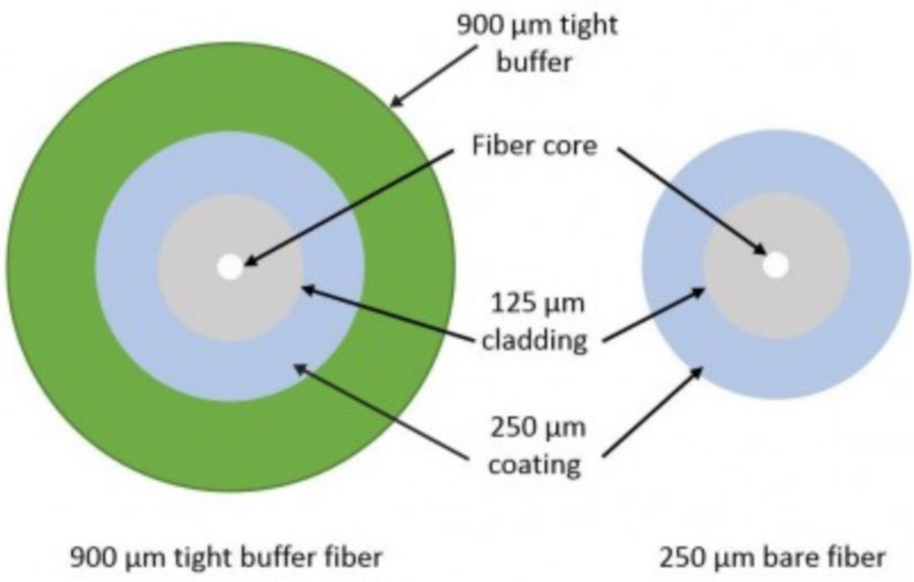
*MFD may differ amongst these fiber types, especially bend insensitive (G.657) fibers.
Use of an OTDR bidirectional testing will help resolve the issue.

# ITU-T G.652
# The Most Popular SMF





- Sets the international standards for geometrical, mechanical and transmission attributes for single-mode fiber and cable.
- Originally developed in 1984
- Zero dispersion wavelength ~1310nm however, can be used at 1550nm wavelength
- 4 revisions all with same core size 8-10microns
  - G.652A, B, C and D
- Todays OS2 fibers are G.652C and G.652D
- G.652A and B rarely used due to water peak




# Single-mode Fiber Coatings

- Dimensions
  - 200/250µm bare fiber (primary buffer coating w/color code)  OS2
  - 600µm tight buffer
  - 900µm tight buffer  OS1
- ID basic 12 colors
  - TIA-598 Std
- Ribbon
  - Layer(s) of matrix + 200/250µm primary
- ID when coating is applied during manufacturing
- ALL Coatings are removed prior to splicing to allow alignment with tight tolerance glass claddings.

# Optical Fiber Color Code Chart

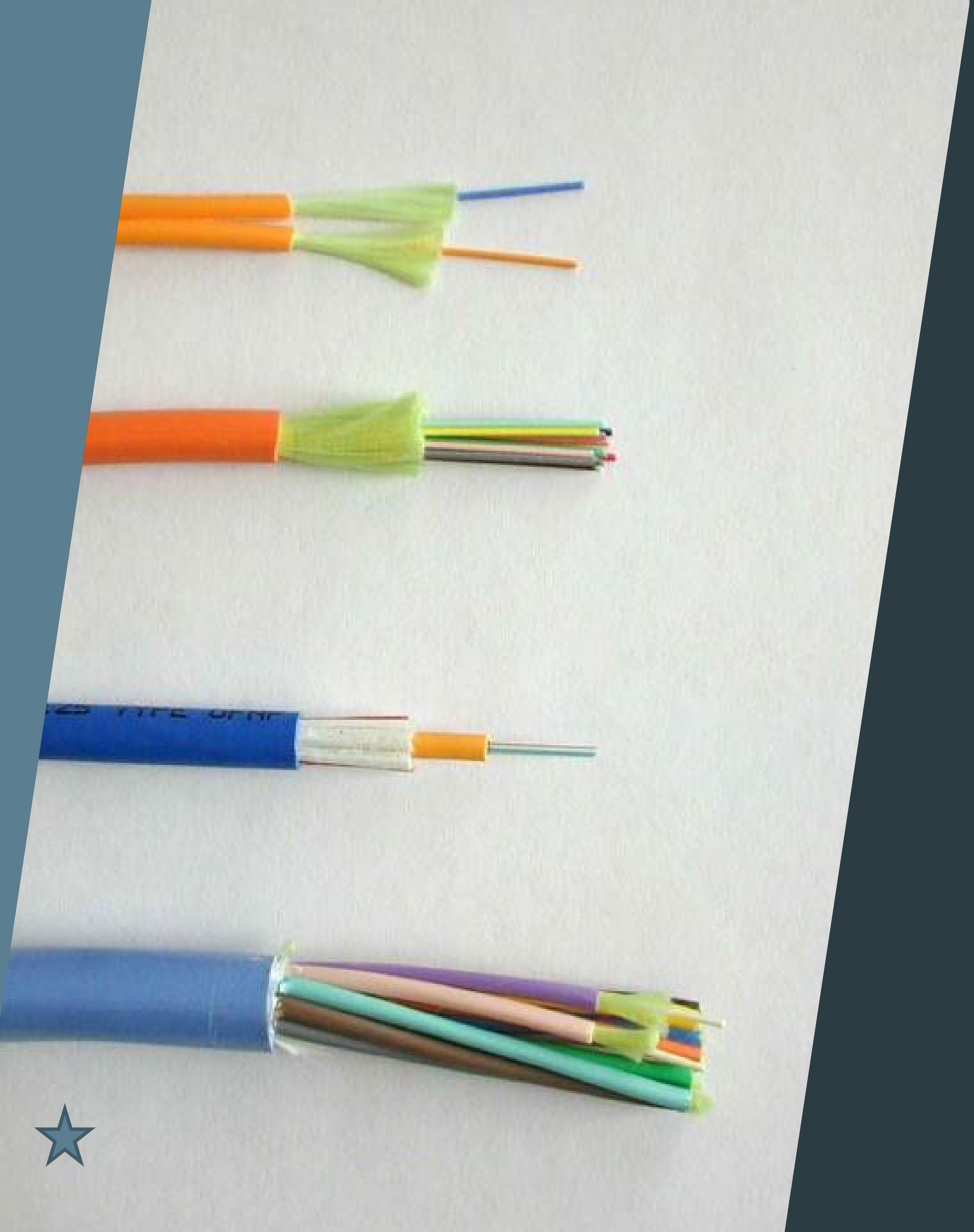
TIA – 598 Standard

TIA – 598 Standard

- Each fiber must be identified for end-to-end terminations along with splicing.
- Continuity of all fibers in the outside plant (OSP).
- Standardized in the TIA-598 “Optical fiber cable color coding” standard.
- Used to identify connector polish
- Identify premise cabling and jumpers.
- Buffer tubes also identified by same color sequence as fibers.

**Unit Position Color Code for Loose Tube (TIA–598)**

| Position | Buffer Tube Color | Position | Buffer Tube Color | Position | Buffer Tube Color |
|---|---|---|---|---|---|
| 1 | Blue | 13 | Blue w/Black Stripe | 25 | Blue w/Red Stripe |
| 2 | Orange | 14 | Orange w/Black Stripe | 26 | Orange w/Red Stripe |
| 3 | Green | 15 | Green w/Black Stripe | 27 | Green w/Red Stripe |
| 4 | Brown | 16 | Brown w/Black Stripe | 28 | Brown w/Red Stripe |
| 5 | Slate (Gray) | 17 | Slate w/Black Stripe | 29 | Slate w/Red Stripe |
| 6 | White | 18 | White w/Black Stripe | 30 | White w/Red Stripe |
| 7 | Red | 19 | Red w/Black Stripe | 31 | Red w/Yellow Stripe |
| 8 | Black | 20 | Black w/Yellow Stripe | 32 | Black w/Red Stripe |
| 9 | Yellow | 21 | Yellow w/Black Stripe | 33 | Yellow w/Red Stripe |
| 10 | Violet | 22 | Violet w/Black Stripe | 34 | Violet w/Red Stripe |
| 11 | Rose (Pink) | 23 | Rose w/Black Stripe | 35 | Rose w/Red Stripe |
| 12 | Aqua | 24 | Aqua w/Black Stripe | 36 | Aqua w/Red Stripe |
| | | | | 37 | Blue w/Green Stripe |
| | | | | 38 | Orange w/Green Stripe |



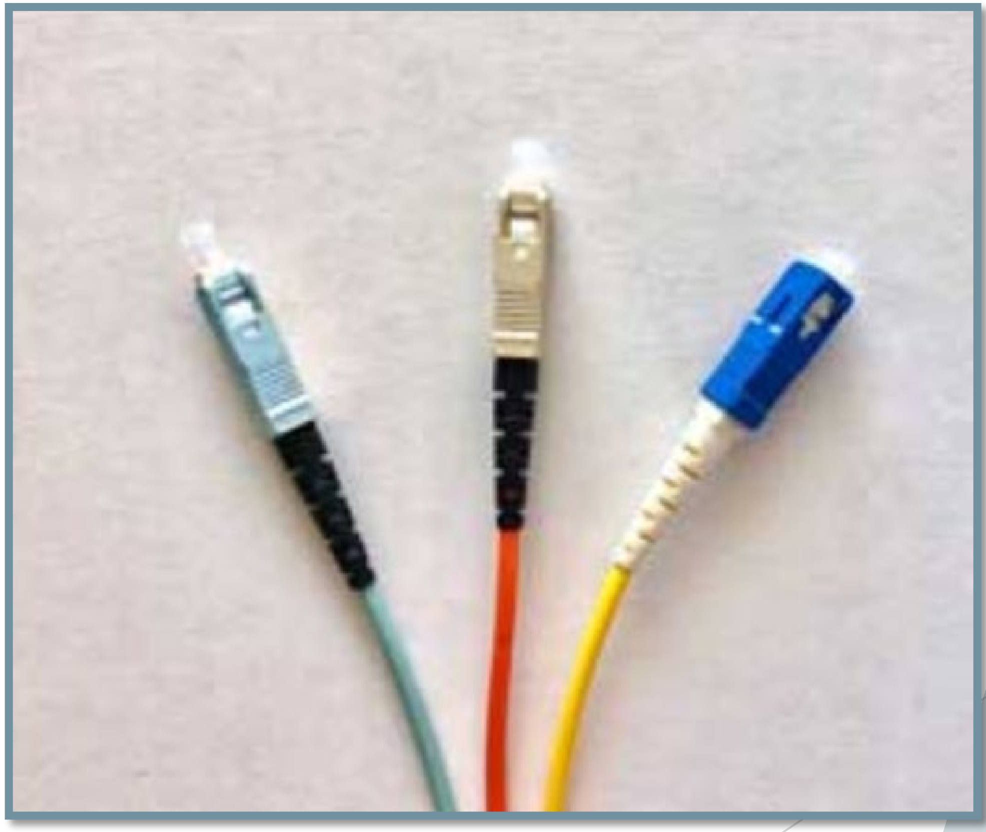
# Fiber Optic Cable Types

- **Tight buffer (Simplex/Zipcord)**
  - 900µ, color coded
  - Patchcords
- **Distribution**
  - Dry conduit runs, plenum and riser
  - Bundled 900µ coated fibers
  - Terminated in a panel/wallbox for protection
- **Loose Tube**
  - 250µ loose fibers in a buffer tube
  - 250µ “ribbonized” fibers
  - Typically used in OSP
    - Armored cable for direct buried
    - Requires furcating for termination
- **Breakout**
  - Tight buffered
  - Rugged, individually reinforced
  - Directly terminate connectors

# Cable Jacket/Sheath Color Codes

## For Premise Application

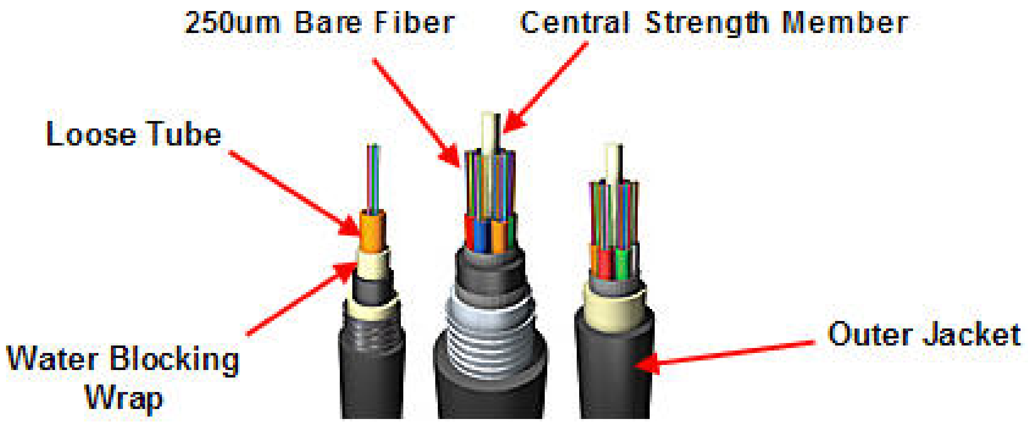
| Fiber Type | General Use | US Military |
|---|---|---|
| OM1 | Orange | Slate |
| OM2 | Orange | Orange |
| OM3/OM4 | Aqua/ Erica Violet | --- |
| OM5 | Lime Green | --- |
| MM 100/140 | Orange | Green |
| SM OS1/OS2 | Yellow | Yellow |
| SM/PM | Blue | --- |



# PREMISE - Cable Ratings and Markings

- All premises cables must carry identification and ratings per the NEC (National Electrical Code) Article 770 or other local building codes. Cables without markings should never be installed indoors as they will not pass inspections!
- ANY cable with metallic MUST be properly grounded/bonded per local practice
- These ratings are:
  - OFN  optical fiber non-conductive
  - OFC  optical fiber conductive
  - OFNG or OFCG general purpose
  - OFNR or OFCR  riser rated cable for vertical runs
  - OFNP or OFCP  plenum rated cables for air-handling areas
  - OFN-LS  low smoke density

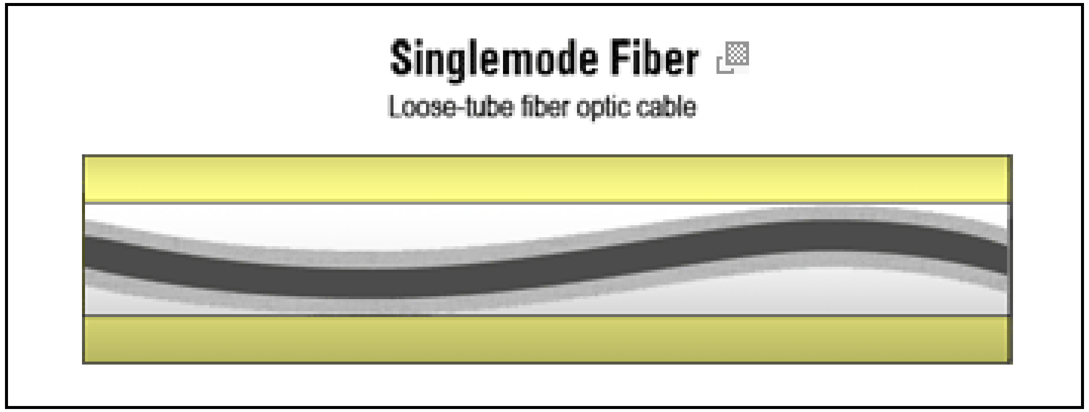
# Outside Plant Cable Construction



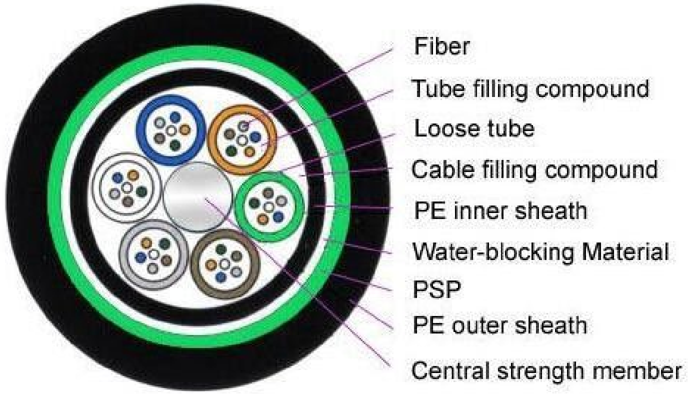

- **Outside Plant Cables - HDPE**
  - Single-mode; Loose tube or Ribbon
  - Water-blocked gel-filled or dry
  - NOT fire rated for indoor use.
    - Can only be used up to 50 feet indoors (NEC 700)
  - ADSS
    - Distribution and transmission environments
  - Armor to prevent rodent damage and crush resistant
    - ANY cable with conductive material must be properly grounded/bonded per local practice,
  - Feed, Distribution and Drop cables
  - Indoor/Outdoor cable types available

https://youtu.be/fjRqGKU9cUU?si=-IRjzXvvaqIcs2im

# Loose Tube Cable Construction

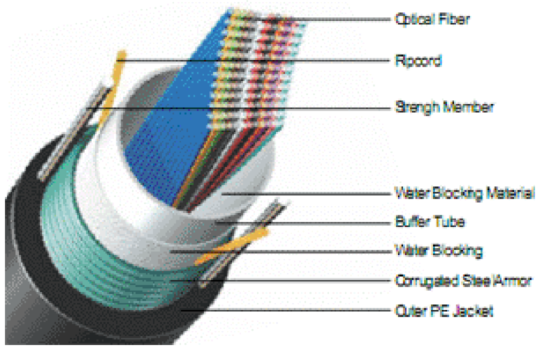


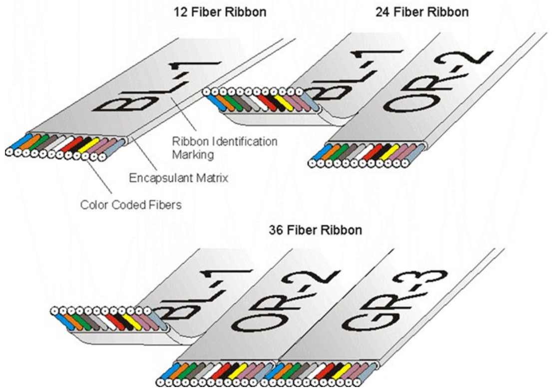

- Fibers are loose in tubes for isolation from installation stress
- Tubes contain several individual fibers (usually 12 – up to 36)
- Tubes and cable can be filled with water-block.
- Tubes are color coded per TIA-598 Standard
- Ideal for OSP trunk applications and often pulled into conduit or innerduct
- Usually spliced and protected in splice trays and must use breakout kit to terminate
- About 1-2% longer than cable jacket markings

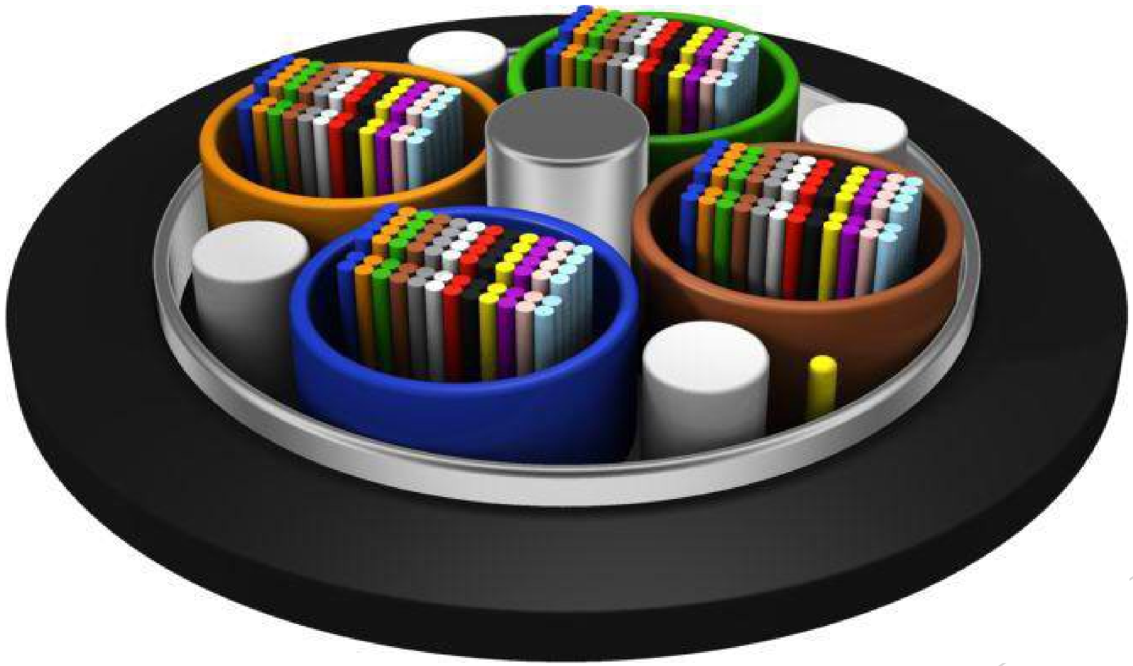


# FLAT Ribbon Cable Construction

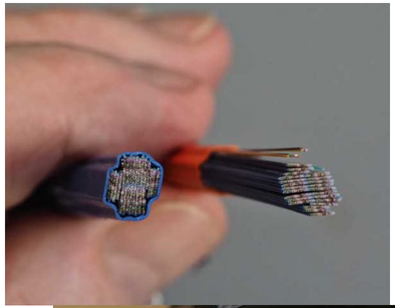
- Provides maximum density of fibers
  - Up to 864 Fibers in stacked footprint
- Ribbons have 12-36 individual fibers held by adhesive/matrix.
- Ribbons are stacked in cable “loose” tube or central tube
- Indoor or outdoor ratings
- Can be mass-spliced 12 fibers at a time
  - V-Groove only
  - Remove matrix for single splice and each 12F ribbon



# 200 Micron and Ultra High-Density Cables



*Corning – RocketRibbon*

Compatible with existing 250µ fibers

2x fiber in the same place – 24F in a 12F loose tube

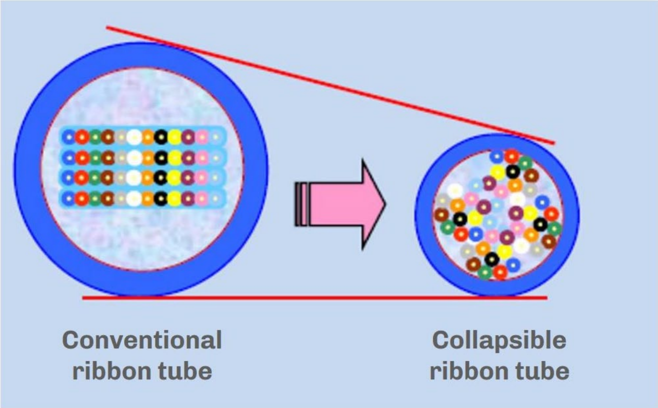
Fully compatible with fiber standards

Special fiber holders may be needed for fusion machine

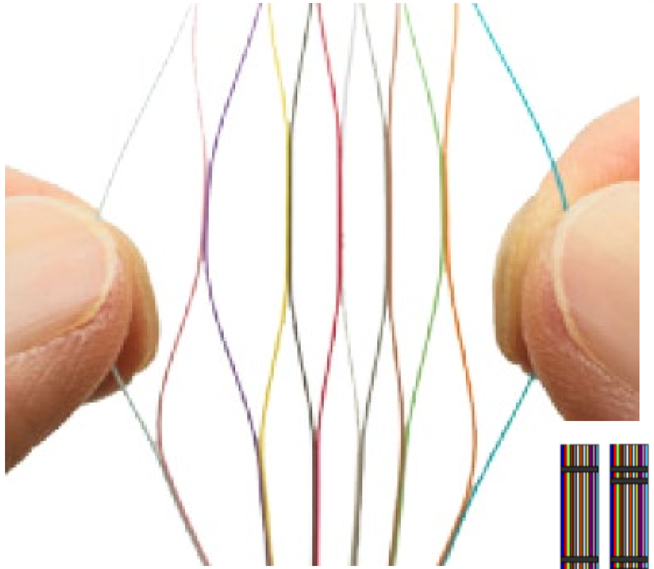
Fiber Density Comparison

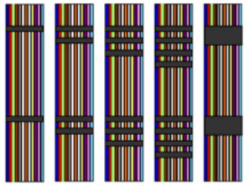
- 3456 fiber cable based on 200 micron buffered fibers, 54% of the cable is fiber.
- Typical 144 fiber loose tube cable, which is about 14% fiber
- 144 fiber microcable which is about 36% fiber.

# Collapsible/Rollable/Bonded Ribbon




Courtesy AFL



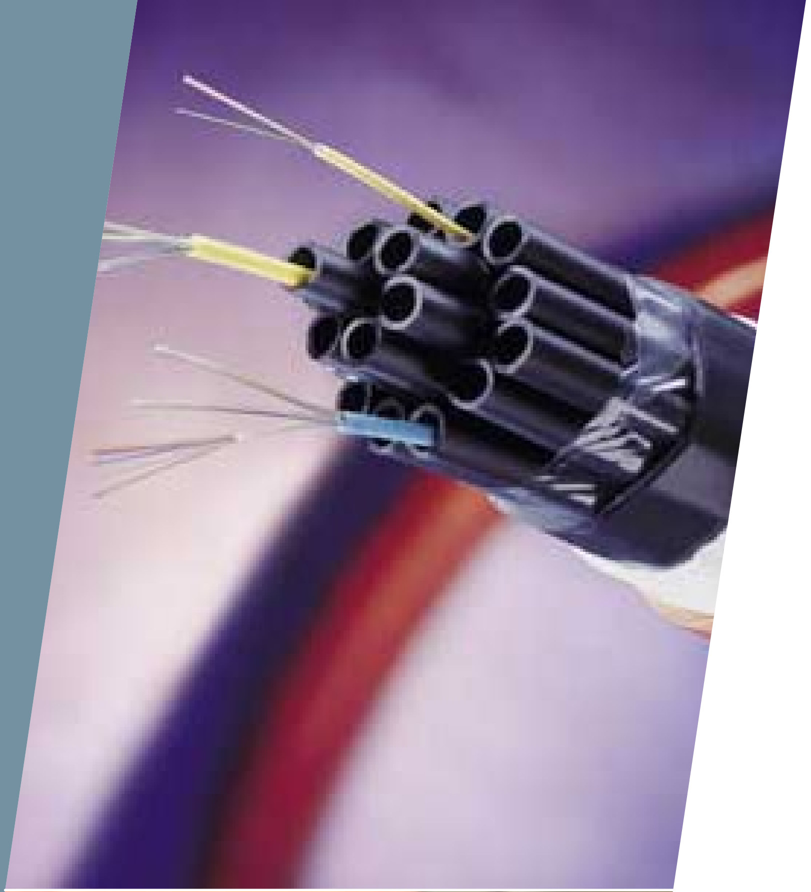


Easy identification of each ribbons

- What is it?
  - Intermittent bonds between fibers in a ribbon
  - Ribbon can be rolled into a cylinder
  - Enables cables with thousands of fibers
    - Today at 6912
  - 200 micron bend insensitive fibers

Benefits

  - Enables 2x fiber vs flat ribbon in a duct
  - Ribbon splicing functionality
  - Gel free



# Air - Blown Fiber
# An Alternative To Cable

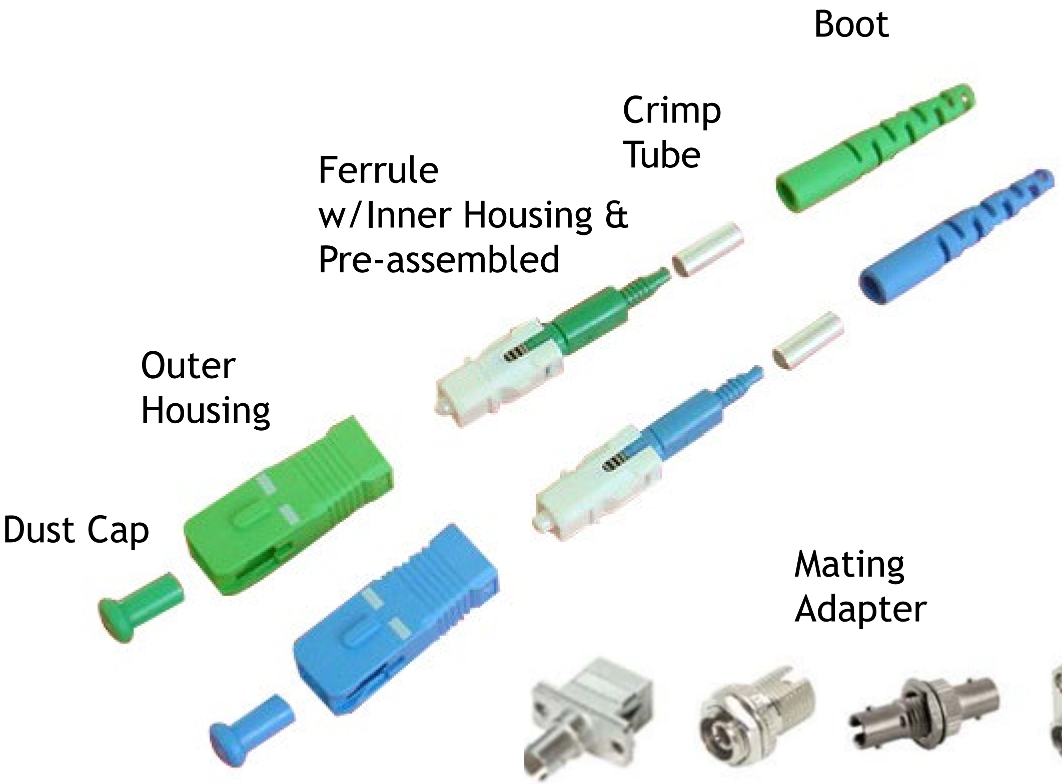
- Install “cable” with empty plastic tubes – indoors or OSP
- Blow special fibers into the tubes
- Allows easy installation but requires special equipment
- Requires special fibers
- More expensive but allows flexibility, easy upgrades
- Not to be confused with “blown fiber” with microcables in microducts

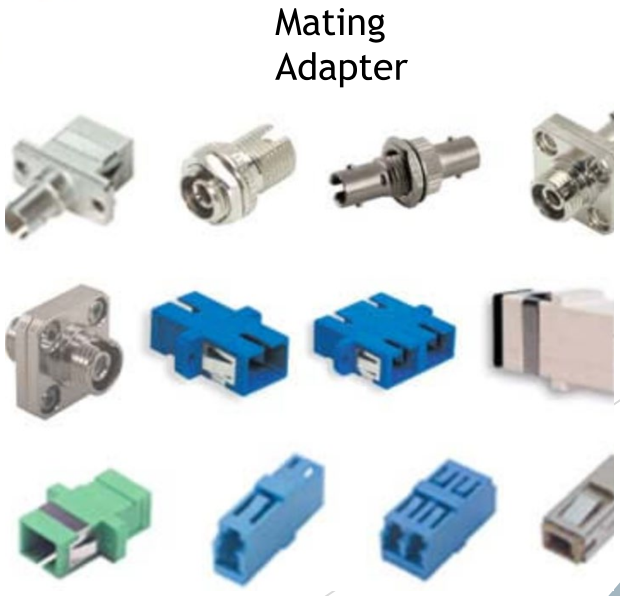
**Fiber optic terminations**

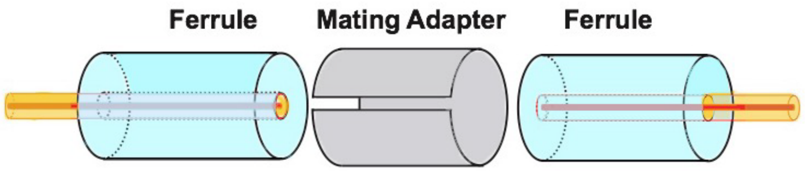
- Connectors
  - Demountable terminations for fiber
  - Connect to transmitters and receivers
- Splices
  - Permanent termination of two fibers
  - Mechanical for multimode or temporary restorations

# Basic anatomy of a fiber optic connector

- Most ferrules are ceramic, but metal and plastics are used
- Connections use mating adapters to align fibers



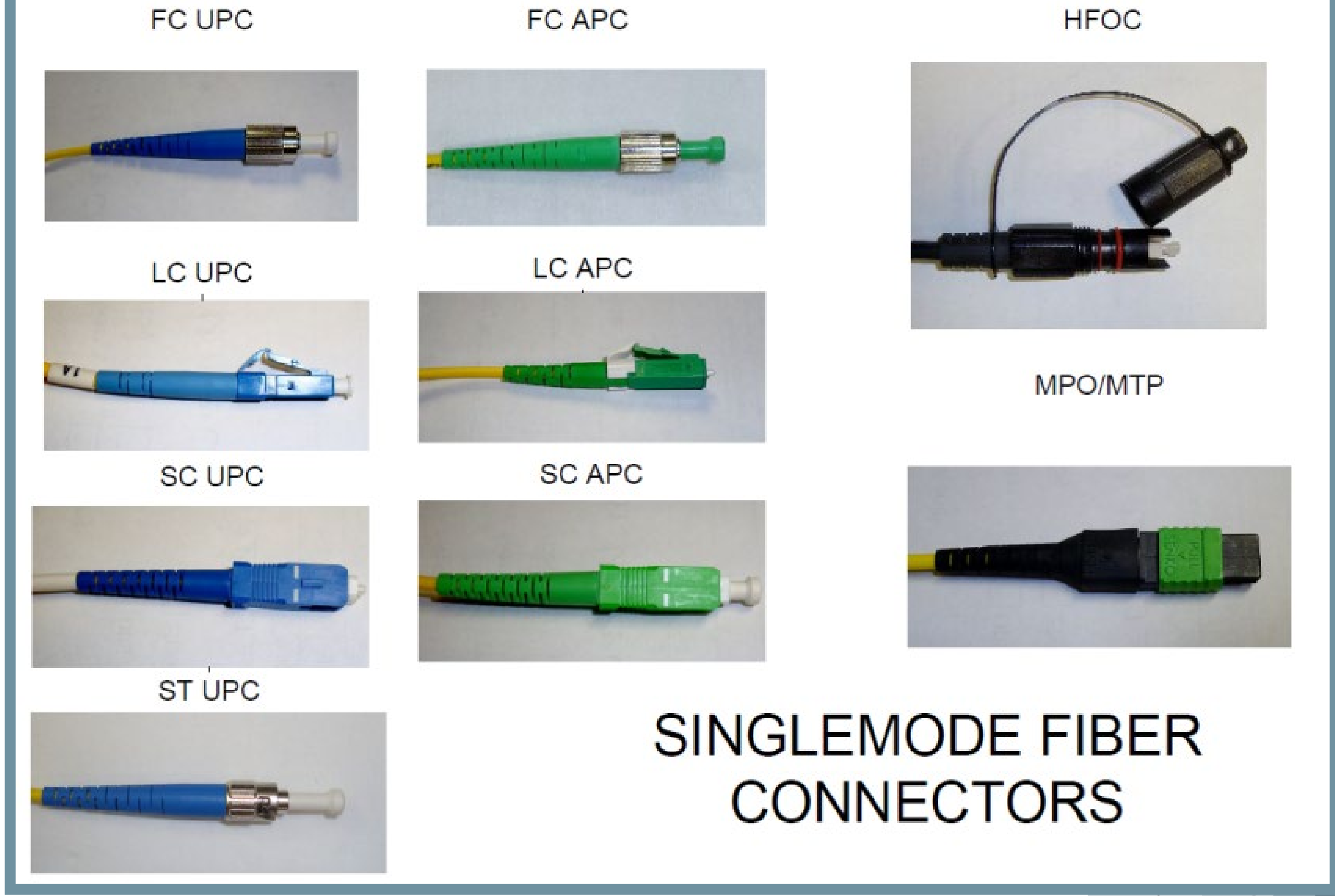



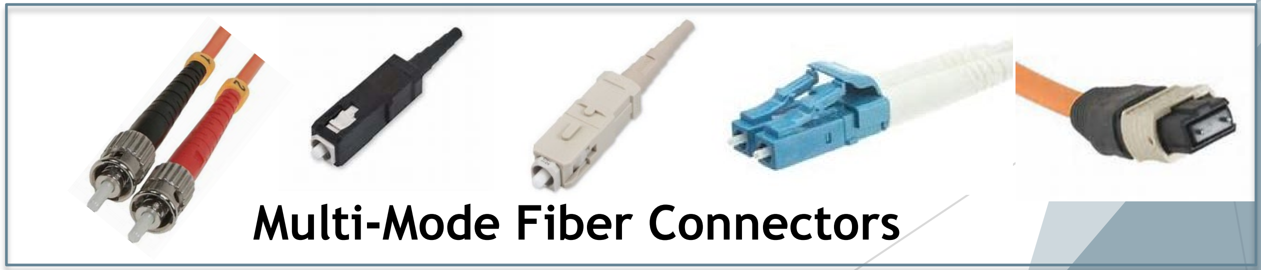



# Connector Color Codes

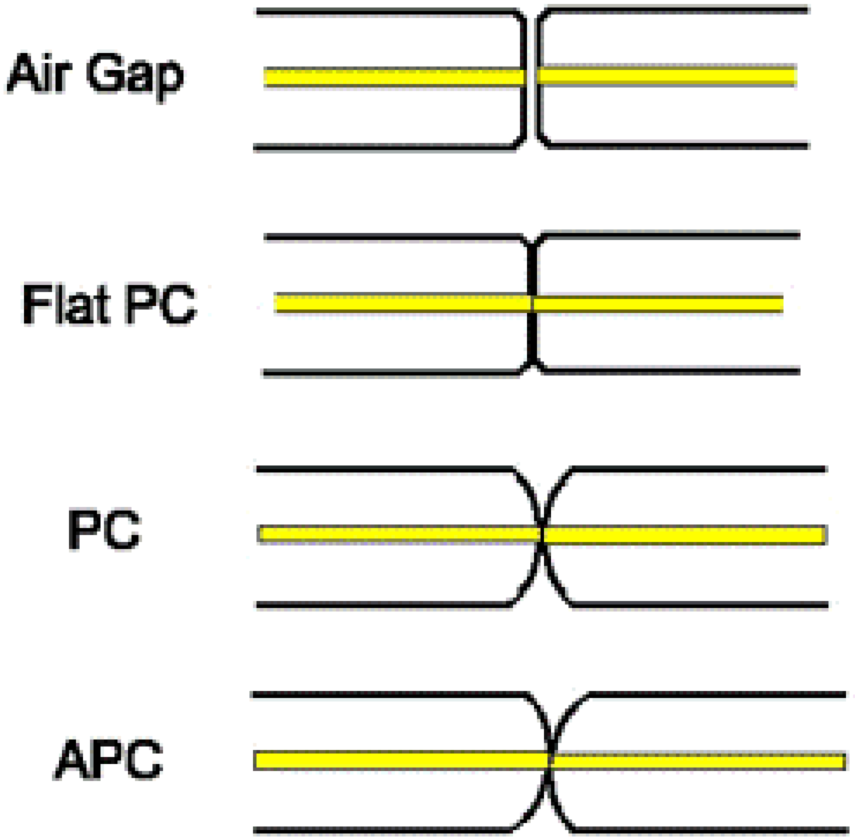
- Blue: Singlemode PC
- Green: Singlemode APC
- Beige: Multimode 62.5µ (orange jacket)
- Black:  Multimode 50µ (OM2 orange jacket)
- Beige or Aqua/Erica Violet:  Multimode 50µ laser optimized (OM3 & OM4)
- Beige or Lime green:  OM5
- **NEVER** mate different colors!
- *Pay attention to cable jacket color*

- **Specifications**
  - Loss/Attenuation
    - 0.50dB (ITUT G.671)
    - 0.40dB (Telcordia GR-326-CORE)
  - Repeatability
    - ≤0.2dB (Telcordia GR-326-CORE)
      - over 50 mating cycles
  - Environment (temp, humidity, stress, etc.
    - Rugged (strain relief)
  - Reliability
  - Reflectance
    - 65dB – APC polish
    - 55dB – UPC polish
    - 25dB – MM MPO
    - 55dB – SM MPO
  - Ease of termination
  - Cost

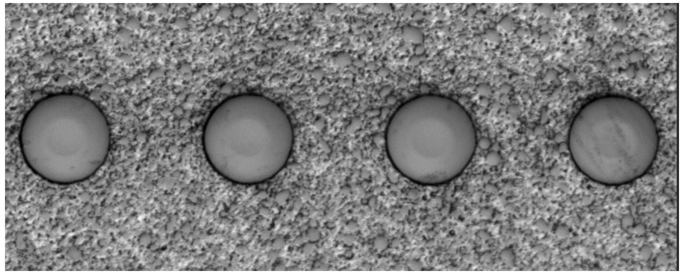


# Connector Endface Finishes



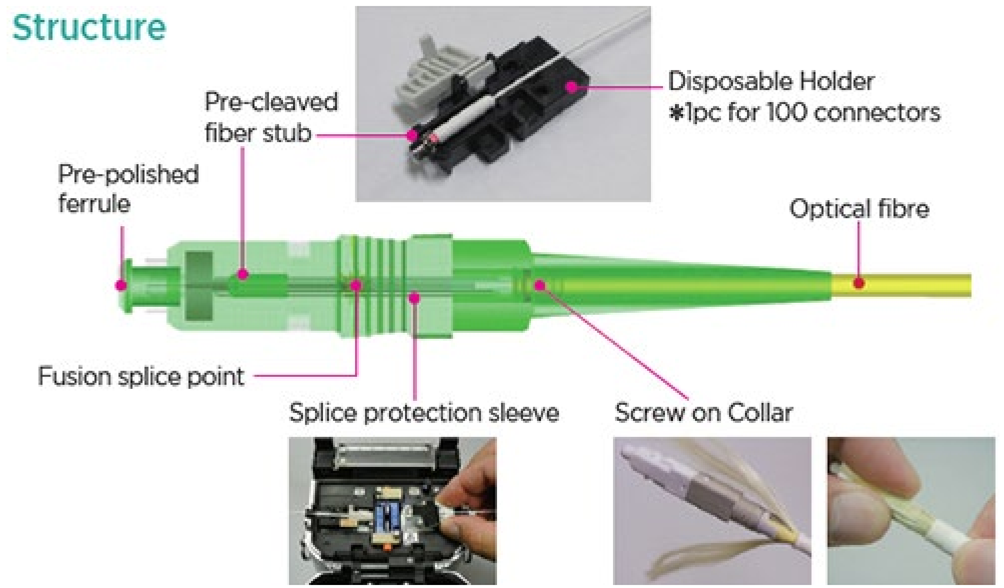




**Single-Mode**
<-55dB
Back Reflection

**Multimode**
<-25dB
Back Reflection

# Field Termination – Fusion




## Epoxy/Polish

- Polishing techniques best done at factory environment

## Splice on “factory terminated pigtail”

- A jumper will provide 2 “pigtails”

## Splice On Connector “SOC”

- A variety of manufacturers offer Splice On Connectors

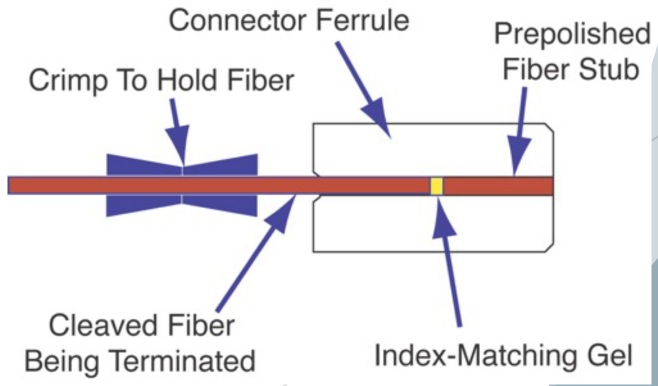
# Field Termination – Mechanical

## Pre-polished fiber stub and mechanical splice

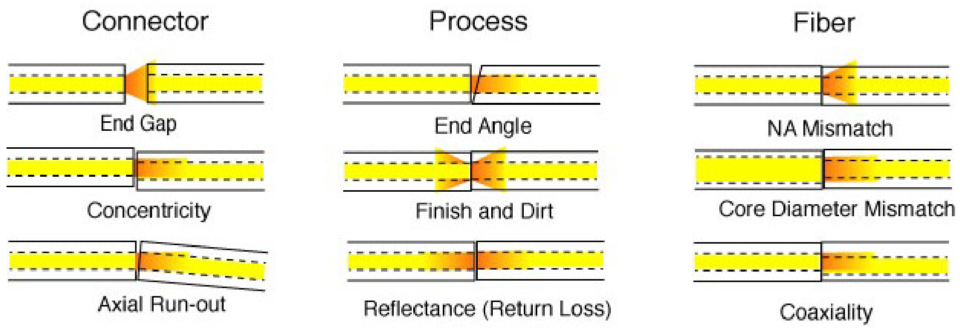
- Terminated with a precision cleave and index matching gel

## Visual Fault Locator (VFL) to verify splice

- Typical loss 0.75dB



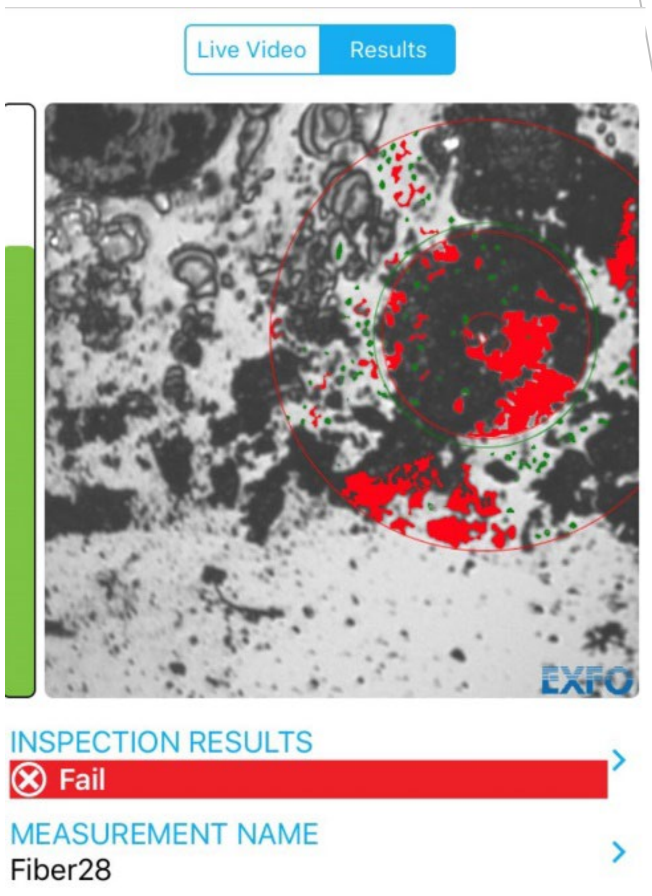

# Causes of Loss




- Lowest loss requires perfect match between cores of two fibers.
- Losses may be caused by imperfect connectors, fibers or processes.
- Loss may also occur when mating fibers within an adapter.

# VISUAL INSPECTION

NEVER assume a “new” packaged connector is clean!!!

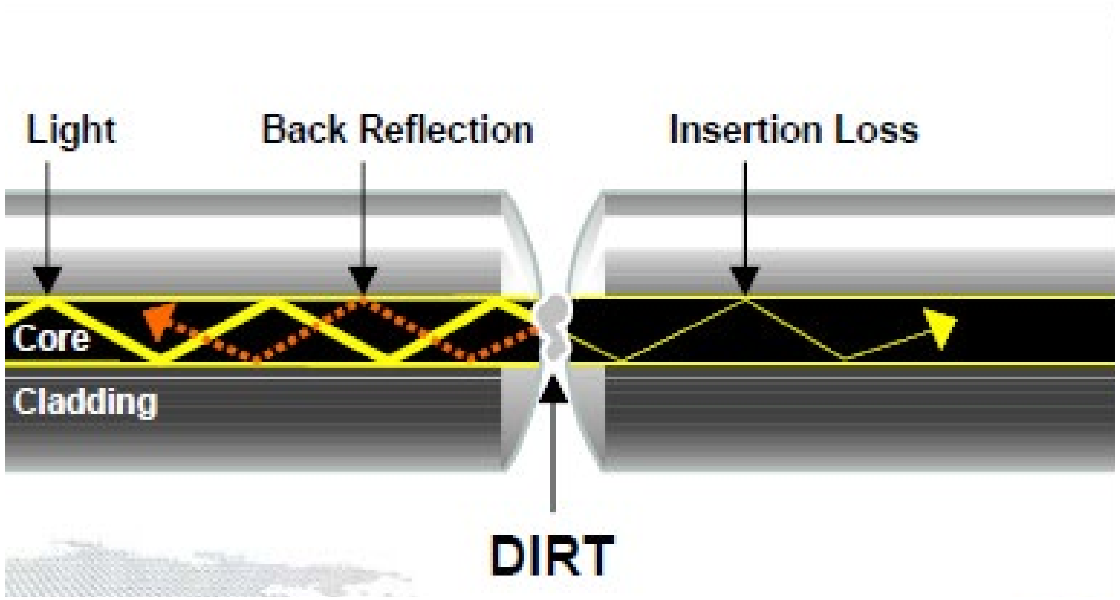



## Why it is so important!

No.1 cause of network failures is contaminated connectors

Recent study by NTT-Advanced Technology, reported that 90% of Installers/technicians reported that issues with connector contamination was the greatest cause of network failure.

# What Makes a BAD Fiber Connection




- A single particle mated into the core can cause significant
  - Back Reflection
  - Insertion Loss
  - Equipment Damage

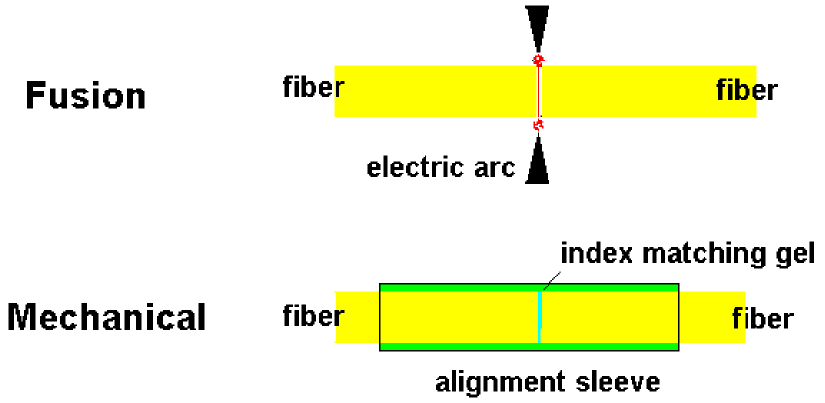
- Endface pressure when mated is up to 50kpsi
  - ….similar to water jet cutters

# Fiber Optic Splices

- *Permanent* terminations for fiber when fusion spliced
- Temporary splice with mechanical means

- Fusion
  - Lowest loss
  - Lowest back reflection
  - Strongest
  - Faster
  - High capital cost
  - Low per splice cost
- Generally used for OSP construction

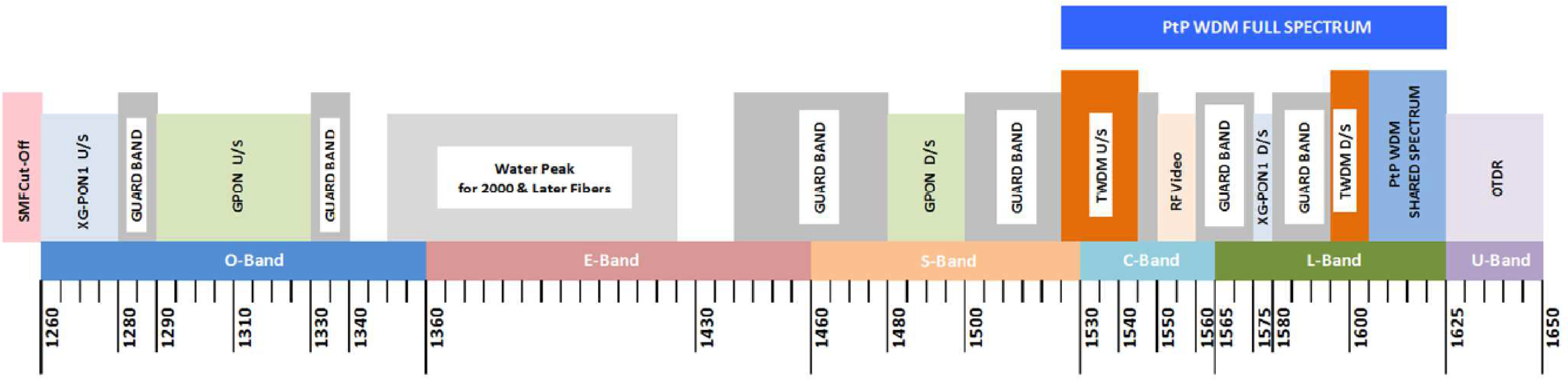
- Mechanical Splices
  - Minimal tooling
  - Low capital cost
  - High per splice cost
- Mostly used for restoration and MM premises cabling




**Splice Loss per TIA - 568C standards**

Fusion 0.3dB
Typical loss <0.05dB

Mechanical splice loss 0.3dB
Typical loss 0.15dB



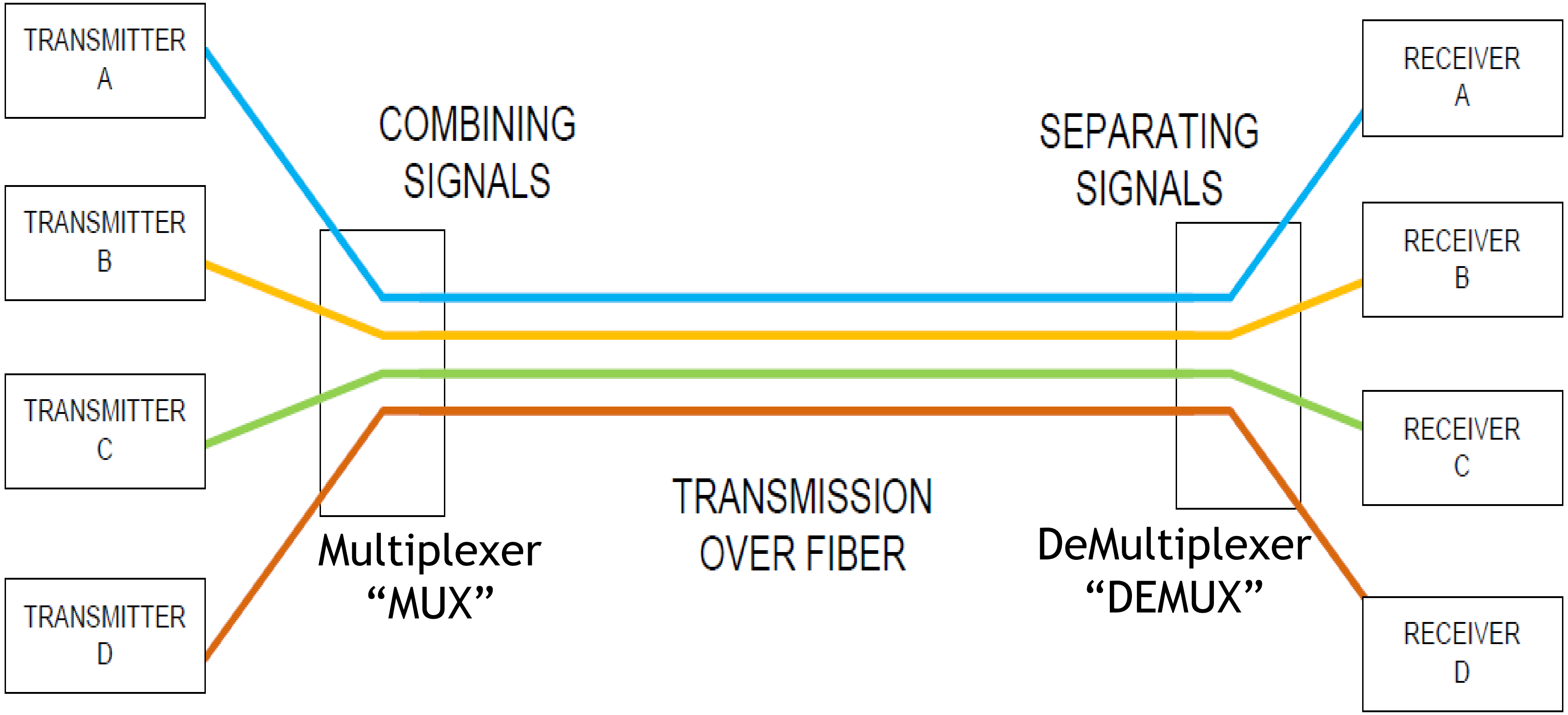

# As technology grows…

The first 30 years used 1310/1550 nm.
The next 30 will require the entire ITU spectrum.

- P2P and DWDM – 1990's
- 12-channel CWDM, E-Band CWDM, GE/GPON, RFOG – 2000's
- 10GPON – 2016
- NG-PON2 – 2018
- 40GPON – 2020
- ……and keeps growing

# What is WDM?
## Wavelength Division Multiplexing

**Wave Division Multiplexing** is possible because multiple wavelengths of light can travel in the same fiber at the same time and in any direction because light has no mass.



# Downstream traffic lanes

NG-PON2 Express

NG-PON2 (10G)

10G-PON

25G-PON

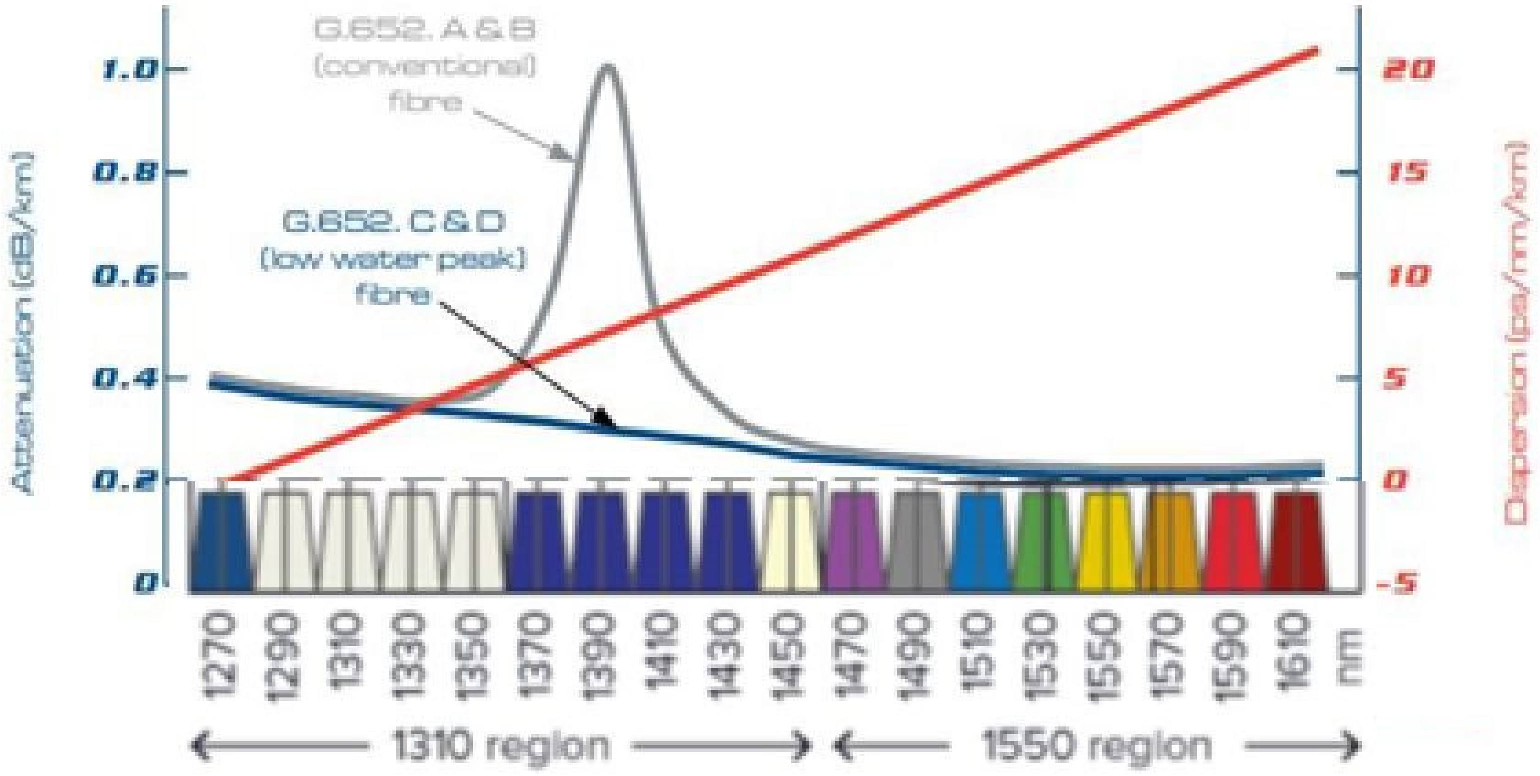
EPON (1G)

XGS-PON (10G)

NG-PON2 (10G)

GPON (2.5G)

# CWDM Technology




- ITU G.694.2 CWDM Grid
- Full λ spectrum: 1270 thru 1610
- 20nm spacing
  - Typically 4/8/16 channel
- Requires SFP based optic transport platforms
- G.652 C & D for optimal performance
- Short-distance (i.e., metro or access networks), up to ~80km

**Increasing capacity and increasing connections**

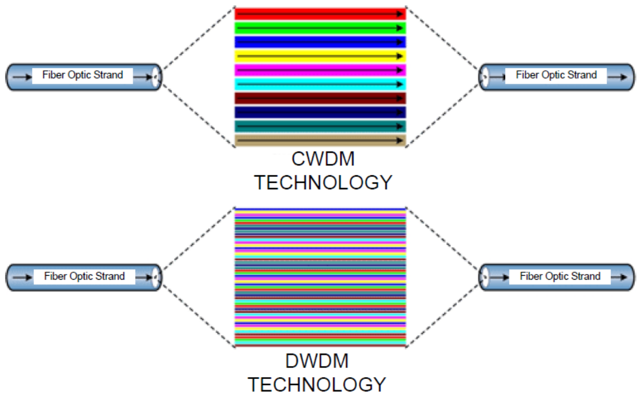
# DWDM – Dense Wavelength Division Multiplexing

**Dense Wave Division Multiplexing** can use multiple standards to determine wavelength spacing

| ITU Grid Channels (100 GHz Spacing) | | | | | |
|---|---|---|---|---|---|
| Channel | Frequency (GHz) | Wavelength (nm) | Channel | Frequency (GHz) | Wavelength (nm) |
| 1 | 190,100 | 1577.03 | 38 | 193,800 | 1546.92 |
| 2 | 190,200 | 1576.20 | 39 | 193,900 | 1546.12 |
| 3 | 190,300 | 1575.37 | 40 | 194,000 | 1545.32 |
| 4 | 190,400 | 1574.54 | 41 | 194,100 | 1544.53 |
| 5 | 190,500 | 1573.71 | 42 | 194,200 | 1543.73 |
| 6 | 190,600 | 1572.89 | 43 | 194,300 | 1542.94 |
| 7 | 190,700 | 1572.06 | 44 | 194,400 | 1542.14 |
| 8 | 190,800 | 1571.24 | 45 | 194,500 | 1541.35 |
| 9 | 190,900 | 1570.42 | 46 | 194,600 | 1540.56 |
| 10 | 191,000 | 1569.59 | 47 | 194,700 | 1539.77 |
| 11 | 191,100 | 1568.77 | 48 | 194,800 | 1538.98 |
| 12 | 191,200 | 1567.95 | 49 | 194,900 | 1538.19 |
| 13 | 191,300 | 1567.13 | 50 | 195,000 | 1537.40 |
| 14 | 191,400 | 1566.31 | 51 | 195,100 | 1536.61 |
| 15 | 191,500 | 1565.50 | 52 | 195,200 | 1535.82 |
| 16 | 191,600 | 1564.68 | 53 | 195,300 | 1535.04 |
| 17 | 191,700 | 1563.86 | 54 | 195,400 | 1534.25 |
| 18 | 191,800 | 1563.05 | 55 | 195,500 | 1533.47 |
| 19 | 191,900 | 1562.23 | 56 | 195,600 | 1532.68 |
| 20 | 192,000 | 1561.42 | 57 | 195,700 | 1531.90 |
| 21 | 192,100 | 1560.61 | 58 | 195,800 | 1531.12 |
| 22 | 192,200 | 1559.79 | 59 | 195,900 | 1530.33 |
| 23 | 192,300 | 1558.98 | 60 | 196,000 | 1529.55 |
| 24 | 192,400 | 1558.17 | 61 | 196,100 | 1528.77 |
| 25 | 192,500 | 1557.36 | 62 | 196,200 | 1527.99 |
| 26 | 192,600 | 1556.55 | 63 | 196,300 | 1527.22 |
| 27 | 192,700 | 1555.75 | 64 | 196,400 | 1526.44 |
| 28 | 192,800 | 1554.94 | 65 | 196,500 | 1525.66 |
| 29 | 192,900 | 1554.13 | 66 | 196,600 | 1524.89 |
| 30 | 193,000 | 1553.33 | 67 | 196,700 | 1524.11 |
| 31 | 193,100 | 1552.52 | 68 | 196,800 | 1523.34 |
| 32 | 193,200 | 1551.72 | 69 | 196,900 | 1522.56 |
| 33 | 193,300 | 1550.92 | 70 | 197,000 | 1521.79 |
| 34 | 193,400 | 1550.12 | 71 | 197,100 | 1521.02 |
| 35 | 193,500 | 1549.32 | 72 | 197,200 | 1520.25 |
| 36 | 193,600 | 1548.51 | 73 | 197,300 | 1519.48 |
| 37 | 193,700 | 1547.72 | | | |

## ITU-T G.694.1 Wavelengths
## Typically 8 or more wavelengths - centered around 1550 nm

- C-Band 1530nm – 1565nm
- L-Band 1570nm – 1625nm




### Typical in networks

- .8 nm (100 GHz) Spacing
- 1.6 nm (200GHz) Spacing

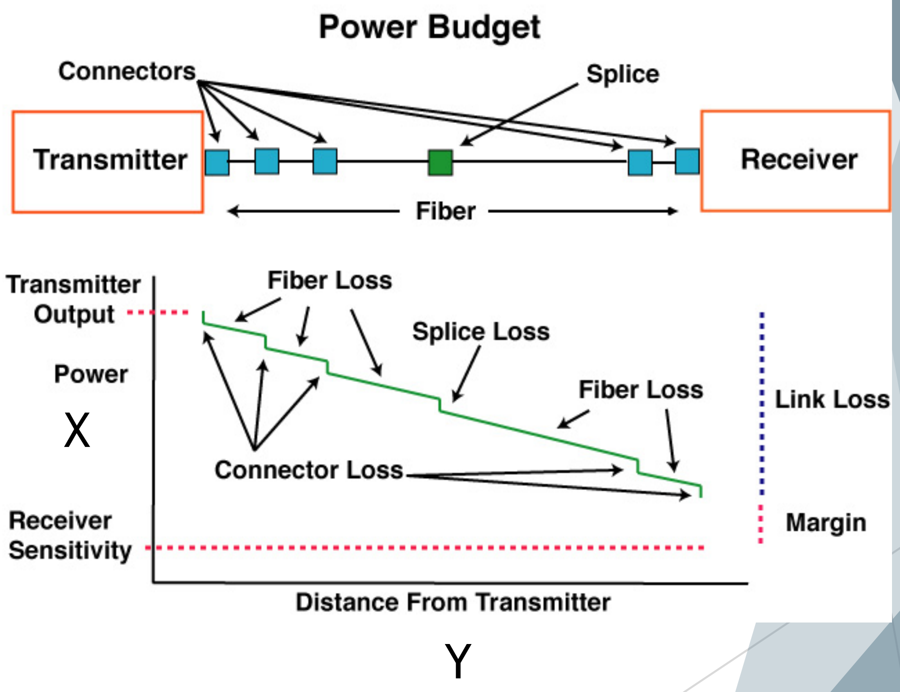
- 160 channels possible on active networks (25GHz spacing)

- 40 channels max on passive

# Fiber Optic Link Loss & Power Budgets

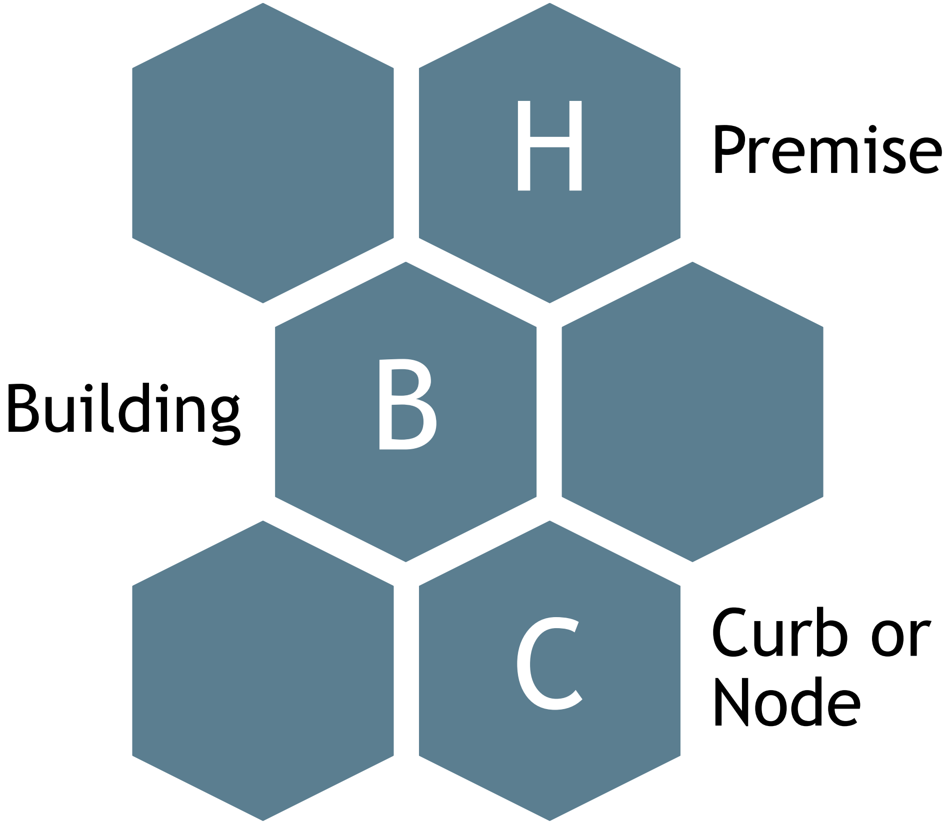
## Estimate how much loss the cable plant should have

- **Every network has a power budget**
  - Transmitter output > receiver input
  - Measured in dBm
- **Every network has a limit on cable plant loss**
  - Fiber loss
  - Connector and splice loss
  - Installation stress (to be avoided)
  - Measured in dB



# FTTx

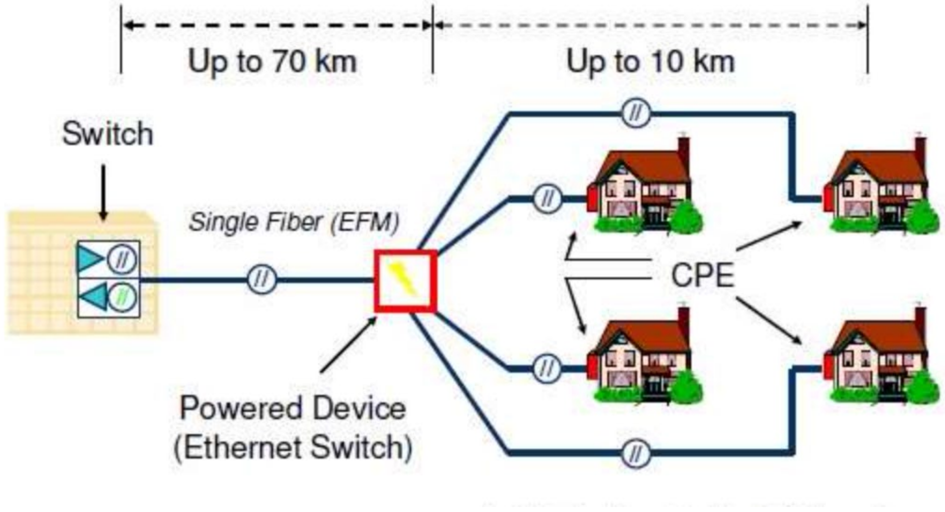
## Architectures and Topologies

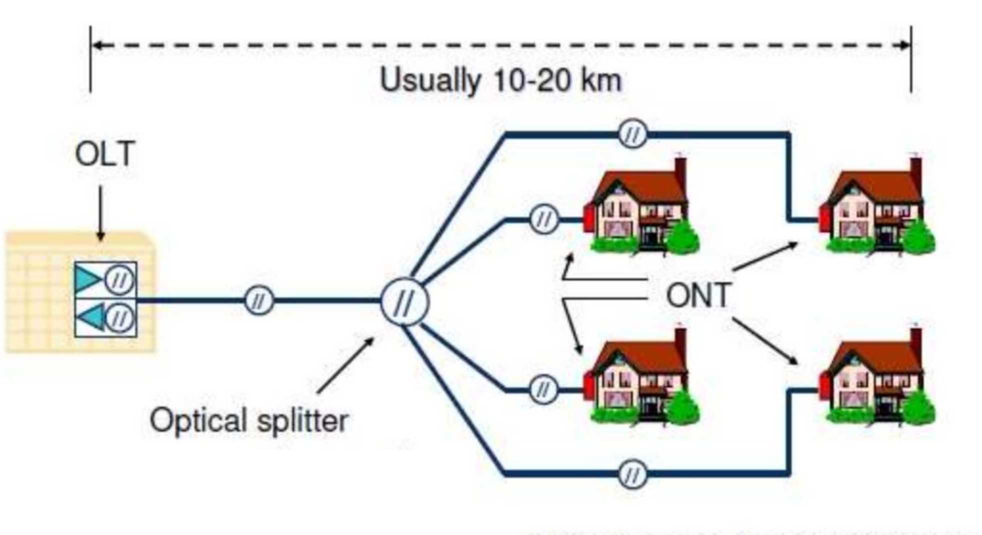



### Active, PON and WDM

- Point to Point – Home Run
- Point to Multi Point
  - Centralized
  
    Distributed
- Bus
  - Distributed Taps

# NETWORK TYPES




**Active Optical Network**
**Active E!**

- Specified by the IEEE 802.3 standard
- Point-To-Point (P2P),
  requires power at the switch
- Dedicated bandwidth to subscriber
  - 1Gbs/10Gbs option to each customer
- Up to 80km footprint*
- Not capable of RF overlay
- One and done future proof network

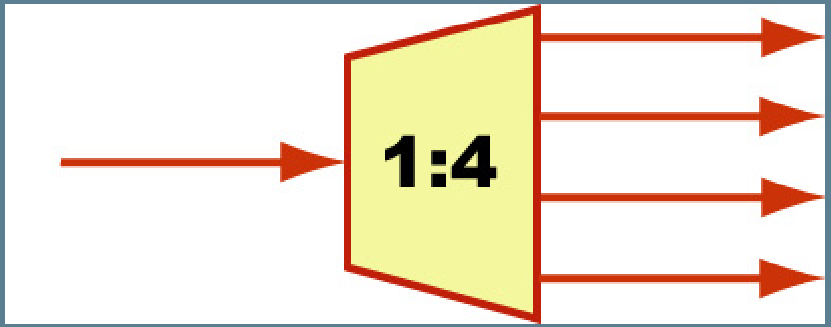
**Passive Optical Network**

- Specified by ITU G.984 standards
- 1 fiber using Passive Optical Components
- Point-To-Multipoint (P2MP)
  - Centralized and Distributed
- Many variations, GPON X-GS PON
- Shared bandwidth up to 32 subscribers*
  - 312Mb/s with 10Gb/s optics
- Up to 20km footprint*
- Can deliver RF overlay

# Understanding PON Splitters

| Splitter | 1:2 | 1:4 | 1:8 | 1:16 | 1:32 |
|---|---|---|---|---|---|
| Ideal loss (dB) | 3 | 6 | 9 | 12 | 15 |
| Excess loss (dB,max) | 1 | 1 | 2 | 3 | 4 |
| Actual loss (dB, max) | 4 | 7 | 11 | 15 | 19 |

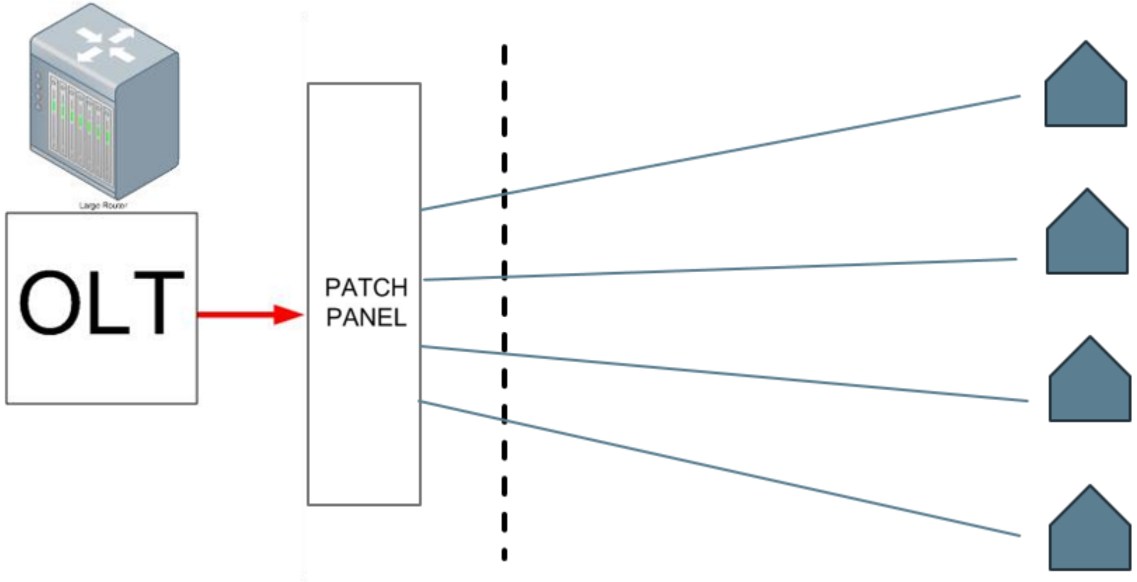
- Passive optical branching device
  - Planar Lightwave Circuit
  - Fused Biconic Tapered
- Bidirectional
- 1:2, 1:4, 1:8, 1:16, 1:32 configurations
- Cascade for desired ratio
- Loss 3 dB per 2x split plus excess loss (inefficiency)



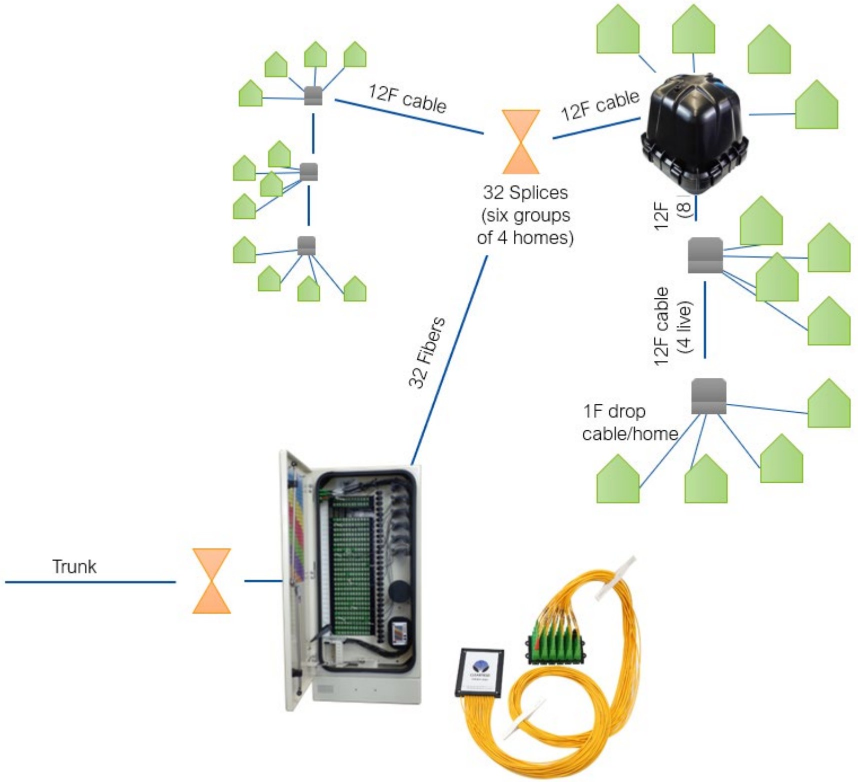
# SPLITTER DEPLOYMENT METHODS

**HOME RUN**
**One-to-One**
**PON**

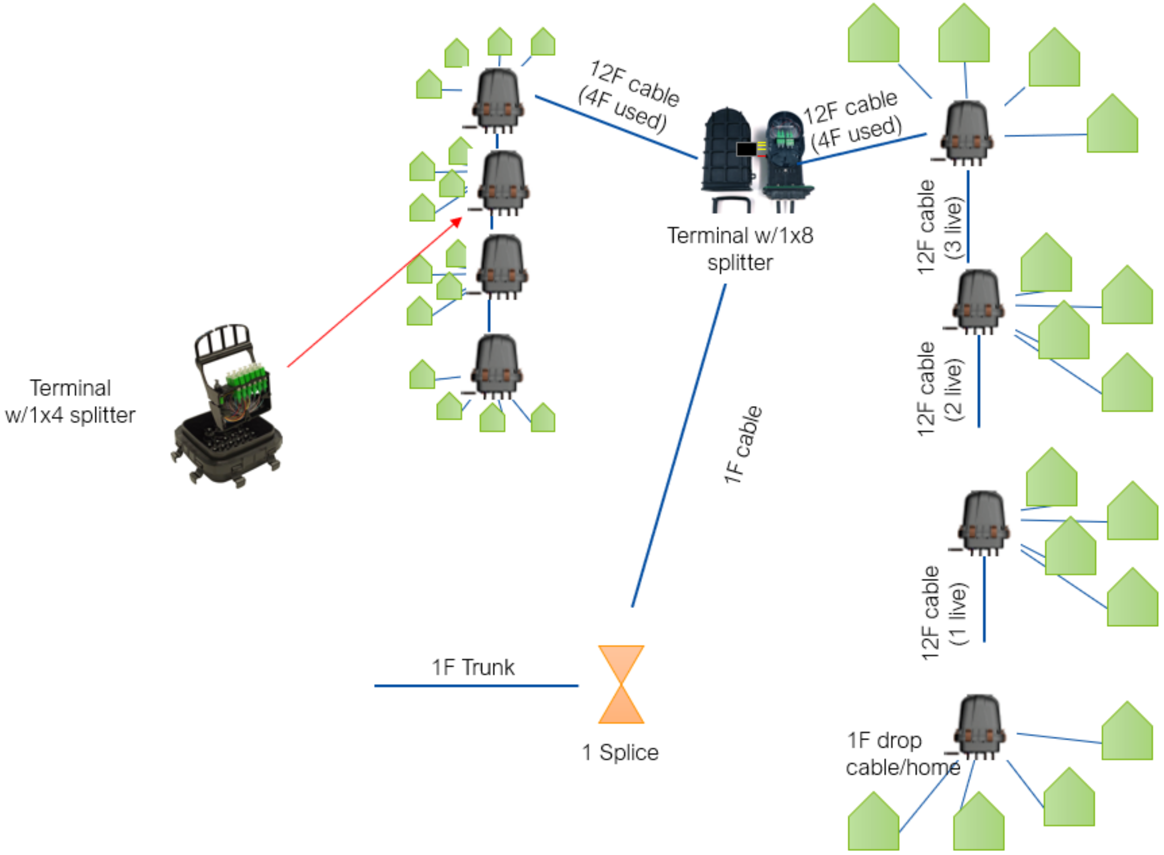
- PON Splitters housed in the Central Office, Headend or Active Cabinets
- Requires fiber rich cables in the OSP.
- Most commonly used in dense urban applications.



# SPLITTER DEPLOYMENT METHODS
## Centralized Field Splitting



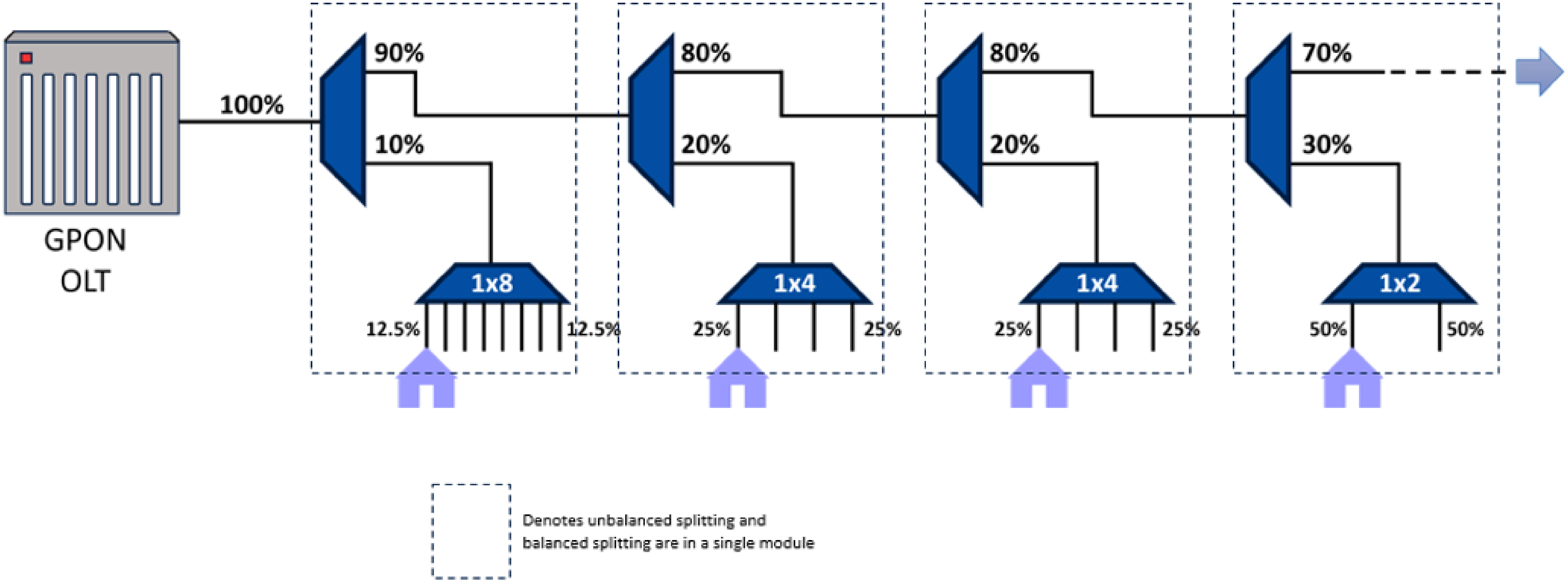

- The Splitter is located in one location in the OSP.
  - Fiber Distribution Hubs.
  - Fiber Access Terminals
    - Plug and Play with MPO Feed
    - Splicing
- One location in an MDU/MTU




# SPLITTER DEPLOYMENT METHODS
## Distributed Split

### Cascaded Splitters

Distributed TAP



# Upcoming Events


# Join our mentoring program


WOMEN IN FIBER

fiberbroadband.org/women-in-fiber-mentoring-program

Thank you for coming

Next Women in Fiber EmpowerHour

and Committee Meeting

March 19, 2025