Cables and Connectors

DOMAIN 1.0

MODULE 2

Cables and Connectors Topics

Ethernet Standards

Copper Cable Types

Fiber Optic Cable Types

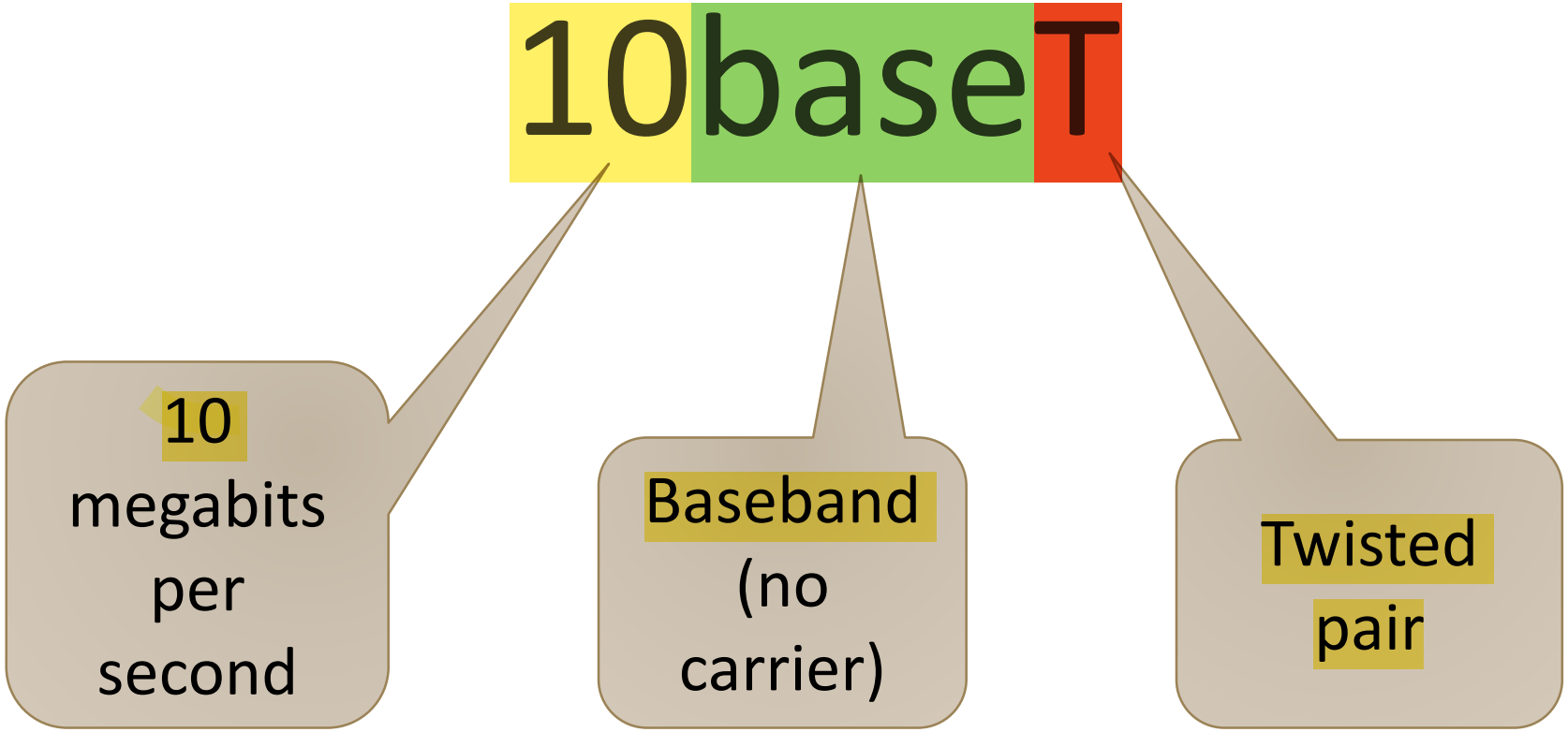
Connector Types

Media Converters and Transceivers

Cable Management

Ethernet Standards

How to Understand Ethernet Cable Designations



Ethernet over Copper Standards

Copper Standard	Name	Max Distance	Description
10Base-T	Standard 10 megabit Ethernet	100m	IEEE 802.3 CAT3/4/5 UTP Uses 2 pairs
100Base-TX	100 megabit Fast Ethernet over twisted pair	100m	IEEE 802.3u CAT5 UTP/STP Uses 2 pairs
1000Base-T	Gigabit Ethernet	100m	802.3z, 802.3ab CAT 5e UTP Uses all 4 pairs
10GBase-T	10 Gigabit Ethernet	100m	802.3an CAT 6 or above
40GBase-T	40 Gigabit Ethernet	30m	802.3bq CAT 7a/8

Ethernet over Fiber Optic Standards

Fiber Standard	Max Distance	Description
100BASE-FX	10 k	Fast Ethernet (100 mb)
100Base-SX	300 m	Lower cost Fast Ethernet Backward compatible with 10base-FL
1000Base-SX	550 m	Gigabit Ethernet
1000Base-LX	2 km	Gigabit Ethernet long-wavelength (LX) transmission
10GBase-SR	400 m	10 Gigabit Ethernet
10GBase-LR	10 k	10 Gigabit Ethernet Long-range (LR) transmission
40GBase-LR	10 k	40 Gigabit Ethernet LR4 multiplexes 4 x 10G links for a total of 40 gb/s

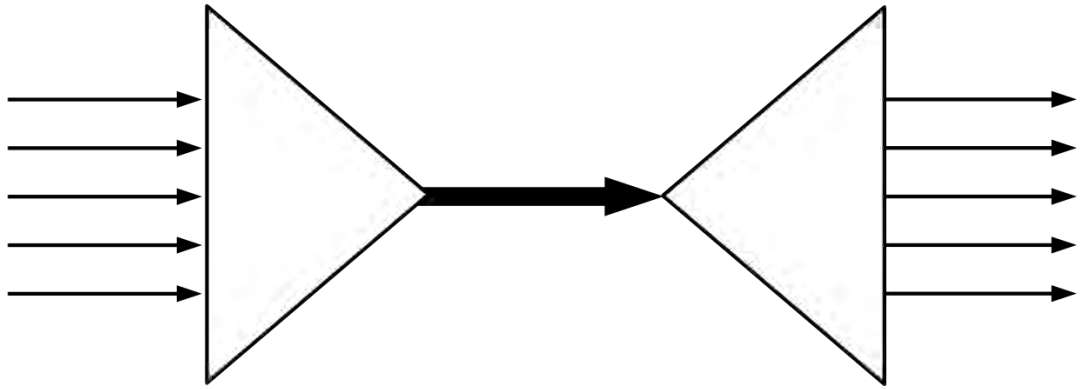
Note: All of the above require 2 strands: 1 Tx and 1 Rx
Cables may require repeaters to achieve max distance

Wavelength Division Multiplexing (WDM)

A technology that multiplexes a number of optical carrier signals onto a single optical fiber

Uses different wavelengths (i.e., colors) of laser light

Enables bidirectional (duplex) communications over a single strand of fiber

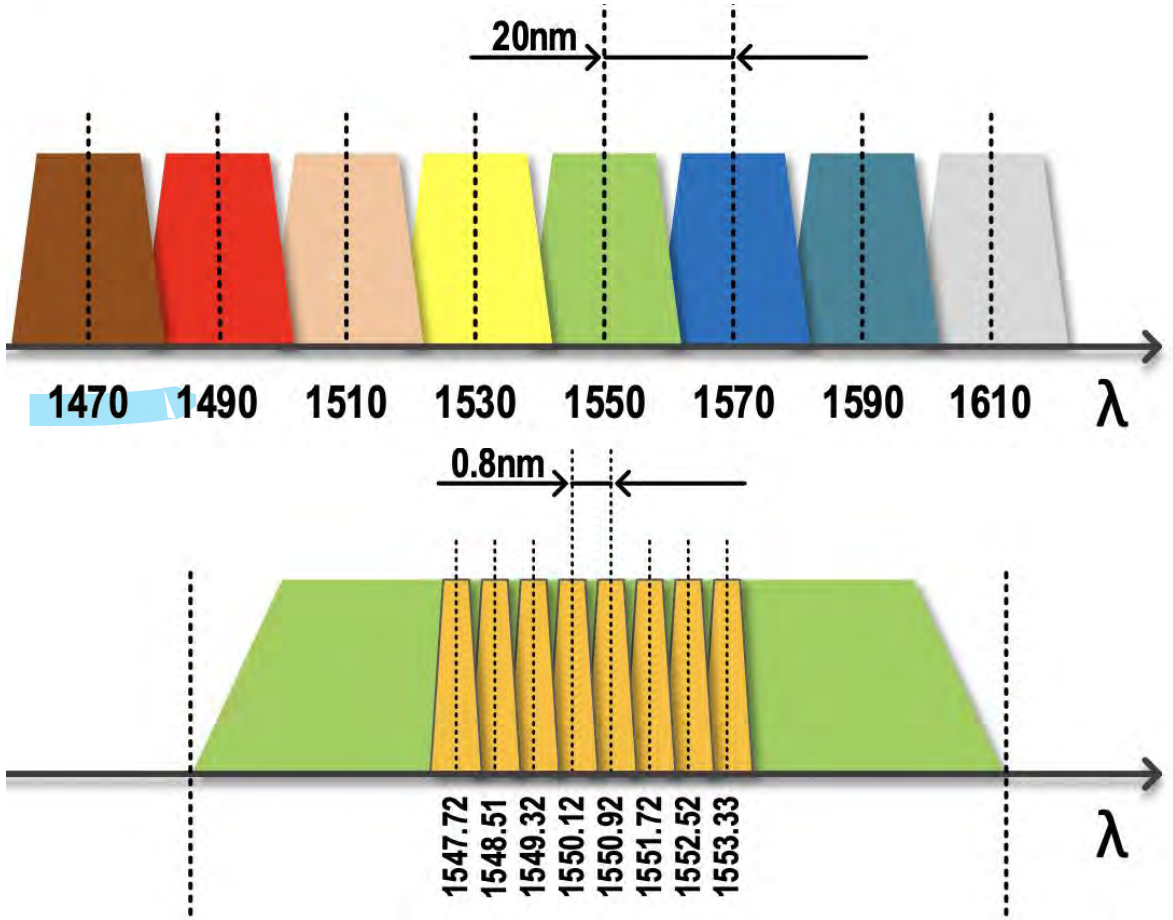


Popular WDM Standards

Fiber Standard	Name	Speed	Max Distance	Comment
CWDM	Coarse wavelength division multiplexing	10 gb/s Ethernet 16 gb/s Fibre Channel	80 km	8 – 18 channels (multiplexed wavelengths) per fiber Wavelengths are 20 nm apart Cannot be amplified
DWDM	Dense wavelength division multiplexing	100 – 400+ gb/s	120+ km	96 channels (0.8 nm apart) per fiber

Note: 20 nanometers = ~15 PHz (15,000 THz)

CWDM vs DWDM Wavelength Spread



Copper Cable Types

Copper as a Conductor

Copper is regarded as the standard in electrical conductors

Used in twisted-pair and coax

These elements have the best conductivity (in order):

- Silver (best)
- Copper (more plentiful/economical than silver)
- Gold (most resistant to corrosion)
- Aluminum (cheapest)

Proper Way to Indicate Network Speed

Network speed

Measured in bits per second

- With a small “b”
- Examples:
  - 56 kb/s – 56 kilobits per second
  - 128 Kbps – 128 kilobits per second
  - 11 Mbs – 11 megabits per second
  - 100 Mb/s – 100 megabits per second
  - 10 Gb/s – 10 gigabits per second

Proper Way to Indicate Storage Size

Network speed

Measured in bits per second

- With a small “b”
- Examples:
  - 56 kb/s – 56 kilobits per second
  - 128 Kbps – 128 kilobits per second
  - 11 Mbs – 11 megabits per second
  - 100 Mb/s – 100 megabits per second
  - 10 Gb/s – 10 gigabits per second

Storage (file and drive size)

Measured in bytes

- With a capital “B”
- Examples:
  - 64 KB – sixty four kilobytes
  - 45 MB – forty five megabytes
  - 1 GB – one gigabyte
  - 2 TB – two terabytes

Unshielded Twisted Pair (UTP)

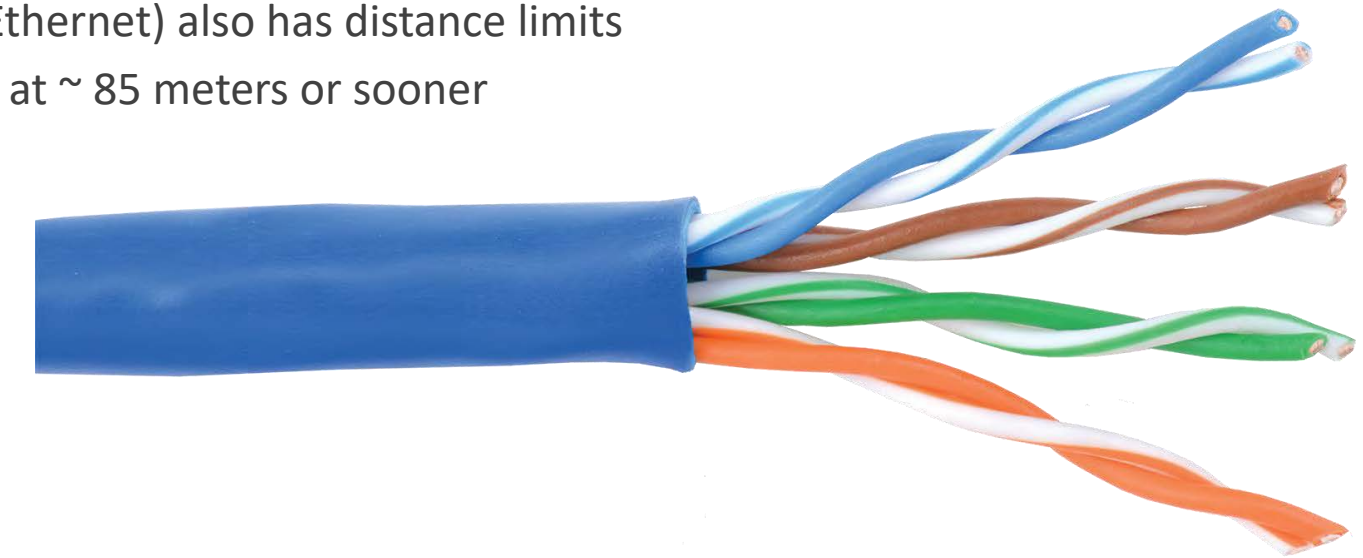
Most popular network cable used around the world

Inexpensive and easy to install

Has an IEEE recommended max distance of 100 meters

- Higher speeds may have shorter distance limits
- Cable that carries PoE (power over Ethernet) also has distance limits
- Anything longer should be repeated at ~ 85 meters or sooner

Primarily used in Ethernet LANs



Shielded Twisted Pair (STP)

Wraps the wire pairs in a conducting shield to reduce electromagnetic interference

Good for areas of higher RFI/EMI

- Not completely impervious

Thicker and more expensive than UTP

Twisted Pair Cable Categories

Category	Data Rate	Application
CAT 1	Up to 1 Mb/s	Old telephone system
CAT 2	4 Mb/s	Token Ring
CAT 3	10 Mb/s	Ethernet
CAT 4	16 Mb/s	Token Ring
CAT 5	100 Mb/s	Fast Ethernet
CAT 5e	1000 Mb/s	Gigabit Ethernet
CAT 6	Up to 10 Gb/s	Gigabit Ethernet 10 gb @ 55 meters
CAT 6a	Up to 10 Gb/s	Gigabit Ethernet Especially for IP cameras & WAPS at longer distance
CAT 7	Up to 10 Gb/s	ScTP up to 100 meters
CAT 8	Up to 40 Gb/s	Short distance – 5 – 30 meters

Comparing Popular Cable Categories

CAT 5e **CAT6** **CAT6a** **CAT7** **CAT8**

Coaxial Cable (Coax)

The standard for original Ethernet networks

Coaxial cables consist of inner copper wire of various thickness
- Covered by insulation and shielding

The stiffness made coaxial cable difficult to install and maintain

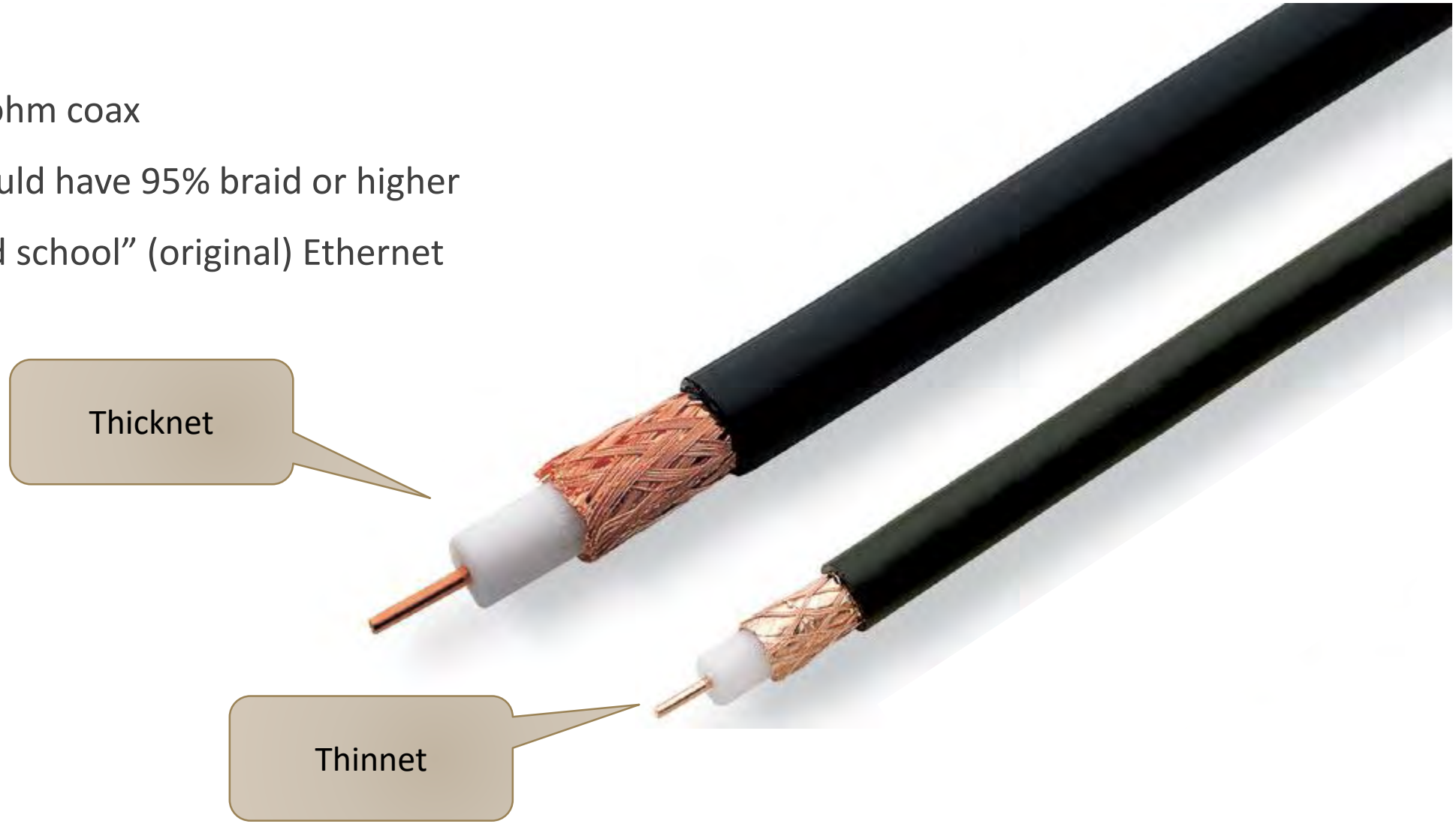
Different impedances make certain cable types incompatible

Thicknet and Thinnet Coax

50 ohm coax

Should have 95% braid or higher

“Old school” (original) Ethernet



Cable Modem Coax

Not compatible with Thicknet/Thinnet

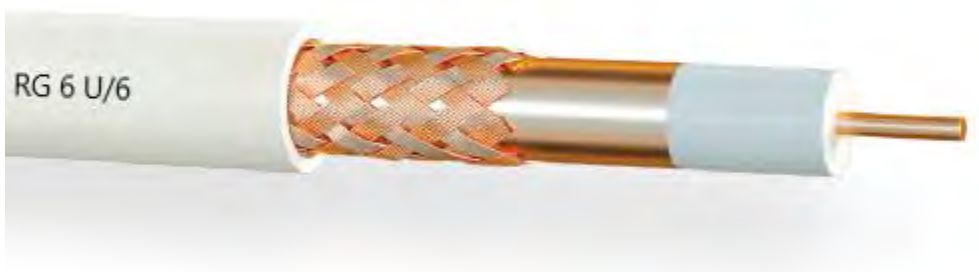
- 75 ohm
- F connectors

RG-6

- Heavier gauge
- Dual shield
- Internet, Cable TV, Satellite

RG-59

- Thinner, less shielding
  - Low bandwidth / low frequency
  - CCTV
  - Short patch cables



Lockheed Martin Radar (LMR) Coax

New generation coax

Greater flexibility, ease of installation and lower cost

Double shielded

Very low signal loss

Used as transmission lines for:

- Antennas on missiles
- Airplanes
- Ships
- Satellites
- Communications

Twinaxial (Twinax)

Low cost alternative to fiber optic

High speed - 1gb/s, 10gb/s

Short distance – 5 meters max

SFP+ connectors

Twin conductors work together

- Both transmit half duplex
- Rising edge of bit – A has a higher voltage
- Falling edge of same bit – B has a higher voltage

Fiber Optic Cable Types

Fiber Optic Cable

Conductor is a strand of glass or plastic

Carries pulses of light instead of electrical signals

Light is fast and is not subject to electrical interference

Common in LAN backbones and trunk links between switches

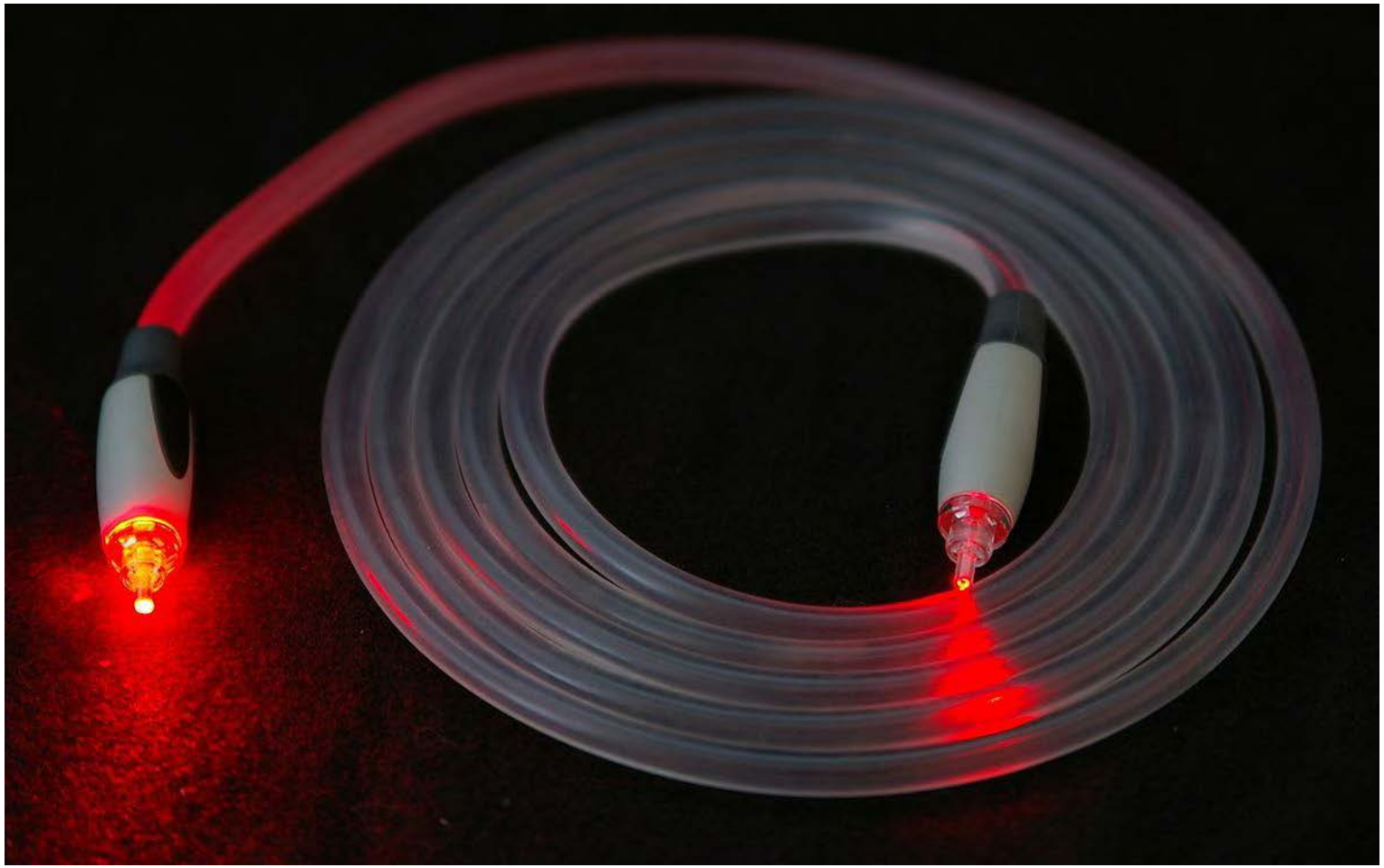
Can run fiber-optic cable over very long distances without having to boost or clean the signal

More costly than copper

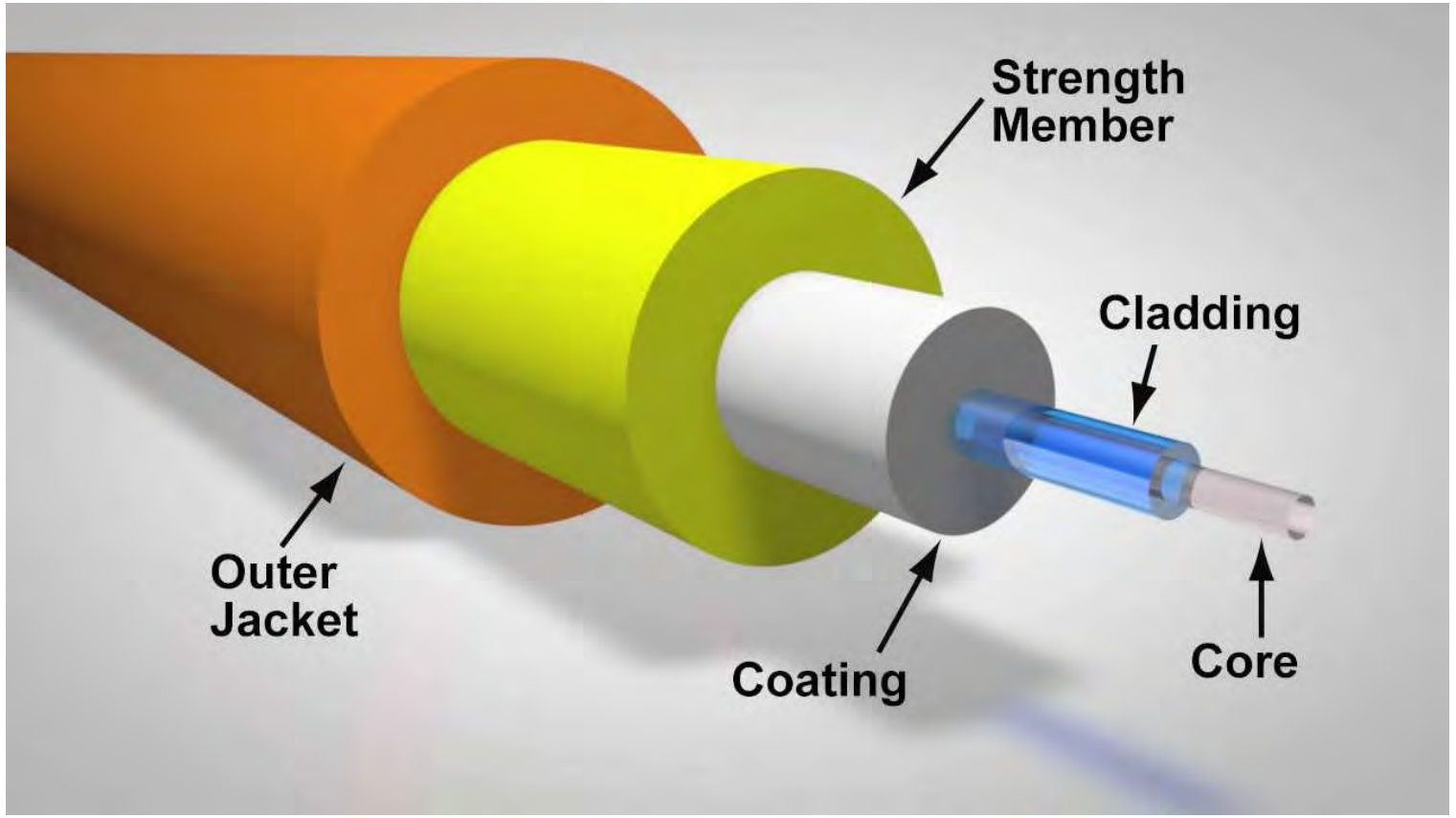
You need two cables two beams of light for two-way transmission

- One Tx
- One Rx

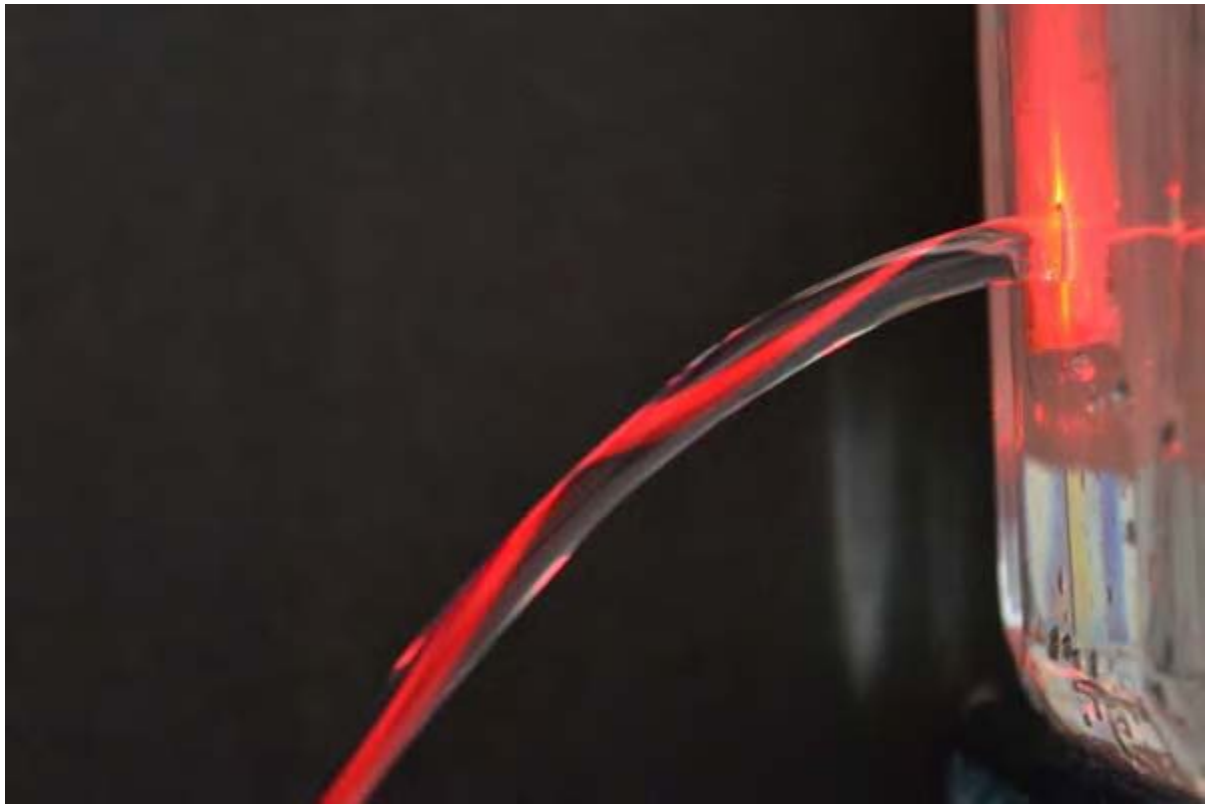
Fiber Optic Light Transmission Example



Fiber Optic Cable Construction



Example of Light Reflecting Inside the Walls of a Conductor



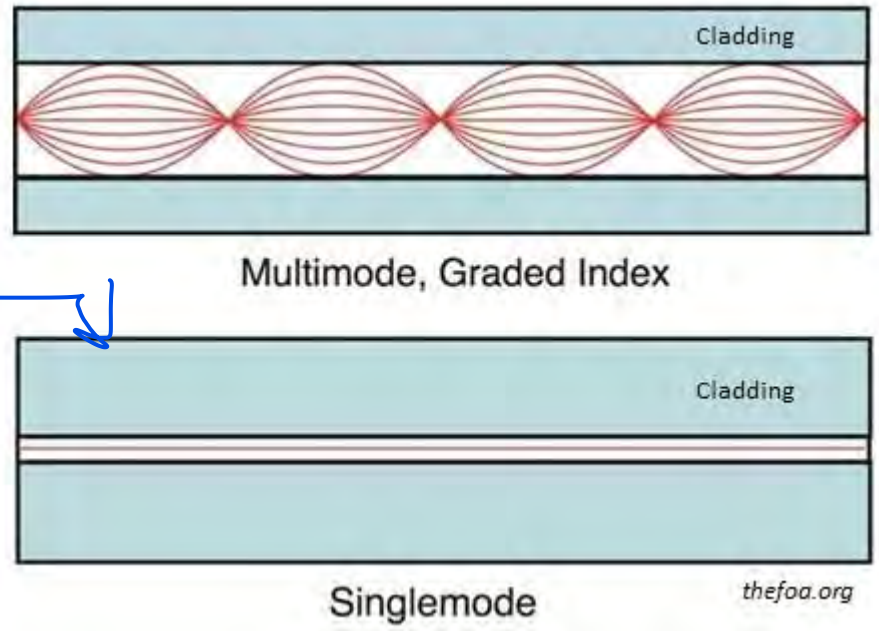
How Light Travels Down a Fiber Optic Cable

Multimode:

- Light travels through a large core in many rays called modes (multiple modes)
- Due to refraction, the rays are reflected from the cladding surface back into the core as they move through the fiber
- More reflection = faster signal degradation = shorter practical distances

Single Mode:

- Light travels through a much smaller core
- This forces the light to travel in one ray or mode (a single mode)
- Less reflection = slower signal degradation = longer distances



Multimode Fiber Optic Cable

50 micron core / 125 micron cladding

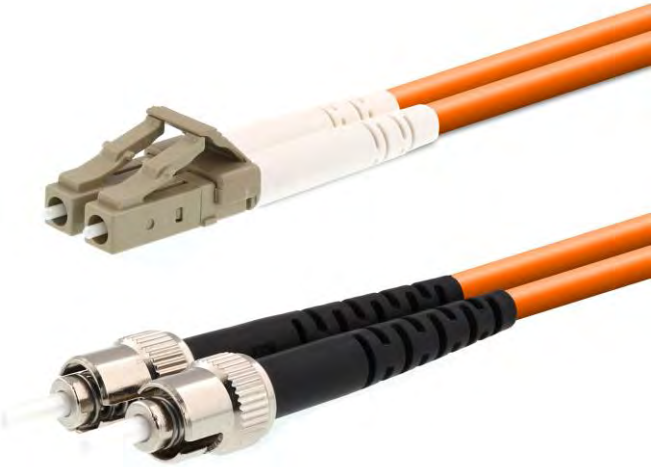
- Wider diameter allows multiple light beams to travel on the cable
- Easier to terminate
- More possible signal distortion at the end

2 km max distance

- **2 km** (100BASE-FX), 1 Gbit/s up to **1000 m**, and 10 Gbit/s up to **550**

850 nm and 1300 nm wavelength

Used in LANs



Multimode OM Cable Designations

Type	Core/Cladding (µm)	Fast Ethernet 100 mb	Gigabit GbE	10 Gigabit 10GbE	40 Gigabit 40GbE	100 Gigabit 100GbE	40G SWDM4	100G SWDM4
OM1	62.5/125	2km	275m	33m	-	-	-	-
OM2	50/125	2km	550m	82m	-	-	-	-
OM3	50/125	2km	800m	300m	100m	100m	240m	75m
OM4	50/125	2km	1100m	400m	150m	150m	350m	100m
OM5	50/125	2km	1100m	400m	150m	150m	440m	150m

Colors indicate cable jacket color

Note: Cable colors are different for military applications

Single Mode Fiber Optic Cable

they are always yellow single mode faiber

Very narrow core

Single beam of light travels through a single path

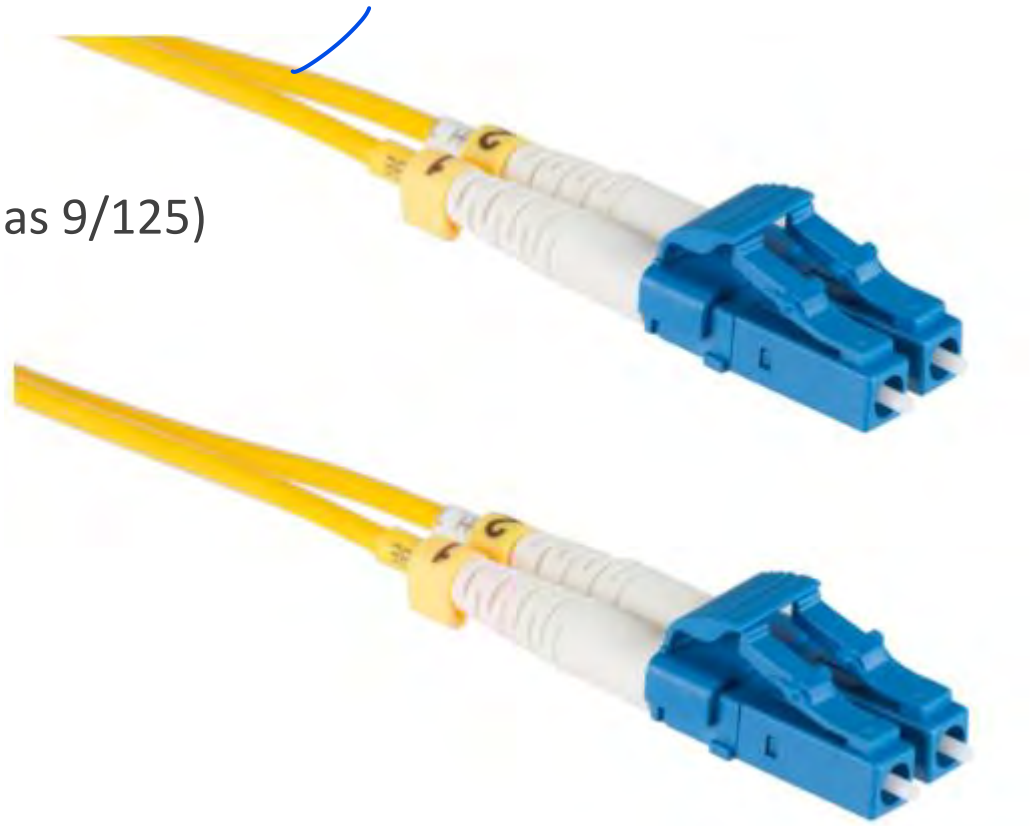
8 – 10 micron core / 125 micron cladding (designated as 9/125)

9/125

Laser light source

Uses:

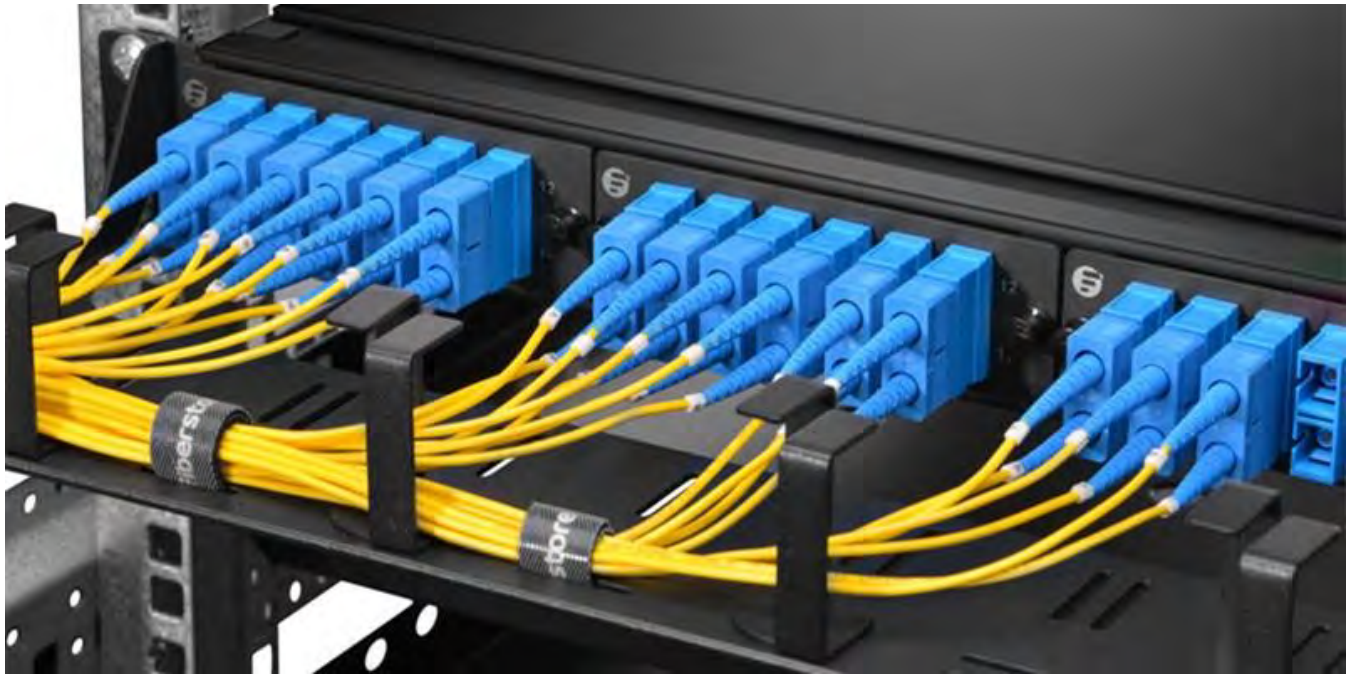
- LAN backbone
- Cable TV
- Telephone company



Single Mode Fiber Optic Cable Types

OS1 cable
- Indoor
- 10 km max distance
- 1.0 db/km attenuation
- Low price

OS2 cable
- Outdoor
- 200 km max distance
- 0.4 db/km attenuation
- High price



Basic specs are the same

Difference is cable quality

SMF patch cables are always yellow in color

Single Mode Fiber Characteristics

TYPE	APPLICATION	DISTANCE	WAVELENGTH
Gigabit	1000BASE-LX	5 km	1310 nm
10 Gigabit	10GBASE-LX4	10 km	1310 nm
10 Gigabit	10GBASE-E	40 km	1550 nm
40 Gigabit	40GBASE-LR4	10 km	1310 nm
40 Gigabit	40GBASE-FR	2 km	1310 nm
100 Gigabit	100GBASE-LR4	10 km	1310 nm

they use ethier of tghese fo4r the single mode fiber

Single Mode Fiber Full Duplex

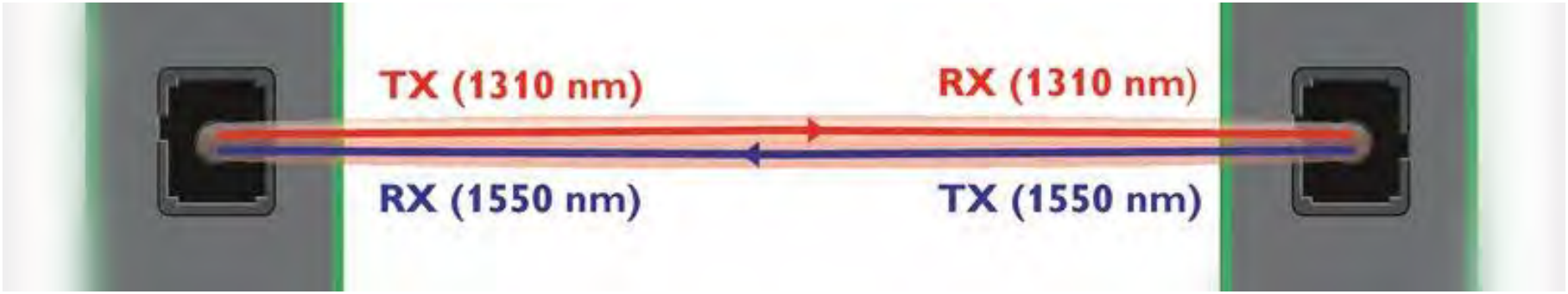
BX (bi-directional) SFP transceiver

Transmits/receives on same SMF cable

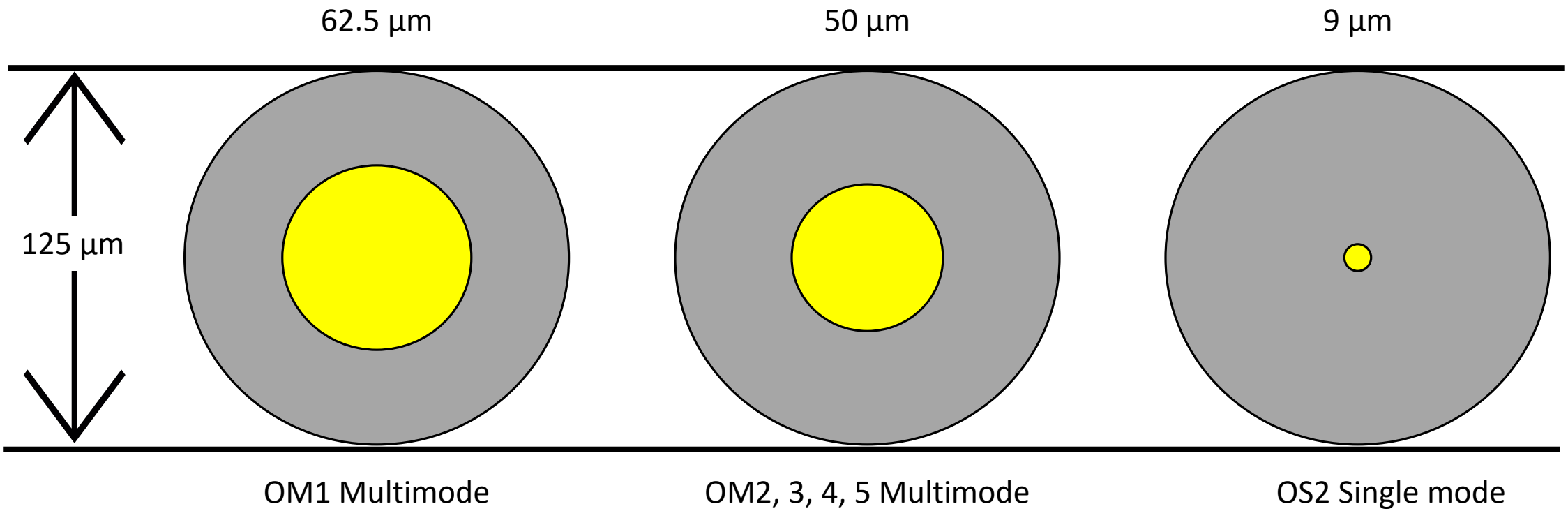
LC connector

Two different frequencies/wavelengths:

- One side transmits at 1310 nm (228.849 THz)
- The other side transmits at 1550 nm (193.1 THz)



Comparing Fiber Optic Cores



Light Emitting Diode (LED)

MMF multi mode fiber

850 or 1300 nm infrared

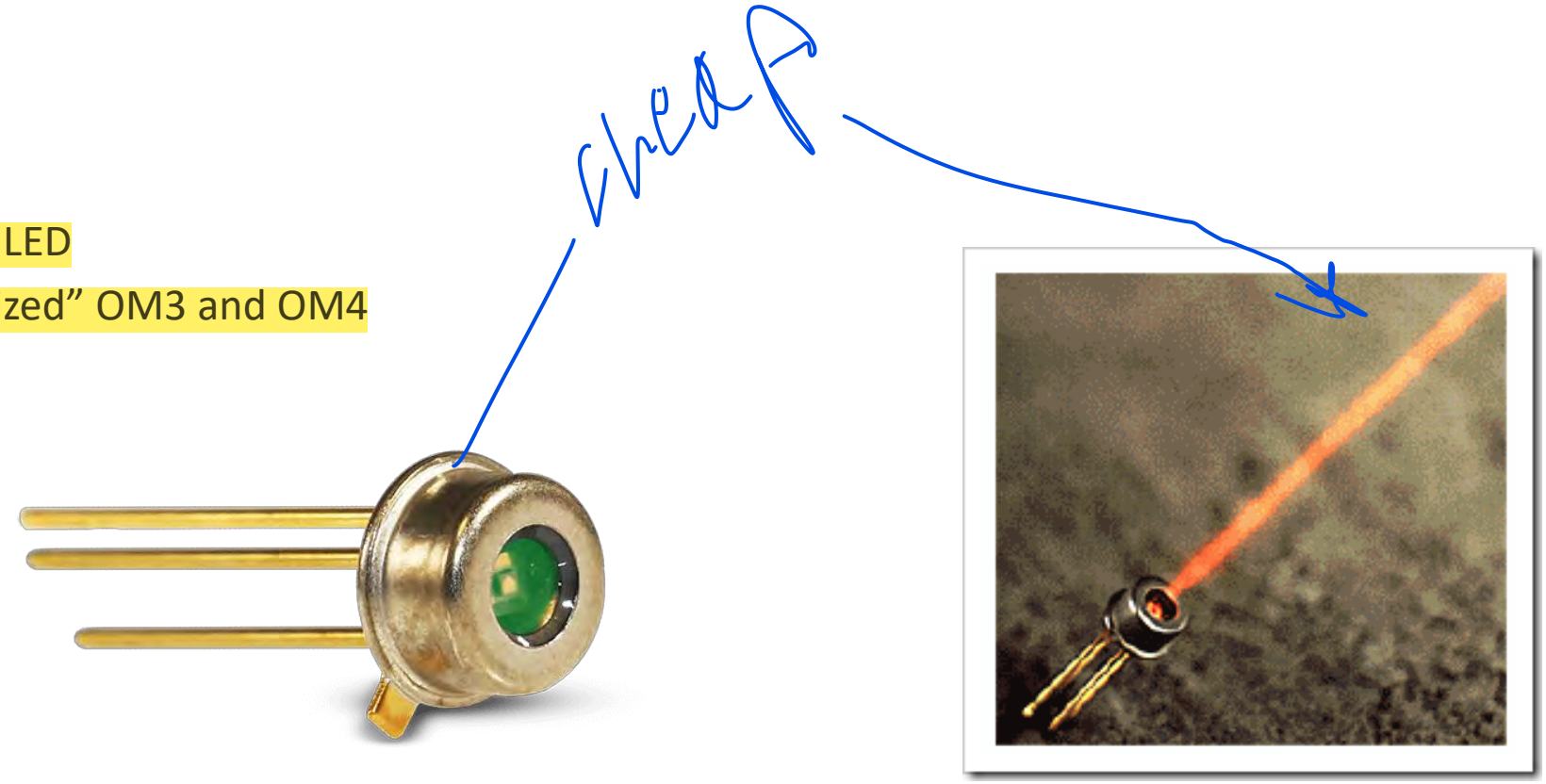
Broader spectrum

Lower speed / shorter distance

Cheapest

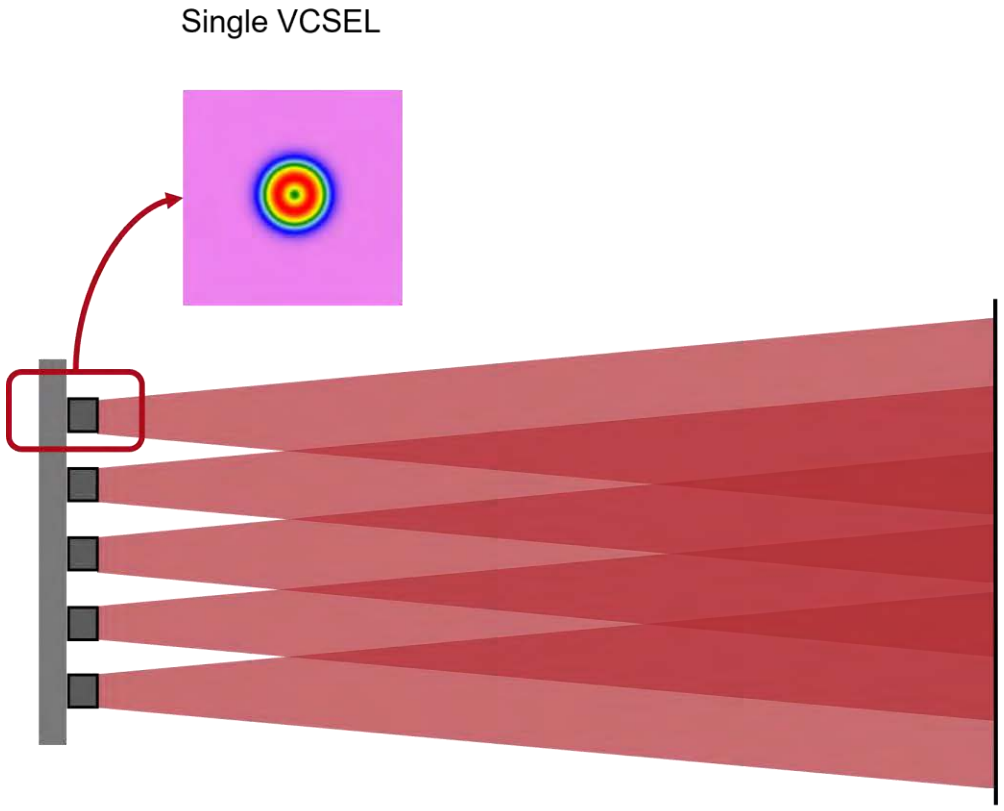
Vertical Cavity Surface Emitting Laser (VCSEL)

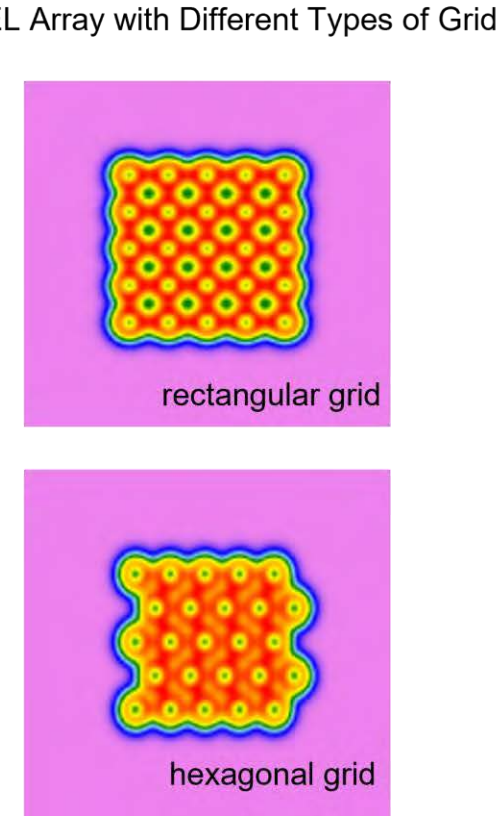
- MMF
- 850 nm laser
- Narrow spectrum
- Better for high speed
- More expensive than LED
- Used on “laser optimized” OM3 and OM4



VCSEL Array

Multiple VCSELs send multiple beams of light down MMF





Laser Diode Single Mode Fiber Optic Light Source

SMF

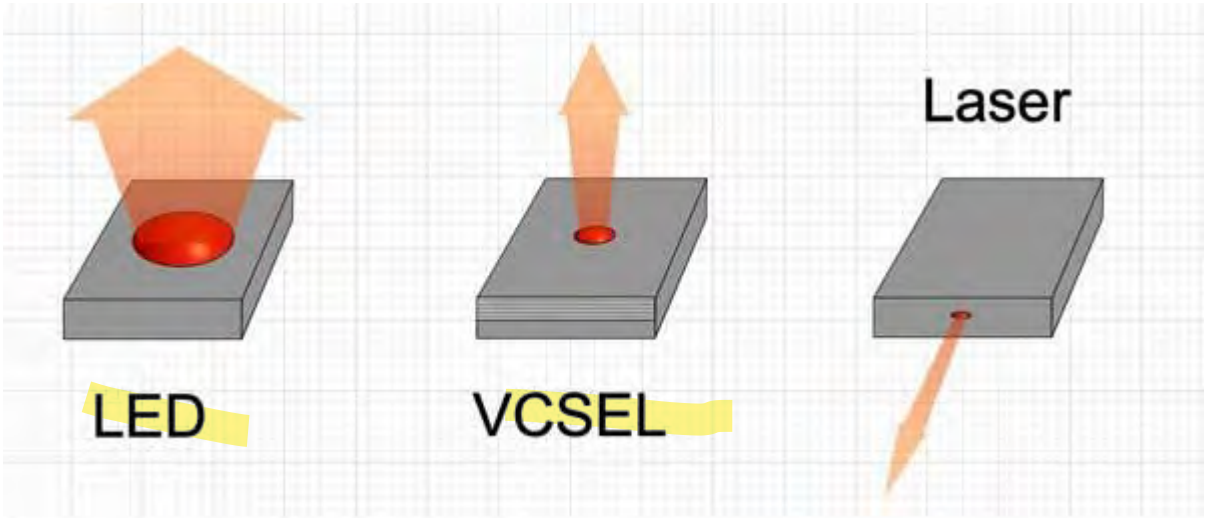
1310 or 1550 nm

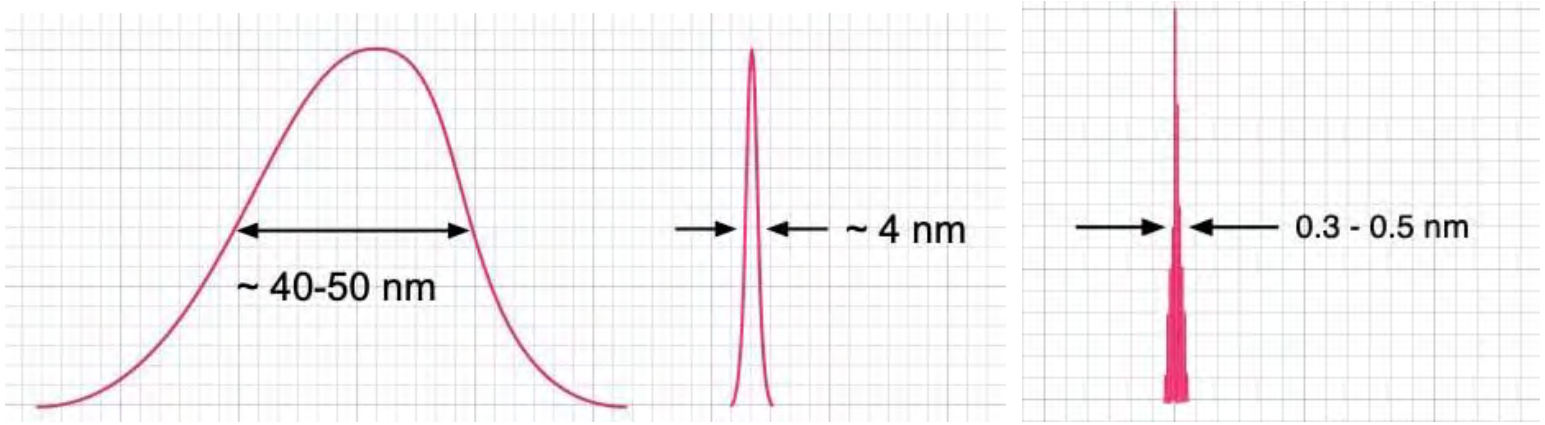
Very narrow spectrum

Best for high speed

Most expensive

Comparing Fiber Optic Light Sources





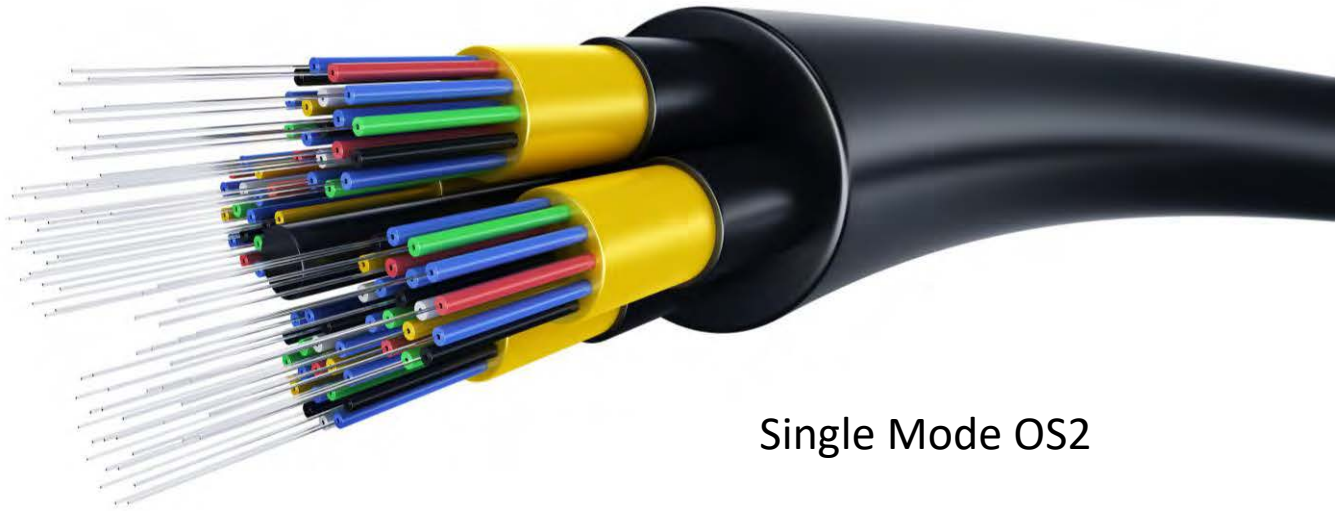
LED VCSEL LASER

Fiber Optic Backbone Cable

Can be SMF or MMF

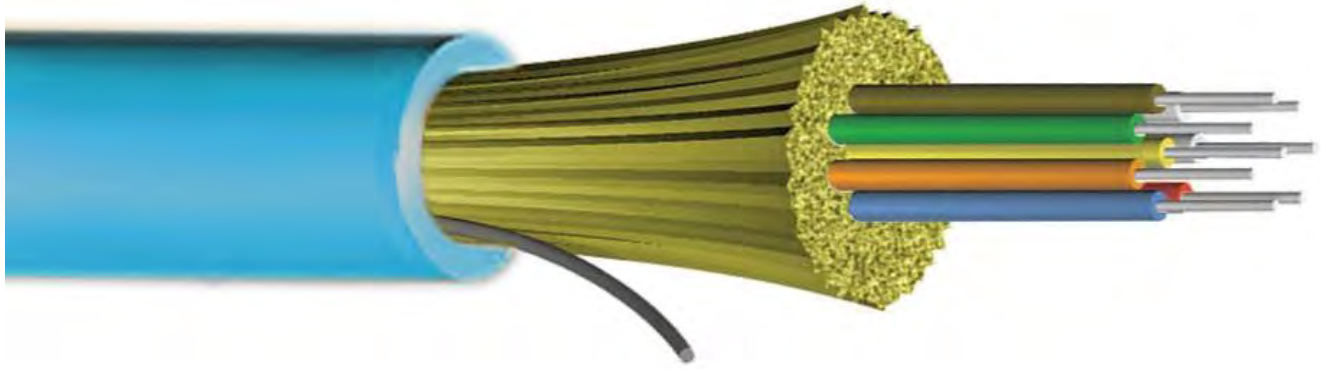
2 - 48 strands

Indoor or outdoor



Single Mode OS2

Multimode OM3



Can You Interchange Single- and Multimode Fiber?

Not a good idea!

Most devices don't support it

Cable designed for specific wavelengths

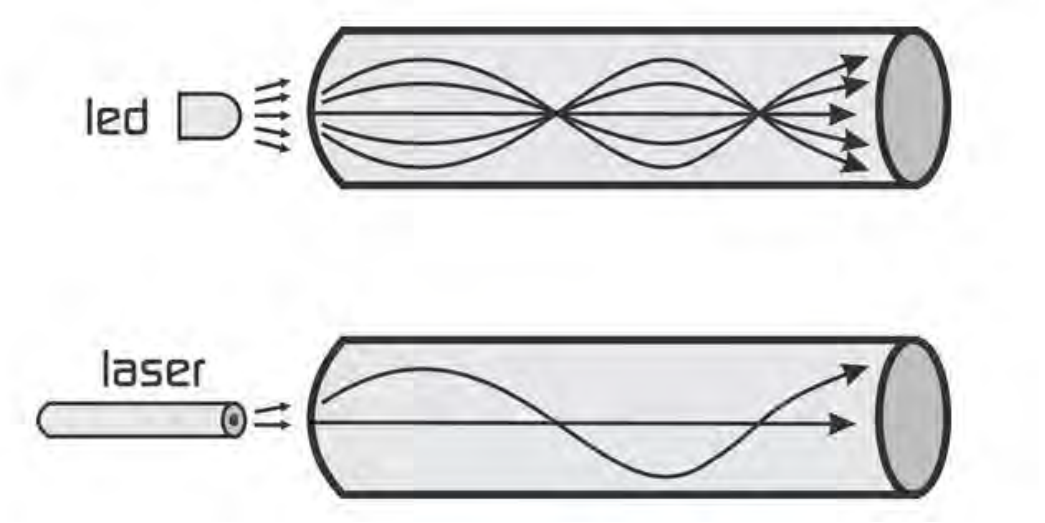
Will degrade signal and reduce distance

SMF signal might overdrive MMF receiver

- Could be too powerful

From end to end, make sure all cable modes, types, and transceivers match!

This includes backbone cable, patch panels, and patch cables!



Wavelength	
MMF	SMF
850 nm	
1300 nm	1310 nm
	1550 nm (1490 – 1625)

Submarine Communication Cables

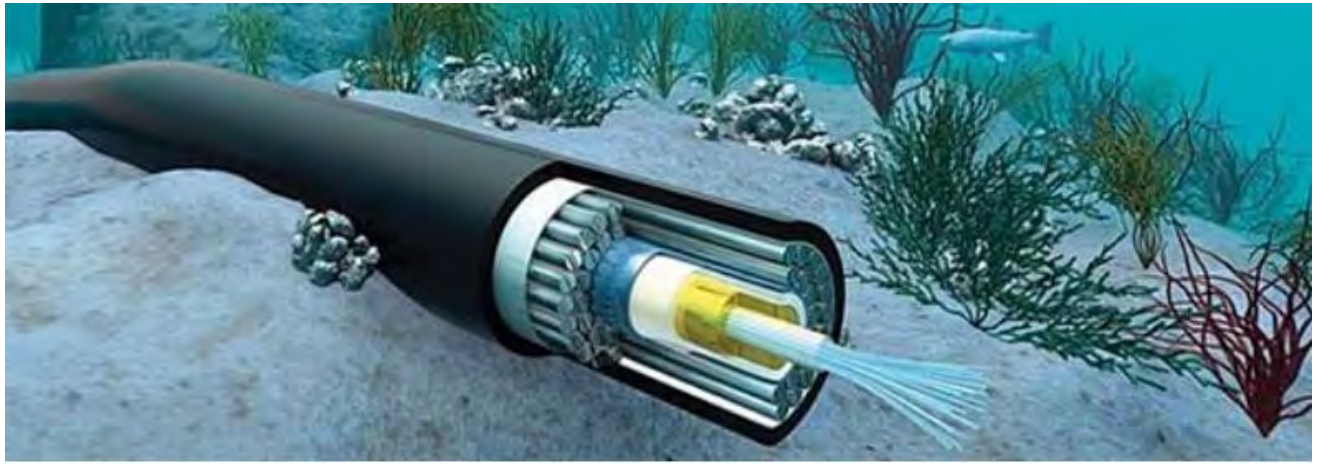
Uses specialized single mode fiber

Inline repeaters boost signal every 100 – 400 km

3000 – 10,000 VDC sent down conductors in the cable

- Close to the core

Kevlar now used to protect cable from shark bites



https://submarine-cable-map-2021.telegeography.com/

Connector Types

Registered Jack 45 (RJ-45)

Found on almost all UTP and STP cables

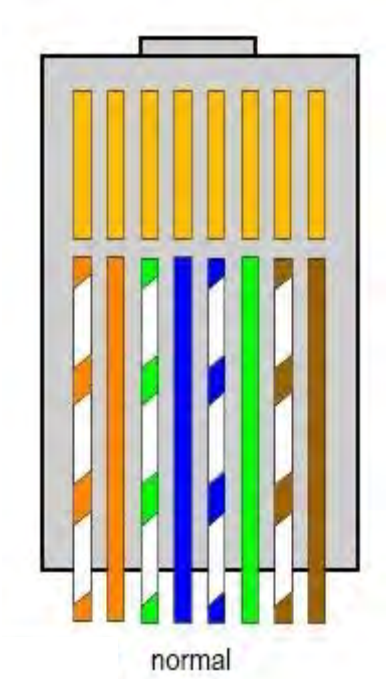
A plastic piece with eight pins on the port

Four pins are used for sending and receiving data

The other four are used for other technologies or to carry power

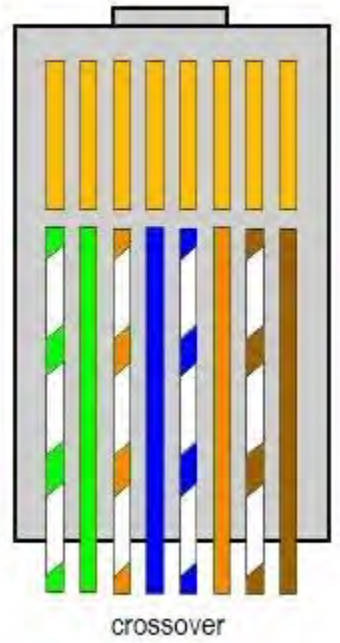
Termination Standards

TIA/EIA-568B

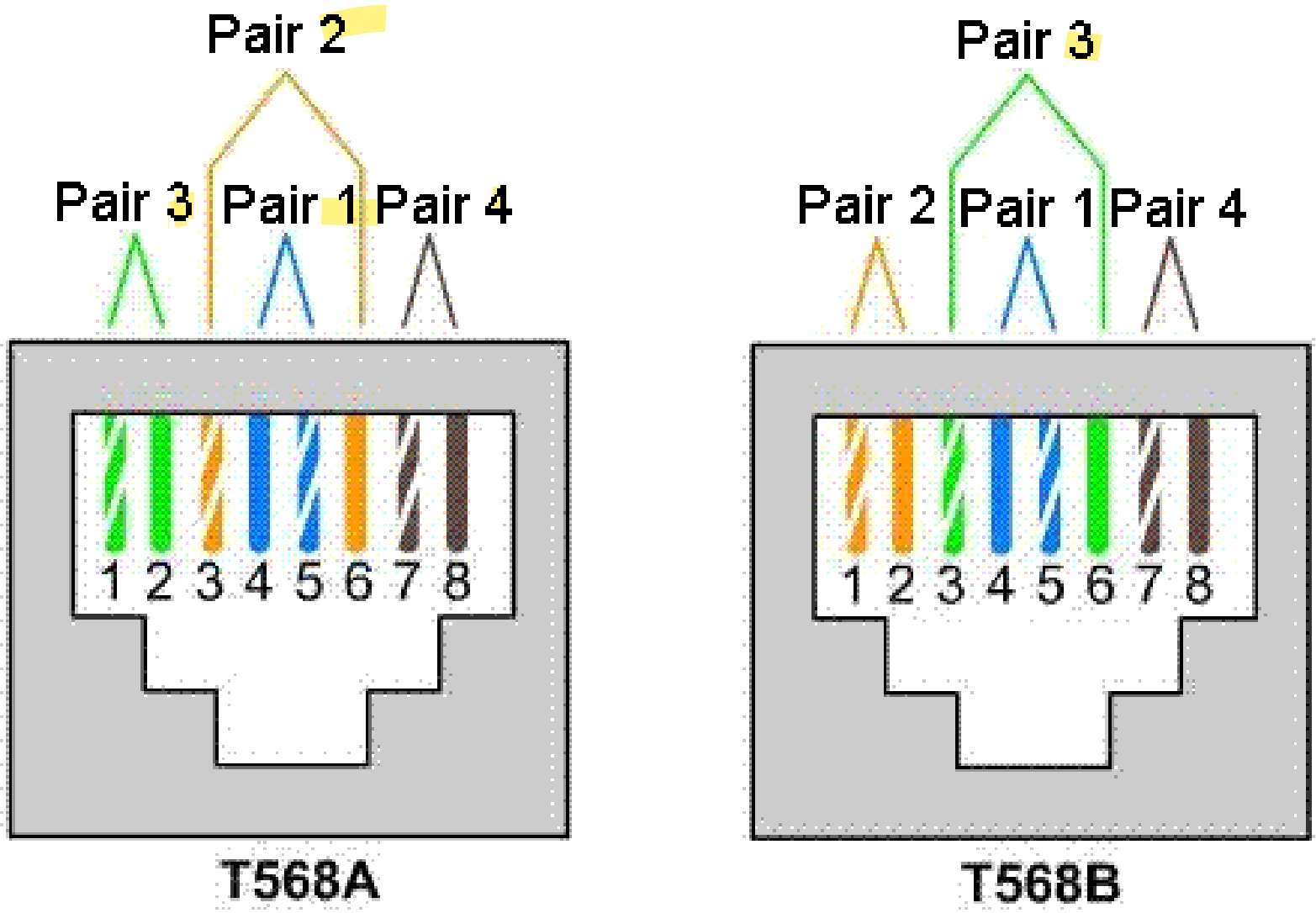


Pin	TIA/EIA-568B	10base	TIA/EIA-568A
1	White orange	TX+	White green
2	Orange	TX-	Green
3	White green	RX+	White orange
4	Blue	NC	Blue
5	White blue	NC	White blue
6	Green	RX-	Orange
7	White brown	NC	White brown
8	Brown	NC	Brown

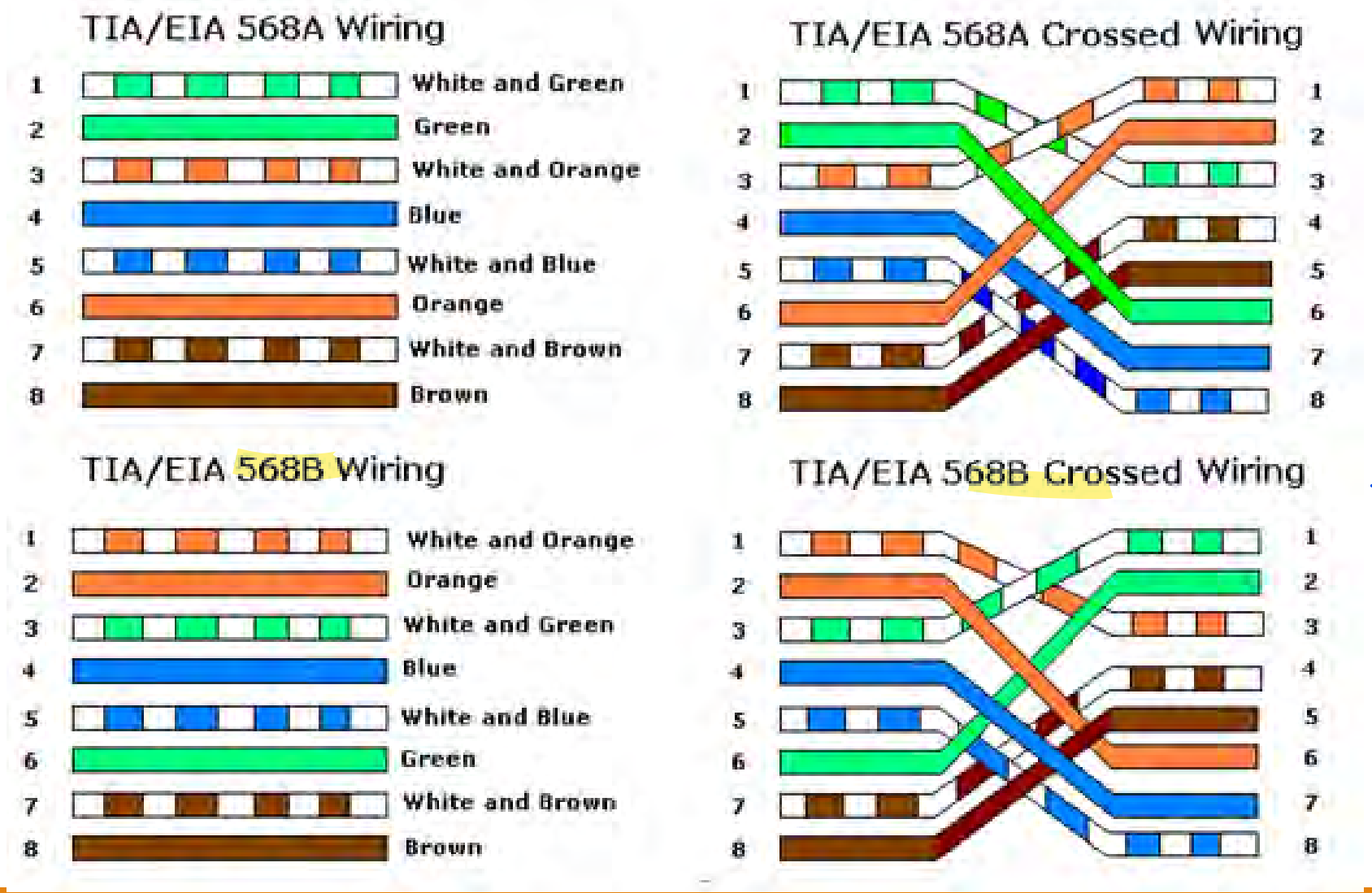
TIA/EIA-568A



Wiring Pairs



Straight-Through and Crossover Cable



B is the most common v ersion that is being useed

RJ-11

RJ-11 is most commonly used connector for telephone lines (landlines)

Has 4 connector positions

One wire is used for transmit, one for receive

F-type

Coaxial RF connector

Used for:

- terrestrial television
- cable television
- satellite television
- cable modems

RG-6/U cable or, in older installations, with RG-59/U cable

Connector pushes on, often with an outer nut that screws in to hold the connector in place

Fiber Optic Connectors

Can be used with either single or multimode cable

LC

Generally used in an organization's network closet or telecom room

Good for both SMF and MMF

Diameter is 1.25 mm

"Lock and click"

ST

Straight tip fiber optic connector

Uses a bayonet type and half twisted lock that holds it in place

Used with single mode cable

The ST connector looks like a small BNC connector

Easier to insert

2.5 mm diameter

“Stick and twist”

SC

One of the most basic types of fiber optic connectors

Uses a push and pull configuration mechanism

Used with multimode cable

“Stick and Click”

MTRJ

Mechanical Transfer Registered Jack

Houses two fibers

SMF or MMF

Mates together with locating pins on the plug

Developed to meet customer demand for smaller, simpler-to-use fiber optic connectors

MPO

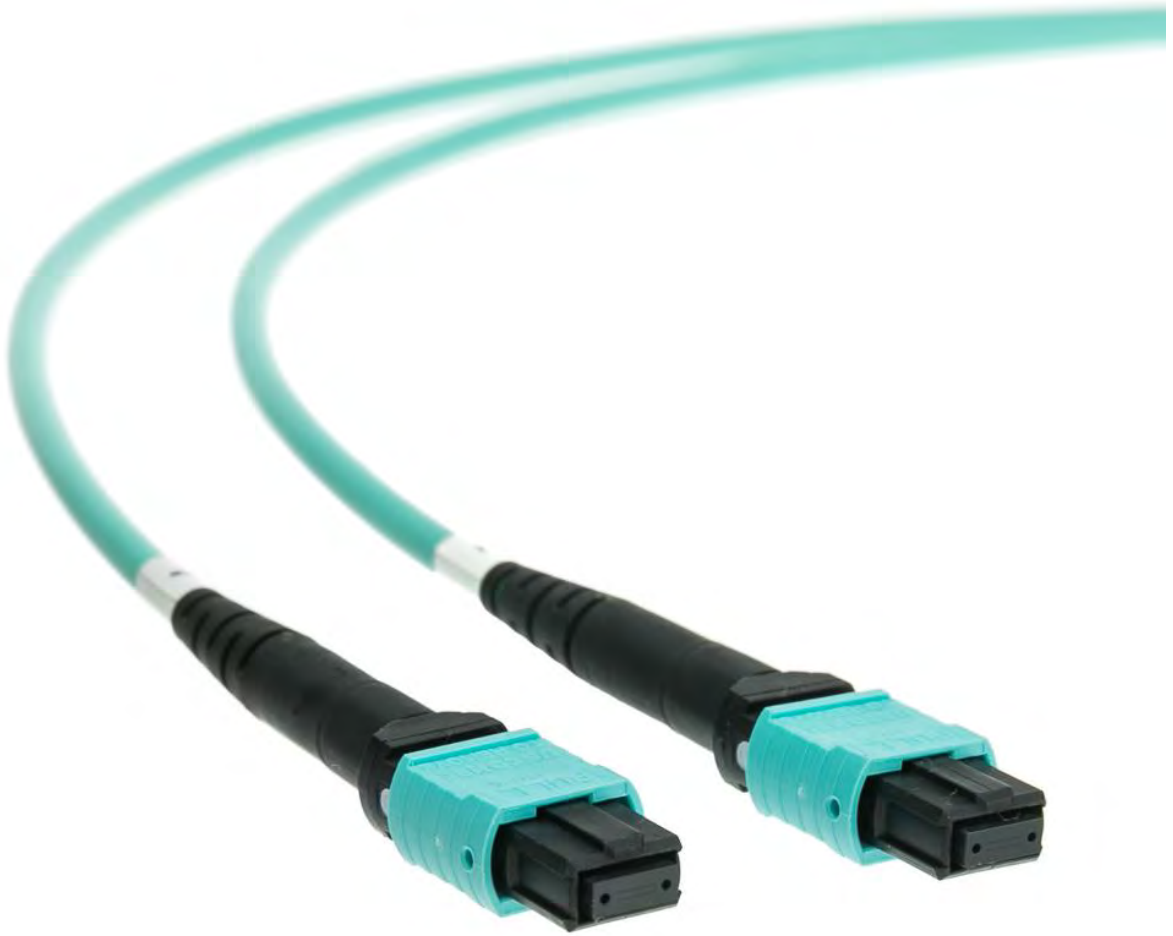
Multi Fiber Push On

SMF or MMF cable

Uses multiple fibers to increase throughput

Currently popular:

- 400G MTP (MPO) OM4 50/125



FP / APC / PC / UPC

Refers to how fiber is attached to the connector

When a fiber optic connector is installed on the fiber end, some loss occurs

- Light is reflected directly back down the fiber to the laser
- Can damage the laser and disrupt the signal

Flat Polish (FP)

Zero dome-shaped geometry

Most common polish type found in OM1 and OM2 MMF

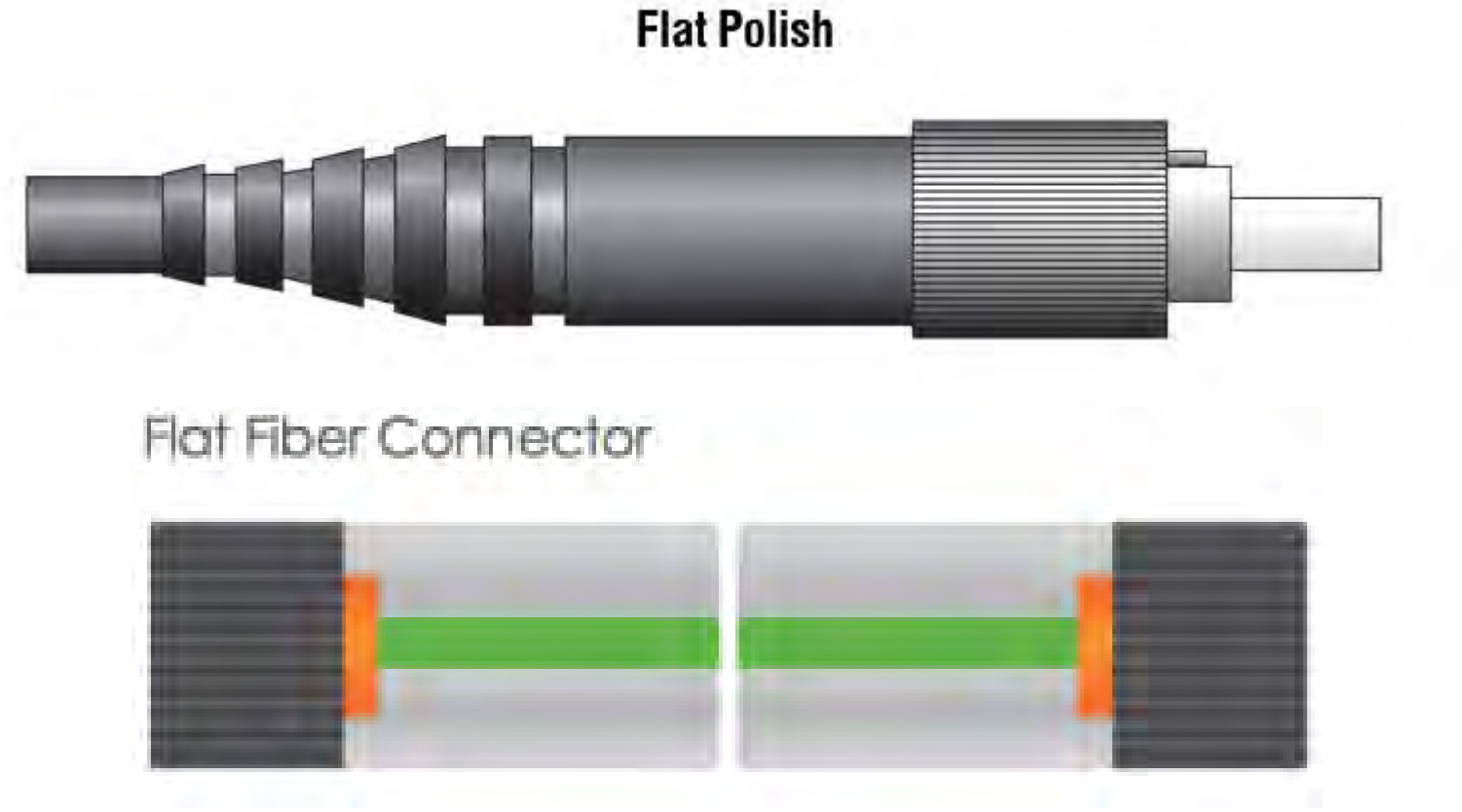
Biggest problem is that it has a small air gap between the two ferrules

This gap occurs naturally when the ends are mated

Gap is caused by numerous slight but significant imperfections on the surface

A flat fiber (FP) connector is not suitable for single-mode fiber cables with a 9µm core size

FP Example



Physical Contact (PC)

Polished with a slight spherical design

Reduces the overall size of the end-face

Helps to decrease the air gap issue faced by Flat Fiber connectors

Results in lower Optical Return Loss (ORL)

Less light being sent back towards the power source

PC Example

Physical Contact Connector

Ultra Physical Contact (UPC)

Polished with no angle, but a slight curve

Connectors undergo extended polishing to render the fiber endface more suitable for optical contact with another fiber than an ordinary PC connector

Any reflected light is reflected straight back towards the light source

Lower insertion loss

Less expensive

Good for less sensitive digital systems

- SMF or MMF
- Ethernet network equipment
- Serial devices
- Media converters
- Fiber switches

UPC Example

Ultra Physical Contact Connector

Angled Physical Contact (APC)

APC (Angled Physical Contact)

- Fiber end is polished at an 8-degree angle
- Any reflected light is reflected at an angle into the cladding versus straight back toward the source
- Lower return loss
- Good for high precision systems
- Connector types can be SC, ST, FC, LC, MU, MT, and MTP

Mostly employed in Radio Frequency (RF) applications, like CATV or Distribution Antenna Systems

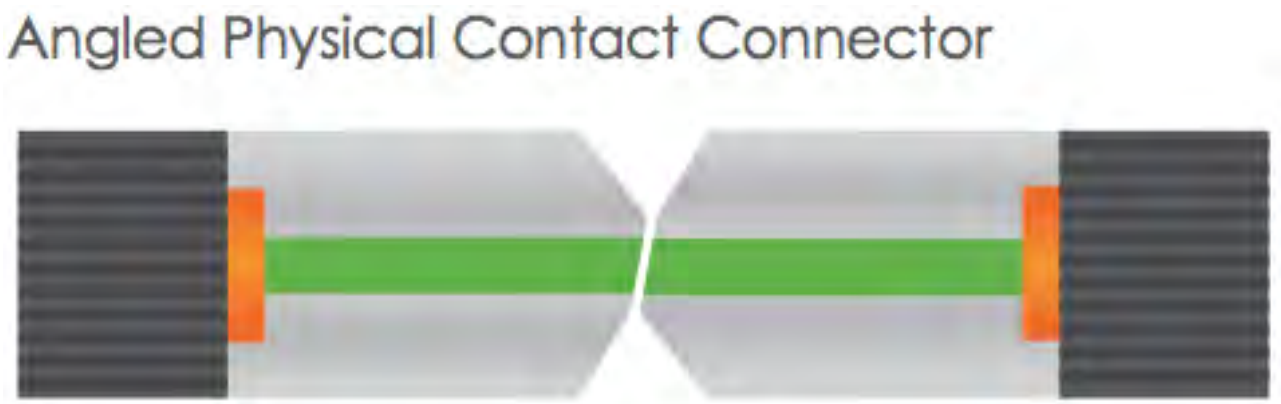
Also used in passive optical LANs

- Single mode fiber up to 20 km
- Campus links access level straight to core

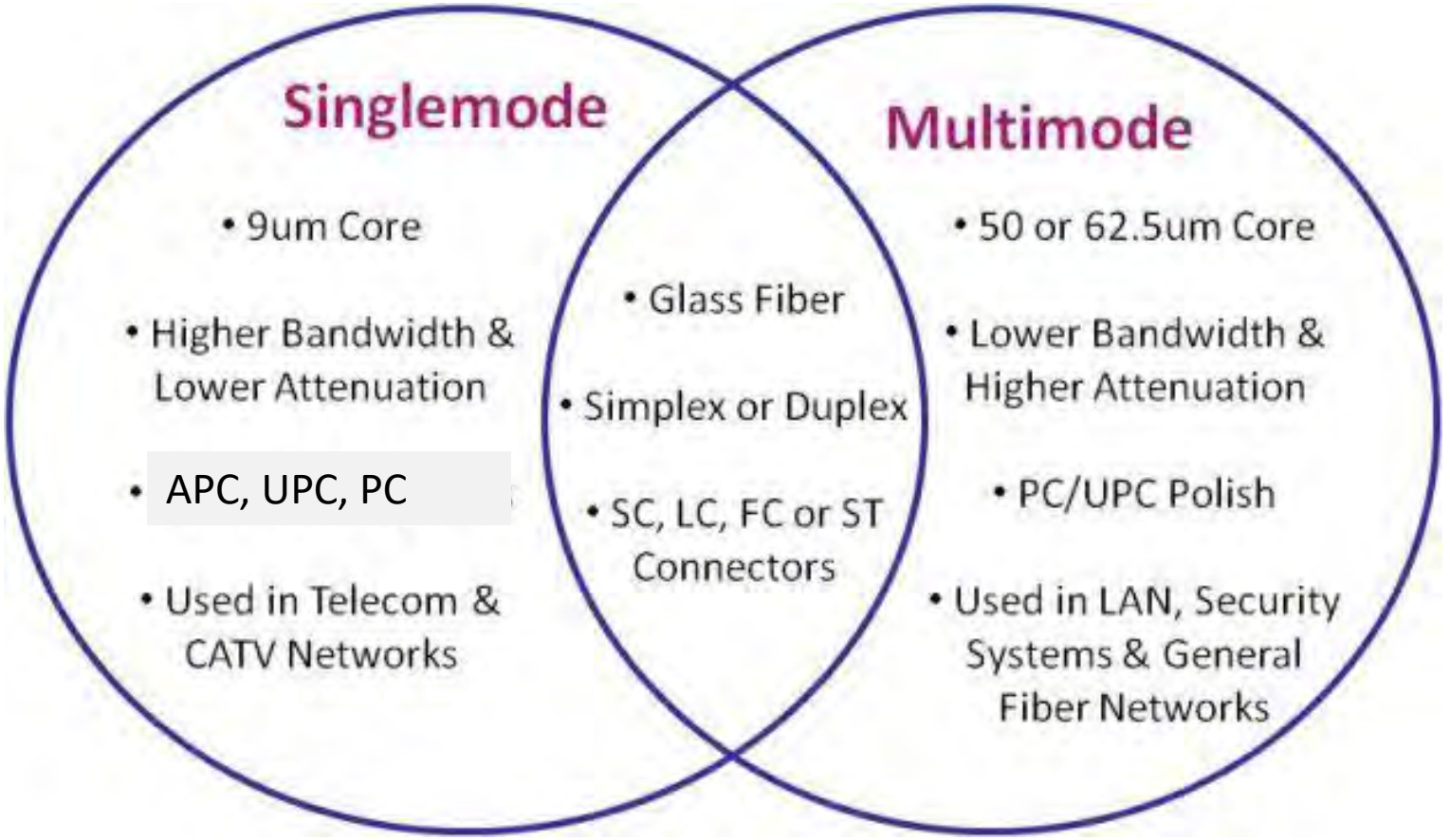
APC conectores are alwyas green in colour

APC Example


Angled Physical Contact (APC)


Angled Physical Contact Connector

Comparing SMF and MMF Applications



Fiber Optic Pigtail

A short SMF or MMF cable with a connector at one end

The other end is raw

You splice the incoming backbone strand to the pigtail using fusion (electric arc)

- or mechanical splicing with epoxy

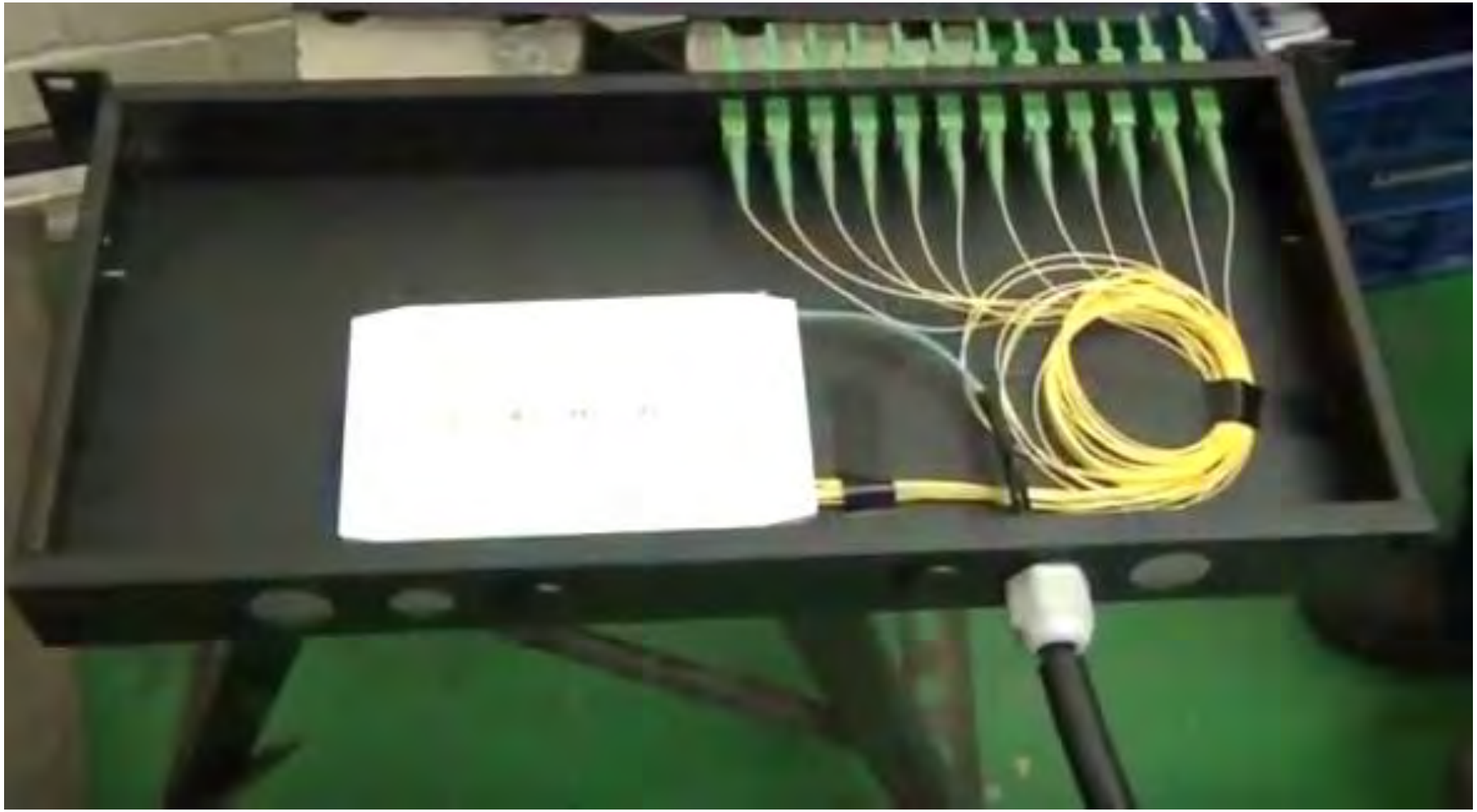
The connector is connected to a pass-through connector on a patch panel

Typically pigtails come in a bundle of multiple strands

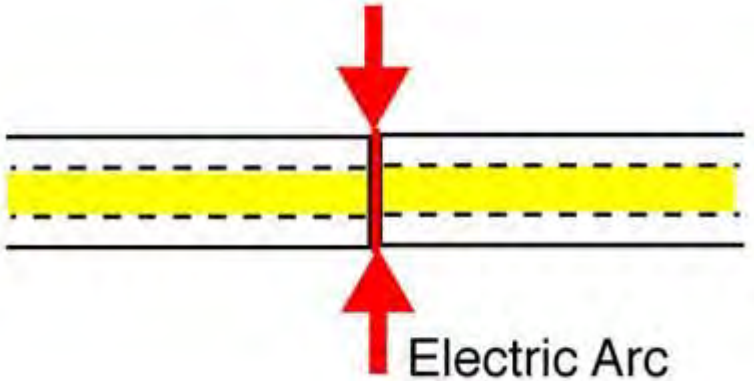
Fiber Optic Pigtail Examples

Fiber Optic Pigtail Examples

Terminating Fiber Optic Cable Example



Fusion Splicing Example



Media Converters and Transceivers

Media Converter

Stand-alone device that connects one cable type to another

Fiber Optic → Twisted pair most common implementation

Transceivers

Typically used to plug different types of cable into empty switch ports

- Fiber optic – SMF and MMF
- Twinax
- Twisted pair

Patch cable then plugs into the transceiver

This allows some flexibility in choosing the type of cable/connector you want

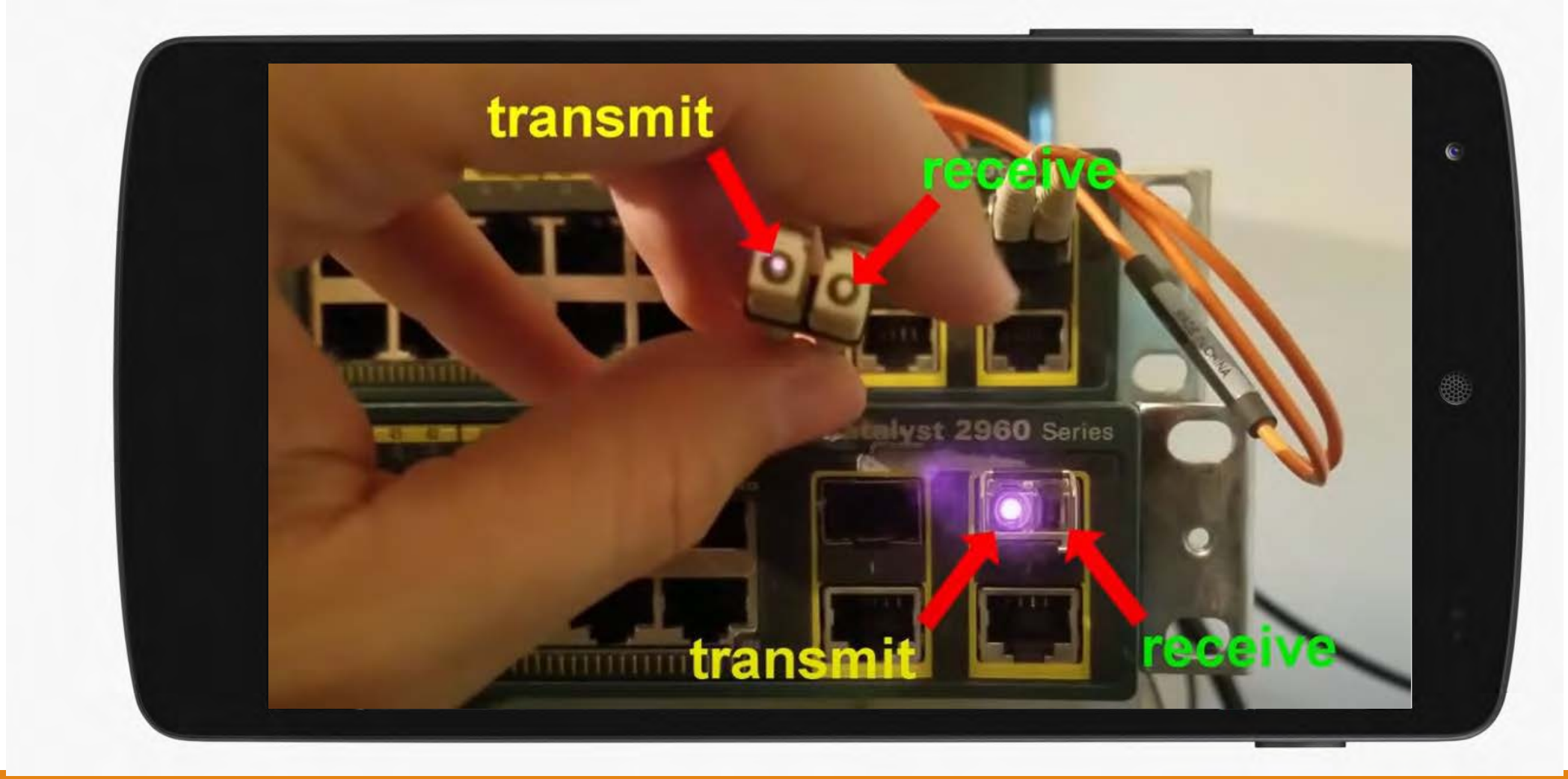
Fiber Optic Transceiver

Bidirectional and capable of operating in duplex mode

Has a receive port (RX) and transmit port (TX)

- The transmit side will show the light
- The receive side will not show a light
- The light is infrared and out of range for the human eye
  - However an MMF LED often generates a wide enough spectrum around the primary frequency for you to see a faint red light on the transmit side
- You can also use a phone camera to “see” the light
  - Some IR energy will pass through a phone camera’s Red, Green, and Blue filters, thus showing you a white light

Use Your Phone Camera to “See” the Light



Small Form-factor Pluggable (SFP)

The small form-factor pluggable (SFP)

Compact, hot-pluggable optical module transceiver

Used for data communications

Supports SONET, Gigabit Ethernet, Fiber Channel, and other communications standards

SFP replaced gigabit interface converter (GBIC)

SFP is sometimes referred to as a Mini-GBIC

Up to 4.25 Gbps

150 km distance

Enhanced Form-factor pluggable (SFP+)

An enhanced version of SFP

10 Gbps

80 km distance

Not compatible with SFP

Quad Small Form-factor Pluggable (QSFP)

Quad Small Form-factor Pluggable (QSFP)

Double fiber pairs

SMF and MMF

Ethernet, Fibre Channel, InfiniBand and SONET

Compact and hot-pluggable

Breaks out into 4 x 1Gbps “lanes”

QSFP Breakout Example

Enhanced Quad Small Form-factor Pluggable (QSFP+)

Modern version of QSFP

1 x 40 Gbps link or 4 x 10 Gbps lanes

used to connect switches, routers, Host Bus Adapters (HBAs), enterprise data centers, high-performance computing (HPC) and storage

QSFP28

A hot-pluggable transceiver module designed for 100G data rate

4x25G breakout connection, 2x50G breakout, or 1x100G depending on the transceiver used

400GBase Optical Transceivers

RJ-45 and Twinax Transceivers

Selecting the Correct Transceiver

Be sure to match:

Cable type

Connector type

Desired distance

For Fiber Optic:

- Mode
- Wavelength

Cable Management

Patch Panel

A patch panel is a device or unit featuring a number of jacks, used to connect and route circuits for monitoring, interconnecting, and testing circuits

Patch panels typically have 110 blocks in back

- You punch down (terminate) raw cable that you have pulled to the panel

Some patch panels have jacks both in front and back

The term patch came from early use in telephony and radio studios

Patch panels can exist in any location:

- Server room
- Wiring closet
- Distribution racks
- User/device area

Patch Panel with 110 Block

66 Block

Older type of punch down block

Used to connect sets of wires in a telephone systems and older low speed networks

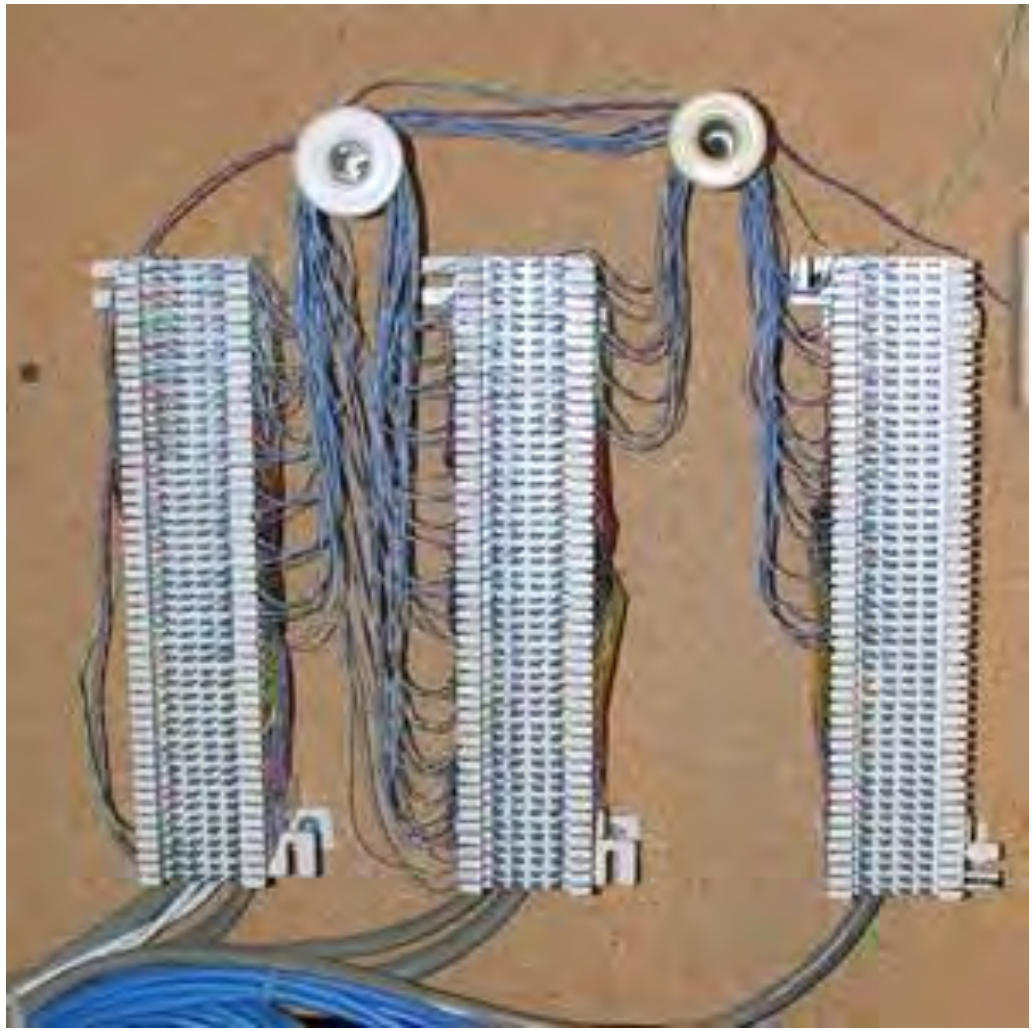
Manufactured in three sizes, A, B, and M

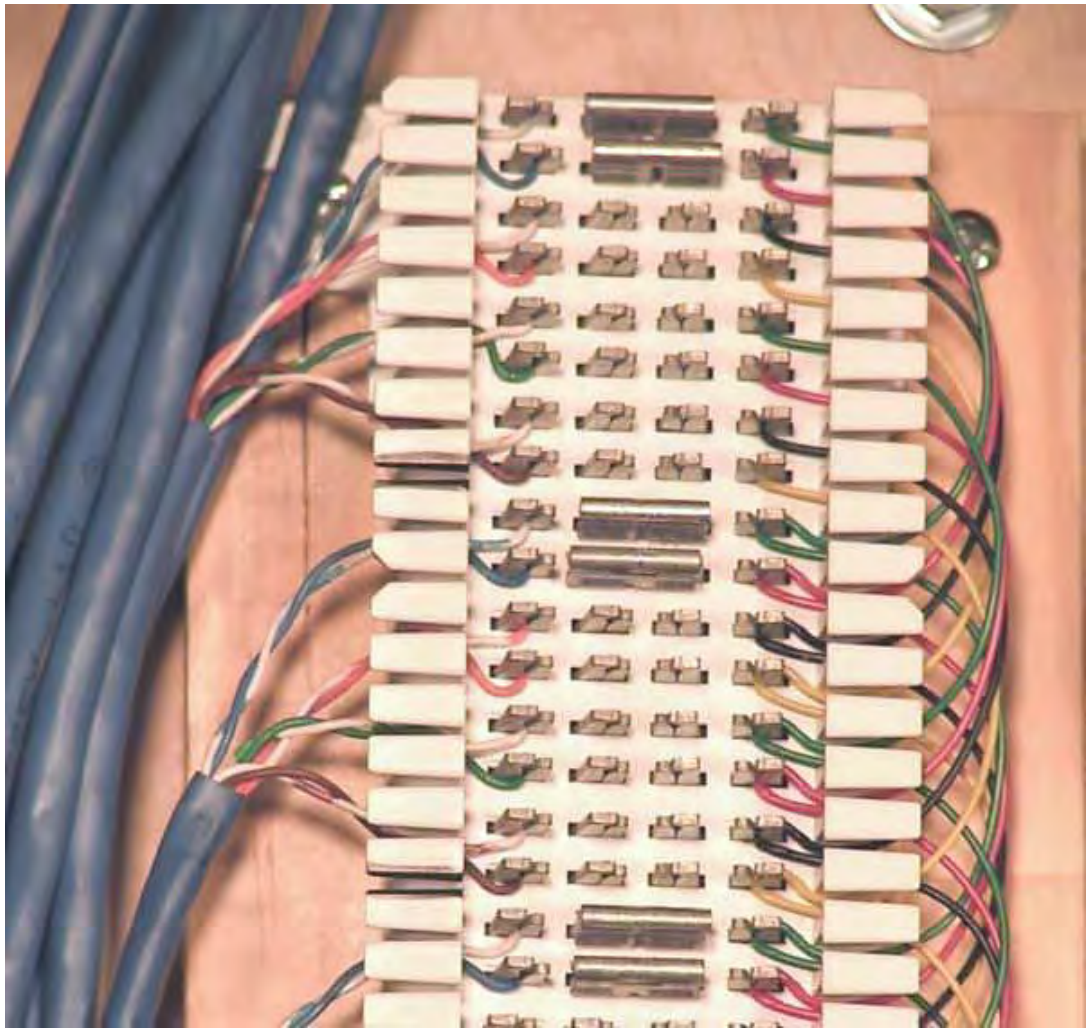
- A and B have six clips in each row
- M has only 4

The 25-pair standard non-split 66 Block contains 50 rows

- Each row has four (M) or six (B) columns of clips that are electrically bonded
- The 25-pair "Split 50" 66 Block is the industry standard for easy termination of voice cabling
  - Is a standard network termination by telephone companies–generally on commercial properties
- Approved for CAT 5, not good for anything higher

66 Block Examples





110 Block

A type of punch block used to terminate on-premises wiring

Usually found on the back side of patch panels

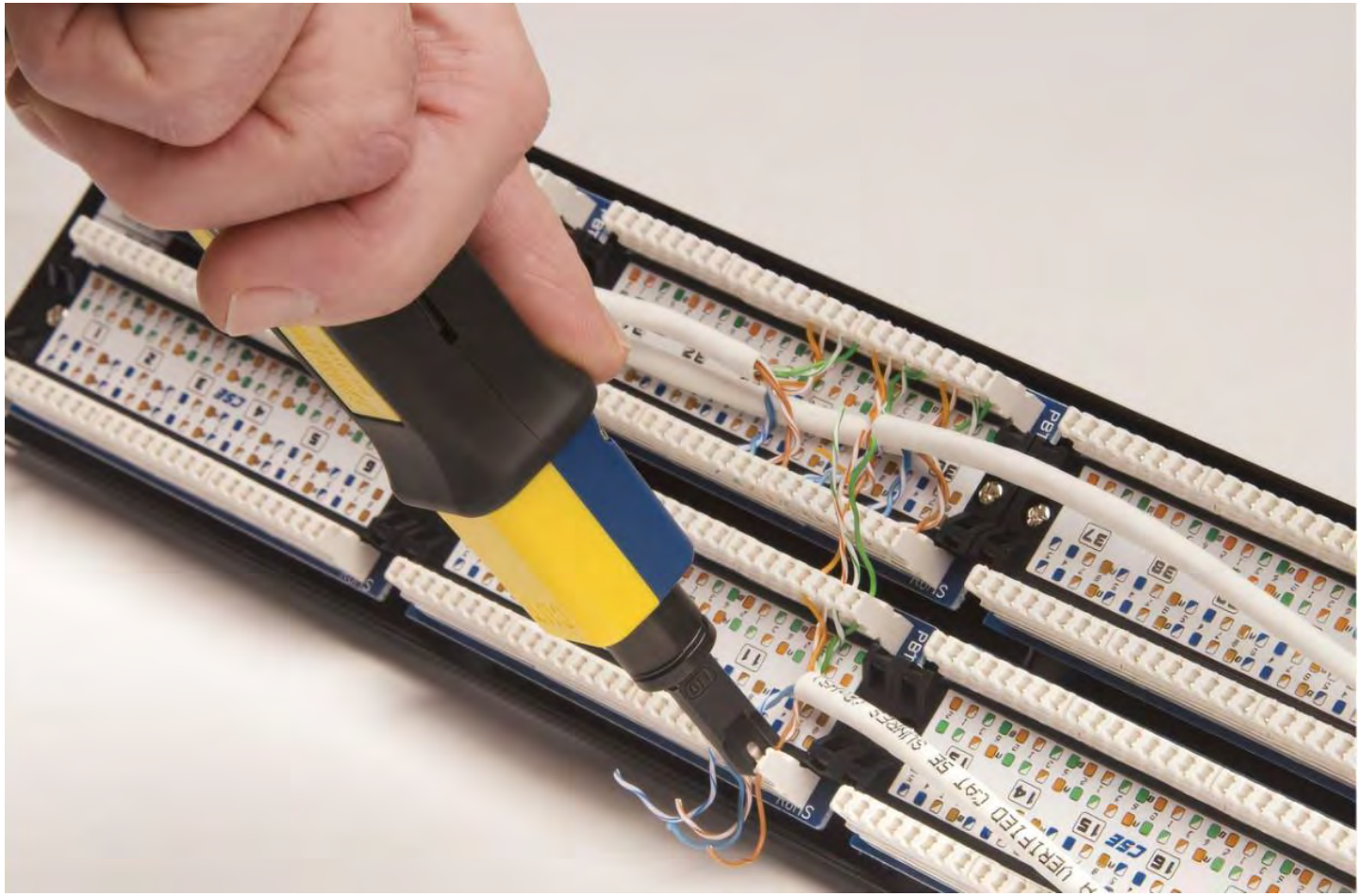
The designation 110 describes a type of insulation displacement contact (IDC) connector used to terminate twisted pair cables

- uses a punch-down tool similar to the older 66 block

Better and more preferred over 66 block type

Termination T568A and T568B

110 Block Example



Fiber Distribution Panel

Used to terminate fiber optic cable

Multistrand cable enters in the back

Strands are separated

- Spliced to jacks in front

Patch cables plug into the front jacks

Krone Block

Proprietary European alternative to the 110 block

Used for telecom, broadcast audio and related control systems

Building Industry Cross-connect (Bix) Block

Proprietary punch down block developed by Nortel

Used to terminate six 4 pair cables to six RJ45 female ports