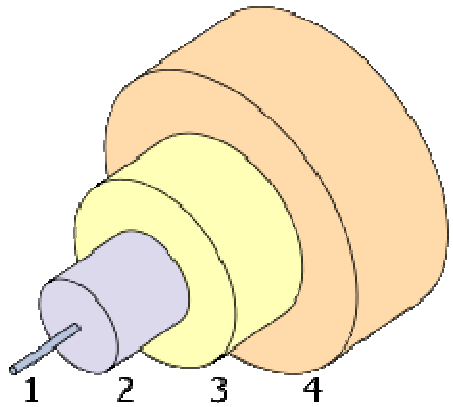
Intro

An optical fiber is a flexible, transparent fiber made by drawing glass or plastic to a diameter slightly thicker than that of a human hair. Optical fibers typically include a core surrounded by a transparent cladding material with a lower index of refraction, a plastic buffer and jacket. The boundary between the core and the cladding acts as a mirror and redirects light back into the core, allowing the light to travel thru bends in the fiber.



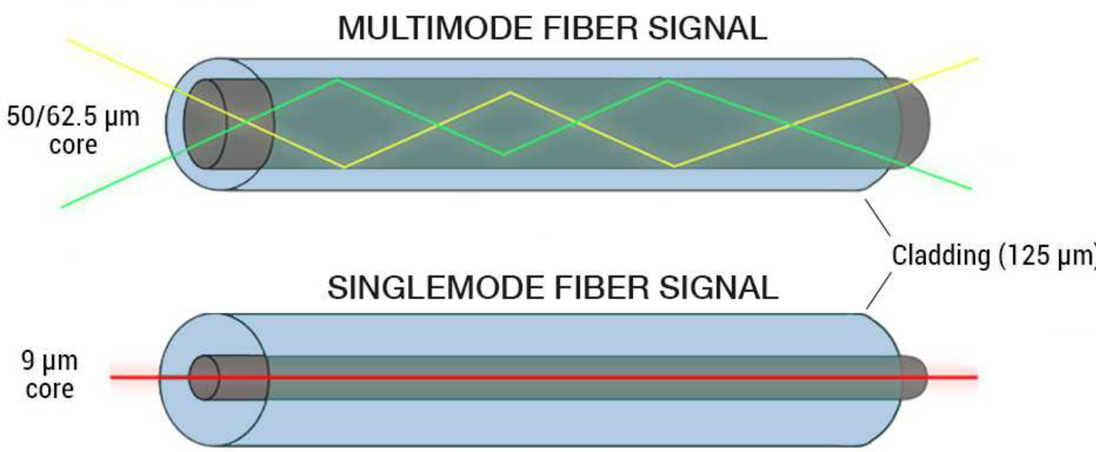
1. Core
2. Cladding
3. Buffer
4. Jacket

Optical fibers are used most often as a means to transmit light between the two ends of the fiber and find wide usage in fiber-optic communications, where they permit transmission over longer distances and at higher bandwidths (data rates) than electrical cables. Fibers are used instead of metal wires because signals travel along them with less loss; in addition, fibers are immune to electromagnetic interference, a problem from which metal wires suffer excessively.

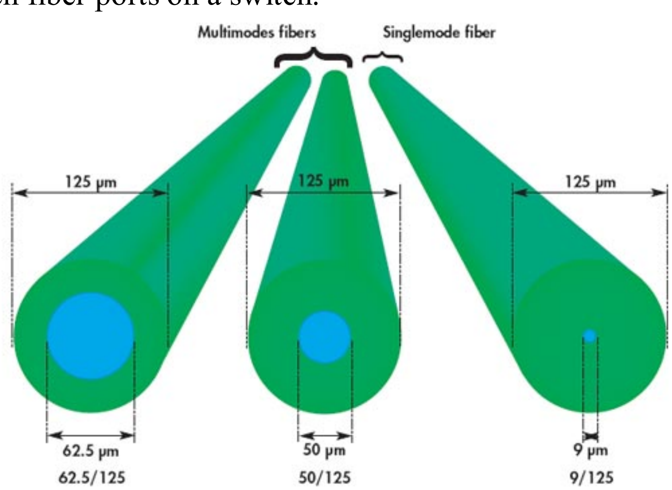
Types of fiber

There are two types of fiber optical cables – **multimode** and **single mode**. Each type has different variants of glass core diameter, such as 9 micrometers, 50 micrometers and 62.5 **micrometers** (also written as “µm” or microns).

When we speak of “modes” in fiber, we are referring to number of paths a light beam can take within the fiber. In multimode fiber, the laser bounces in multiple directions, i.e. the light coming from the laser can split and can recombine multiple times into multiple beams. In single mode fiber, the laser beam takes only one path, or travels as one ray.



The benefits of multimode fiber are it’s easy to work with, requires less accuracy during termination and has lower cost. **Distance is limited to 2-3 KM at 100 mbit/s, 550-800 meters at 1 Gbit/s and 75-150 meters at 10 Gbit/s with multimode fiber.**
Single mode fiber has significantly lower optical losses and **can transmit signal beyond 80 Kilometers** before an amplifier is needed. Due to high power lasers used in such transmitters, it is extremely dangerous to look into the light sources with a naked eye, immediate and permanent eye damage will occur. Most network lasers are in infrared range, i.e. the light is invisible to human eye. Never look into fiber cable ends or into open fiber ports on a switch.



Identifying types of cable

Single mode fiber typically has **yellow color jacket**, while multimode fiber jacket is **orange** (62.5 micrometer core) and **aqua** (50 micrometer core).

Multimode 62.5 micrometer fiber (orange):

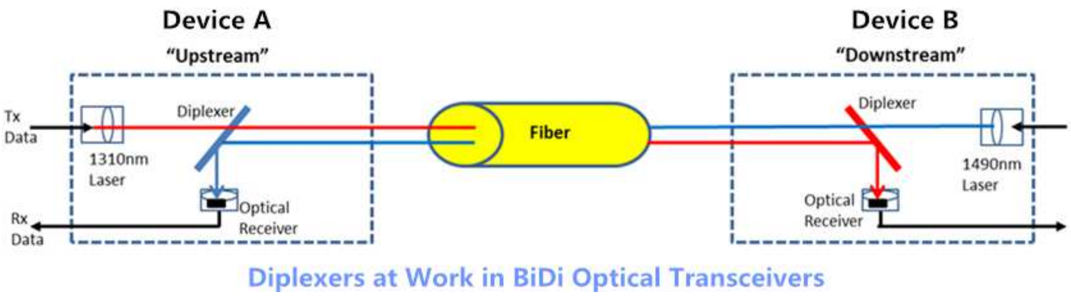
Multimode 50 micrometer fiber

Single mode 9 micrometer fiber

Duplex and simplex

In a typical application, two strands of fibers are used, one for sending data and one for receiving. One end of the fiber strand has a laser shining into it, while the other has a photosensor that measures the light intensity. By controlling the laser intensity we can transmit data to the photo sensor on the other end of the fiber. A fiber system with 2 strands is called a **duplex** system; a patch cord with 2 strands is called a **duplex** patch cord.

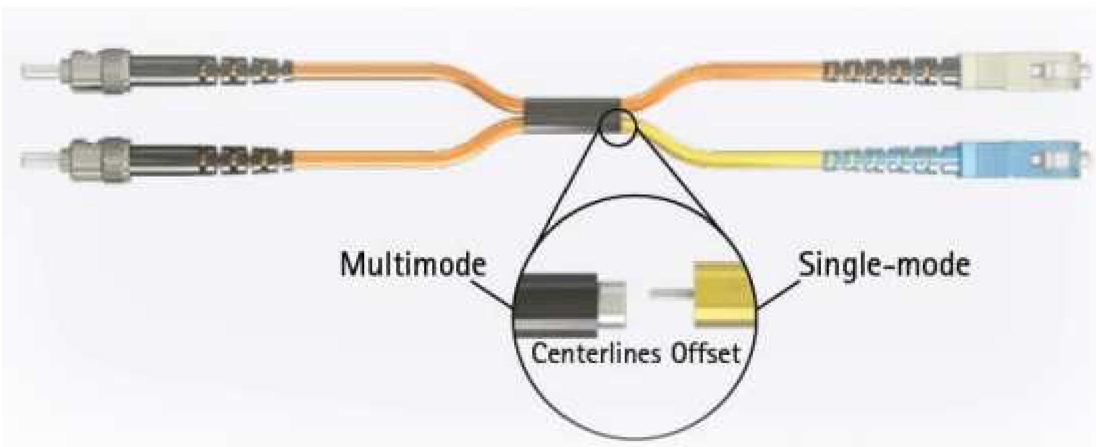
It is possible to send data both ways via a single strand using special bidirectional devices that use a system of prisms and/or half-transparent mirrors. An example would be Pelco fiber adapters used extensively in some of our customer facilities for receiving video from the camera and sending PTZ movement commands *to* the camera via a single strand. Another example would be Bell residential fiber internet.



This type of system is called a **simplex** system, and a patch cord with a single strand is called a **simplex patch cord.** A laser transceiver capable of sending and receiving data via one strand is called a **bidirectional** transceiver or a BiDi transceiver.

Mode conditioning

As stated before, multimode fiber has severe distance limitations when running at gigabit speeds. It is possible to overcome these limitations by using single mode transceivers with multimode fiber. If you attempt to connect a multimode fiber directly to a single mode transceiver, the laser will spread out into multiple paths and will confuse the receiver by illuminating it with multiple copies of the same signal. To correct this, **mode conditioning patch cords** are used. A mode conditioning patch cord is a multimode patch cord, with a short length of "launch" strand (transmitting strand) replaced with a single mode fiber, welded onto the edge of the multimode fiber. Injecting the laser off-center into the multimode fiber allows it to stay "together" for longer and deliver useable signal to the other end.



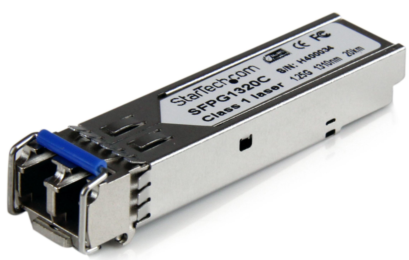
If you are reusing customer's existing multimode infrastructure and the fiber length is more than 500 meters between devices, use single mode gigabit transceivers with mode conditioning patch cords. If the distance is less than 500 meters, use gigabit multimode transceivers.

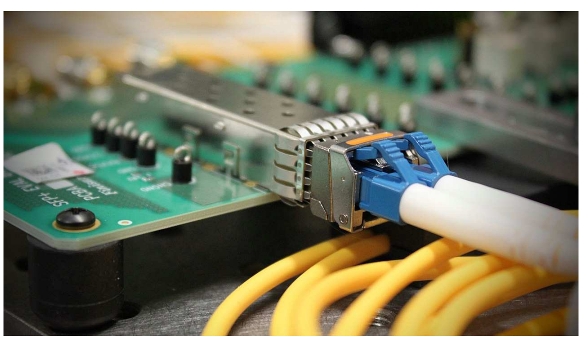
Transceivers / media converters

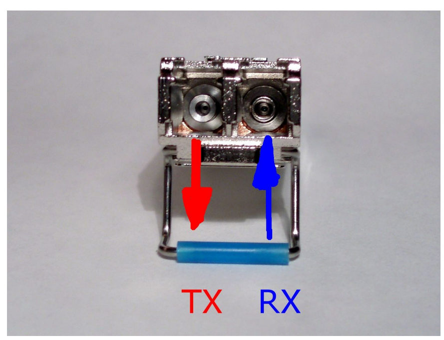
A **transceiver** is a device comprising both a **transmitter** and a **receiver** that are combined and share common circuitry or a single housing. Fiber optic transceivers come in several flavors, with the most commonly used being **SFP (Small Form factor Pluggable)**.

They could also be referred to as **media converters.** When we speak of "media" we are talking about means of transmission. Telephone lines are made of copper, so the media for telephone is **copper** wire. Sound is naturally transmitted via air, so the media is air. A telephone is a type of media converter, you can think of it as "air to copper" and "copper to air" media converter. In fiber optic networking, laser light is transmitted via glass fiber, so the media is glass **fiber**. An SFP is a **copper to fiber** and **fiber to copper** media converter.

An SFP takes electrical signal from a network switch, camera or a network card and converts them to light or some other type of signal, such as copper Ethernet.

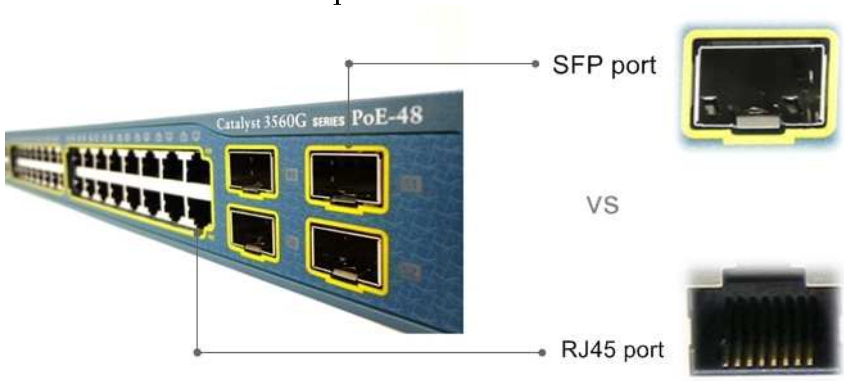






The back of the SFP looks like this:

SFP ports on a device look like this:



It is possible to connect two nearby devices directly from SFP to SFP port using **direct attach cable**:

For example, if you have two SFP-only network switches (no RJ45 copper ports available), you can link them together using an **SFP direct attach cable**. This saves you cost from purchasing two fiber SFPs and using a fiber patch cord between them. These cables are not cheap, 3 meter cable is $100 or more. A typical gigabit SFP is $60-$120 (you need two) and a short fiber patch cord is $25.

In the field you may see all kinds of media converters, here's an example of one with an integrated multimode transceiver:

You may also find SFP capable fiber to copper media converters, these allow you to use either a singlemode or multimode SFPs:

You can also get multimode to single mode fiber-to-fiber converters:

An SFP port can be built in directly into a POE injector, such as this Axis one:

As you can see, there is a wide variety of media converters, and you can mix and match them as long as they use the same type of fiber and speed. Please note that both devices must communicate at the same speed, i.e. you cannot connect a 1 gigabit/sec SFP to a 100 mbit/sec SFP port, or you cannot connect a gigabit media converter to a 100 mbit/sec media converter on the other end. In some instances, you *can* connect a 100 mbit/sec SFP to a gigabit SFP port, as long as the device allows you to slow the SFP port down to 100 mbit/s.

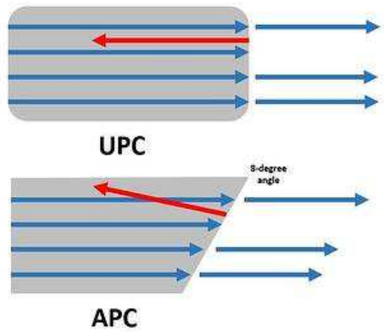
In older systems, you may also find GBIC transceivers. A **gigabit interface converter** (GBIC) is a transceiver that converts electric currents to optical signals, and optical signals to digital electric currents just like an SFP does. GBIC is about twice the size of SFP:

You can convert a GBIC port to standard RJ45 Ethernet using a GBIC to Ethernet adapter:

GBIC and Ethernet switch example:

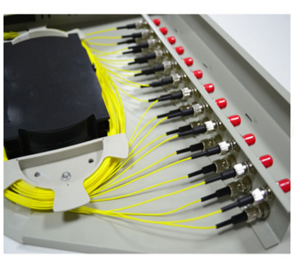
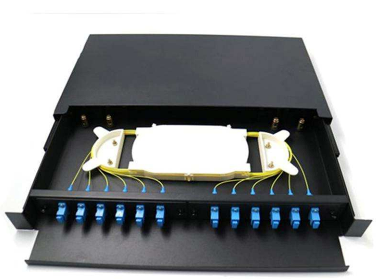
Types of fiber connectors

A fiber cable could be terminated with a variety of connectors, so it us crucial you know how they look and what they are called, and that you can precisely describe to a supplier, tech or IT person what type of fiber you are working with during installation and troubleshooting. There are two categories of connectors – UPC (ultra polished connector) and APC (angle polished connector). All it means is if the end of fiber is cut and polished flat or at an angle:



Most connectors we will be dealing with are UPC type connectors. **APC type connectors are typically GREEN**. Example of single mode UPC and APC connectors:

You will often see fiber cables terminated with patch panels in LAN cabinets in customers' facilities:

Remember: the end of the connector must be extremely clean, so avoid touching the end of fiber connectors with your hands, keep the protective caps on them until the moment of insertion. Always install rubber plugs into unused patch panel ports and SFPs.

Table of connectors

In this table, the LC connector is blue, meaning this is a flat polished (UPC) fiber connector. SC connector is grey, which means it's most likely also an UPC connector as well. E2000 connector is green, which means it's an APC (angle polished). The color of connector is chosen by the installer based on how the end of the fiber is polished. Both angled and flat polished fiber has it's pros and cons, that's outside of scope of this document.

You will often see systems that use SC or ST patch panels for fiber, however the network gear uses SFPs which have LC connectors, meaning you will need to order appropriate patch cords to connect things.

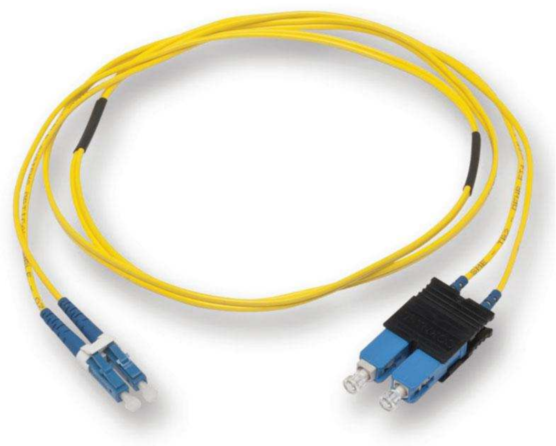
Things you learned so far:

1. Types of fiber
2. Duplex vs simplex fiber
3. Type of connector

Remember: Transmitting (TX) strand on one end has to go to the receiving port (RX) on the other end and vice versa, meaning that sometimes you have to remove the bracket that holds the duplex connector together and switch the connectors around so that TX goes to RX, and RX goes to TX on the other end.

Ordering fiber equipment

So now you have enough knowledge that if you need to order a patch cord, you can call up a supplier and say: I need 2 meter long, duplex, single mode LC to SC patch cord, this is what you get:



Regular multimode and singlemode patch cords can be ordered from ADI, Tried, Graybar etc

If you need mode conditioning patch cords, they are made by Tripp-Lite and can be bought from ADI or Tri-ed.

SFPs are rated for different cable length (in Kilometers), so ensure you get the correct type. If you use a 100 Kilometer rated SFP with a 300 foot fiber run, you will blind and possibly damage the receiver in the SFP on the other end, even if it is also rated for 100 Km. Buy the ones with the lowest rating for your application. We use 2-10 Km rated SFPs most of the time (for single mode). For multimode SFPs assume they are 2 Km rated. Remember that gigabit will not work over multimode fiber over 500 meters long, you must use singlemode SFPs with mode conditioning patch cords.

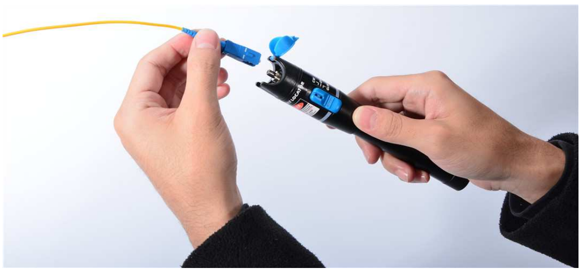
For Cisco SFPs and switches you can call IMP Supply, for other brands such as DLink/Trendnet etc you can call ADI or Tri-ed. Keep in mind that off-brand SFPs may not always work in Cisco, HP or Dell switches. If a non-Cisco SFP is labeled as MSA-compliant (MSA – multi source alliance), it should work in Cisco gear.

If you need a simpler media converter, Tri-ed sells Startech ones, or you can get them from Graybar (Transition Networks brand).

Troubleshooting fiber links

1. **Check fiber polarity (RX to TX, TX to RX strands)**
2. Ensure patch cords and SFPs are inserted all the way
3. Ensure you are plugged into the correct patch panel port
4. Ensure all components on both ends are compatible (fiber type, speed)
5. Ensure all components are powered on, active and the port is enabled in the switch config
6. Check for damage such as sharp bends or kinks in fiber

You will run into situation where the fiber is not labeled, or damaged and you need to find working strands. You can use a visible laser source (can be purchased online or from our suppliers) to troubleshoot fiber:



Remember: never look into the end of fiber. Use a piece if white paper and point the tested strand onto it while you partner is connecting the laser source on the other end to see if the light is passing thru it.

If you suspect the fiber is damaged in conduit or underground, suggest to the customer to hire a fiber specialist with an OTDR or run new fiber. An OTDR is an Optical Time Domain Reflectometer, a test instrument for locating faults within the fiber. OTDR works by sending a pulse of light down the fiber. If there is a crack in the glass strand, some light will reflect back to the OTDR. The OTDR has an extremely precise timer (picoseconds, or 0.000000000001 second accuracy) that measure how long it takes for the light to travel to and back from the fault. Light travels around 300,000 Km/second thru fiber. Using **distance = speed*time** formula, OTDR will tell you how many feet is between the end of the fiber and the fault.