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OPTICAL FIBER **101**

OVERVIEW

This white paper explains optical fiber basic concepts, as well as its uses, types and the components needed to build a fiber optic link.

1. In **Optical fiber basics** you will find fiber applications, the basic elements that compose a cable and the principle of Total Internal Reflection.

2. In **Types of optical fiber** you will read about multimode and single mode fiber and the most used cable types.

3. **Fiber optic link components** points out and explains the elements that compose an optical fiber network.

INTRODUCTION

Optical fiber technology refers to the use of light to transmit voice, video or data information through thin strands of glass or plastic. In the 70s, Corning Lab's scientists created a fiber with a loss of 20 dB/km, which was the beginning of optical fiber commercial use.

Nowadays, fiber optic has become the transmission medium of choice because it offers several advantages such as: transporting more information over longer distances and in a shorter time than any other medium. Also, it is immune to electromagnetic interference.

Though fiber optics are used in several fields, such as telecommunication, medicine, lighting, optical inspections and sensors.

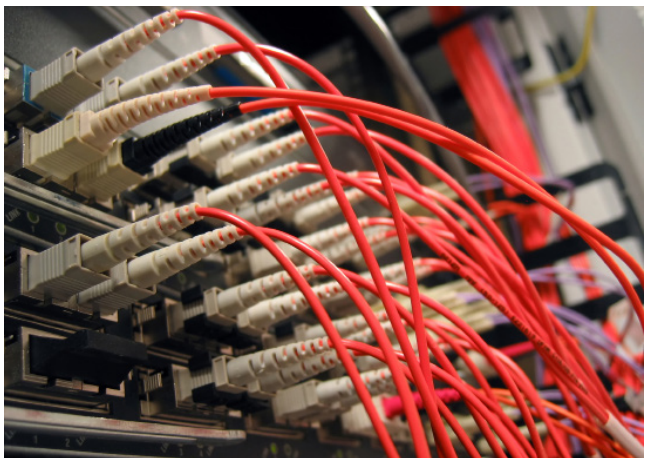
The purpose of this paper is to offer and overview of optical fiber, focusing on its use in telecommunication systems in an easy-to-understand way for non-experts who want or need to learn about this amazing subject.

OPTICAL FIBER BASICS

Optical fiber applications

Optical fiber applications in the telecommunication field are numerous, from WAN to industrial communication systems and even desktop computers. Since its invention, optical fiber demand has enormously grown and it is used to transmit voice, data, image and video over distances from 1 meter to hundreds of kilometers.

It is used by carriers to transmit telephone services through worldwide networks, between offices and homes. Extensively data transmission between international firms is done with fiber optics, because it is the most secure and reliable system. CATV providers use fiber optics to transmit their broadband signals, such as HDTV, due to its high bandwidth.



Basic elements

There are several types of fibers and cables, but they all are composed by three basic elements:

- The core:

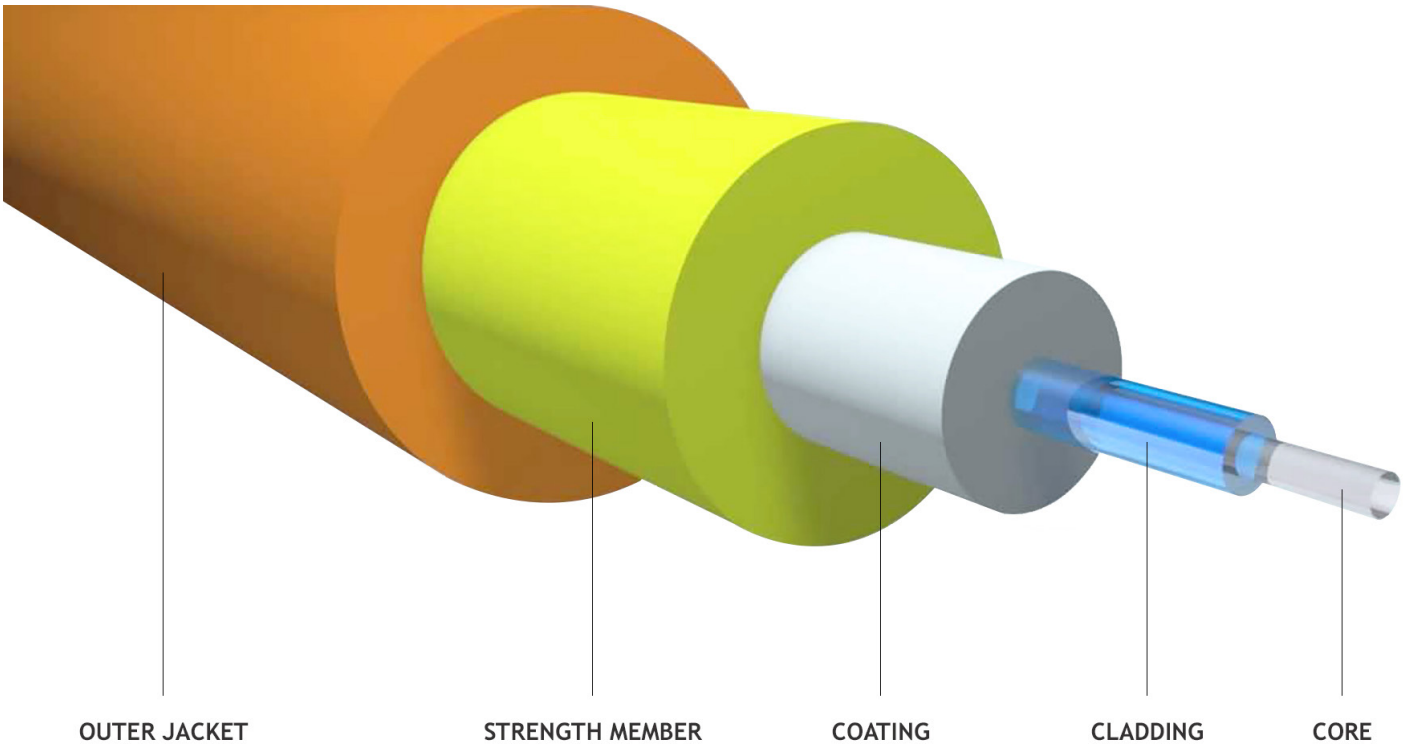
Is the part of the fiber where light is transmitted, it could be made of glass or plastic. The amount of light that is transmitted depends on the size of the core.

- Cladding:

It is also made of glass, but has a lower refractive index than the core, so it causes reflection. And allows light waves to be transmitted through the fiber.

- Coating:

Several layers of PVC that preserve and protect the fiber. They measure from 250 um to 900 um.



Total Internal Reflection

This is the physical concept that makes it possible for light to travel through fiber optics and it depends on the core and the cladding. The core has a refractive index of n1 and the cladding of n2, therefore light travels through the core by constantly reflecting from the cladding, even when it is bent.

The index of refraction refers to the radio of velocity of light in a vacuum to the velocity of light in a material. The higher it is, the lower the velocity light will travel through the material.

TYPES OF OPTICAL FIBER

Types

There are two basic types of optical fiber: single-mode and multimode. Multimode fiber is widely used in LAN and video surveillance systems, because it is designed for short transmission distances. Single-mode fiber is designed for long transmission distances and is suited for telephony and multi-channel television systems.

Multimode fiber:

Multimode fibers have a larger core, which makes it easier to couple them with low cost sources such as LED's. In multimode fibers, numerous nodes -light rays- travel simultaneously through the waveguide. Fiber modes are related to the possible ways light may travel through the fiber.

Multimode fibers are classified as step-index and graded-index:

- Multimode step-index fiber:

Three different modes travel down this kind of fiber. The first one is transmitted straight down the core. The second one bounces back and forth inside the core in a sharp angle by total internal reflection. And the third one refracts into the cladding by exceeding the critical angle.
The second mode travels at a longer distance than the first one, so they arrive at separate times, which causes dispersion. Thus, high dispersion is an inevitable in this kind of fiber.

- Multimode graded-index:

This kind is fiber is designed so the refractive index gradually decreases farther the center of the core, which slows the speeds of some modes, allowing them to arrive at roughly the same time, reducing dispersion.

Single-mode fiber:

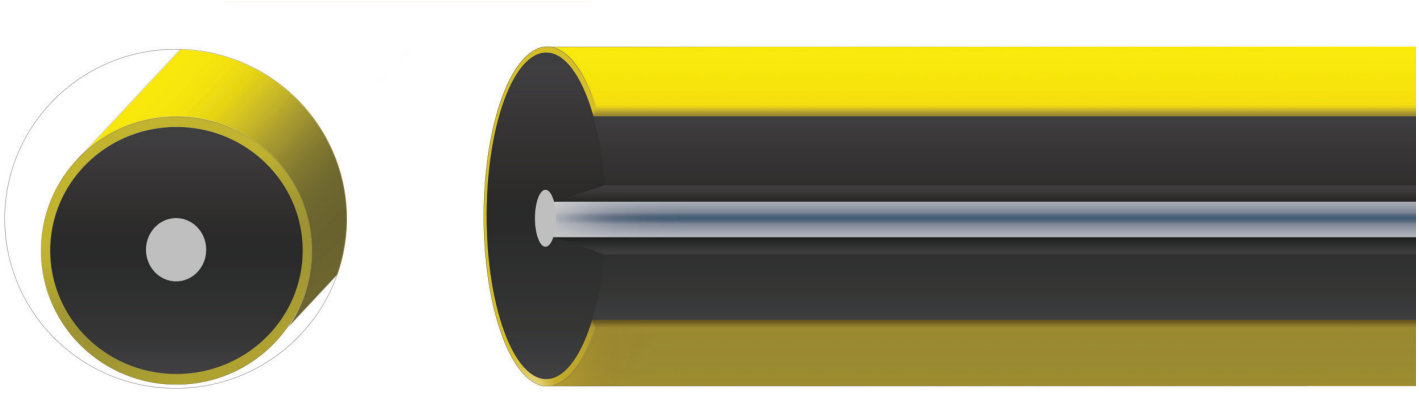
The core of single-mode fibers is smaller, so it is reduced to a few wavelengths of the incoming light and only the primary mode can travel inside the fiber in one path. Single-mode fiber has a higher transmission capacity because there is not dispersion caused by multiple light rays. The small diameter makes it difficult to couple light sources to the core and terminations need to be done carefully.
Single mode fibers are classified as step-index and dispersion shifted fiber:

- Step-index single mode fiber

Because light travels in a single path, in single mode step-index fiber light stretches and shrinks by chromatic dispersion, meaning a beam of light has several wavelengths and they travel at different speeds, which causes the beam to spread.

- Dispersion shifted single mode fiber

This kind of fiber has low attenuation loss, higher bandwidth and reaches longer transmission distances because it uses several layers of the core and cladding to reduce dispersion.



Single mode and Multimode fiber characteristics

	Single mode	***Multimode***
Bandwidth	High	Low
Signal Quality	High	Low
Main source of attenuation	Chromatic dispersion	Modal dispersion
Fiber design	Step index, &	Step index & Graded
	Dispersion shifted	index
Applications	Long transmission systems	Short transmission systems

Cable types

There are several types of optical fiber cables that can be either single mode or multimode and are used in a variety of applications.

- Simplex and Zip Cord

Simplex cables composed by a fiber coated with a 900um buffer, aramid threads and a jacket. They are usually used in patch cords, indoor applications and desktop connections. When two of these cables are joined, it is called a zip cord.

- Duplex

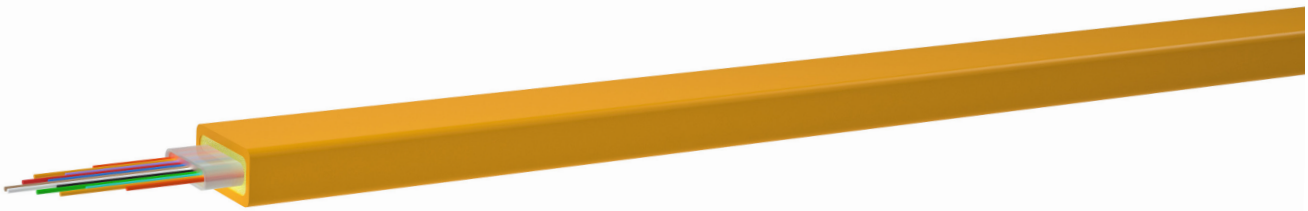
This cable contains two tight-buffered optical fibers, surrounded by Kevlars within a strong jacket. Usually one fiber transmits light and the other receives it.

- Distribution cables

The jacket covers a bundle of tight-buffered fibers surrounded by aramid threads. The fibers can be directly terminated using a breakout box. This is the preferred cable for indoor applications because it is small and light in weight.

- Breakout cables:
Several tight-buffered fibers are contained together inside a strong jacket.
They allow direct terminations without junction boxes or patch panels. It is larger and more expensive than distribution cables.

- Ribbon cable
A cable that contains several unbuffered fibers lying side by side in a flat jacket. It usually contains from 6 to 12 fiber optics, which are typically terminated into MPO connectors.



- Armored:
Armored cables often have a metal armor between two jackets. They are used in outside plant applications where strong cables protection for rodents is needed.

- Loose Tube
This cable is composed by several 250 um fibers inside a small tube, which is surrounded by a water resistant tape. It is widely used in outdoor applications because it is well protected from humidity and doesn't break under pulling tensions.

FIBER OPTIC LINK COMPONENTS

Fiber optic link components

In order to understand how optical fiber works, it is mandatory to know the components of a fiber link.

There are three main components, besides the fiber cables.

- The transmitter

Is a device that converts an electrical output into an optical input. The fiber and the light from the transmitter are coupled with a connector. Fiber optic transmitters have three kind of light sources: LED, VCSEL and LASER.

- LED sources have much lower power outputs than the other sources. It has the largest spectral width and carries the least amount of bandwidth. LEDs are used with multimode fibers.
- VCSEL has a narrower spectral width than LEDs and carries more bandwidth. It is used in multimode applications.
- LASERs carry the most bandwidth, has the smaller spectral width and is used with singlemode fibers.

Fiber optic cable type and applications

Source characteristics	LED	Laser Diode
Output power	Low	High
Switching speed	Slow	Fast
Output pattern	Wide	Narrow
Spectral width	Wide	Narrow
Expense	Cheap	Expensive
Application	Multimode	Single mode

Connectors:

Optical fiber connectors are mechanical devices placed at the end of a fiber cable, allowing it to be joined to telecommunication equipment. They terminate the fiber and attach to it with epoxy or by a splicing mechanism. Connectors allow the fiber to be mated and unmated any time over hundreds or thousands of times.

By the way their ferrules are polished, connectors can be classified as:

- PC (Physical Contact): PC connectors are polished with slight curvature, which reduces the air gaps between fibers. These connectors' back reflection is between 30dB and 40dB.
- UPC (Ultra Physical Contact): UPC connectors also have a convex end-face, but have a finer surface finish. Their return loss goes from -40dB from -55dB, which makes them reliable for transmitting TV and data signals.
- APC (Angled Physical Contact): APC connectors have an 8° angle cut in their ferrules, which makes connections between optical fibers even tighter. Industry standards indicate that APC connectors back reflection is 60dB.

Connectors have to be chosen according to the application, the loss, footprint size and mating capabilities. The most widely used are:

SC: They are low cost, simple and durable. They offer excellent fiber alignment thanks to their ceramic ferrule.

LC: These connectors' small size makes them perfect for high density environments.

ST: They are still the most used in campuses and building multimode fiber applications.

FC: These connectors provide more reliable real-time data transmission in high vibration scenarios.

If you want to learn more about connectors, you can check our paper The most used Fiber Optic Connectors.

- Receiver:

This devices use a photodiode that converts optical signals into electrical. It is composed by an optical detector; a low-noise amplifier, in charge of increasing the electrical signals to a level suitable for additional signal processing and signal conditioning circuitry.

Two types of photodiodes are used: Positive Intrinsic Negative (PIN) and the

CONCLUSION

Optical fibers are widely used in the telecommunication field, because it offers a lot of advantages over copper cables, such as higher bandwidth, longer transmission distances and immunity to electromagnetic interference. Enterprises are using optical fiber to increase their LANs bandwidth and government to improve the metropolitan networks.
It has become the industry standard for aerial and terrestrial data transmission and they will continue being over several years to come.

Definitions

Absorption: Is a signal loss caused by impurities in the fiber such as metal or hydroxyl ions which convert the light into heat.

Attenuation: Is the power reduction in the light signal as it is transmitted along a cable. It is caused by absorption and scattering.

Bandwidth: Is the amount of data an optical fiber can carry from a point to another in a specific time period, generally a second.
Chromatic dispersion: It is a delay of a light pulse as it travels through the fiber, caused by difference in refractive indices at different wavelengths.

Decibels (dB): A unit of measurement of optical power which indicates relative power. Expressed as dB and dBm.
Dispersion: The spreading of a light signal as it travels through fiber, caused by light signals moving at different speeds due to modal of chromatic effects.

Insertion loss: The amount signal loss after the insertion of a coupler, splice or connector into a previously continuous wire.

Modal dispersion: The temporal spreading of a signal caused by the difference between the velocities of the modes.

About Beyondtech

Beyondtech has been established in America as a fiber, rack network and infrastructure equipment designer, manufacturer and provider. And also an adviser regarding telecommunication topics, supporting our clients in anything they need.
Besides designing and distributing plug and play products, Beyondtech's heritage of service and innovation along with a business model driven by entrepreneurialism, customer service and ethics places us as a leading connectivity solutions provider for the global telecommunication industry.

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