Optical fiber technology and its applications

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Abstract

In this article, I will introduce some of the applications of optical fiber, both in the laboratory and in commercial applications. Then the principles of these applications are explained and some extensions are made, including basic equations of optical fiber optics, characteristic parameters of optical fiber and testing techniques, including loss of optical fiber.

1 Introduction

Optical fiber communication is based on the principle that light travels in fine glass fibers by total reflection. In 1870, John Tyndall first realized the use of total internal reflection to conduct light. In front of an audience at the royal society of art in London, he performed an experiment in which light from the surface of a bucket of water could be transmitted by water flowing through a small hole in the side of the bucket. Since then, people have made amazing progress. Today's fiberglass has become a viable means of transmitting light in optical communications. Today, I'm going to introduce you to this advanced science, the principles and applications of optical fiber.

2 What's light

Light is an electromagnetic wave (visible spectrum) that can be seen (accepted) by the naked eye. In science, light is sometimes defined as all electromagnetic waves. Light consists of an elementary particle called a photon. It has the characteristics of particle and wave, or wave-particle duality. The object that is giving off light is called illuminant, "be" this condition must have, illuminant can be natural or man-made. Physics refers to the electromagnetic wave can emit a certain wavelength range (including visible and ultraviolet, infrared, X-ray and other invisible light) objects. Light can travel in a transparent medium such as vacuum, air and water. The speed of light in a vacuum is the fastest known speed in the universe. Light can travel 299792458m in a vacuum for 1s. That is to say, the speed of light in vacuum is $c = 2.99792000 \times 10^8 m/s$. In every other medium the velocity is lower than in a vacuum. The speed of light in the air is approximately $2.99792000 \times 10^8 m/s$. In our calculation, the speed of light in vacuum or air is set as $c = 2.99792000 \times 10^8 m/sm/s$.(fastest, limit speed) light speed in water is much smaller than that in vacuum, which is approximately 3/4 of the speed of light in vacuum. Light travels faster in glass than in a vacuum, about two-thirds the speed of light in a vacuum. If a human being were to orbit the earth at the speed of light, it would be able to orbit the earth 7.5 times in 1 second. The light from the sun takes 8 minutes to reach the earth. If a 1000km/h racing car runs continuously, it will take 17 years to cover the distance from the sun to the earth.It has been proved experimentally that light is electromagnetic radiation, and the wavelength range of this part of electromagnetic wave ranges from 0.77 (m) micron of red light to 0.39 m of purple light. Electromagnetic waves with a wavelength of above 0.77 m to about 1000 m are called "infrared". Below 0.39 m to around 0.04 m is called "uv". Infrared and ultraviolet rays do not cause vision, but optical instruments or photographic methods can be used to measure and detect the presence of such luminous objects. So the concept of light in optics can also be extended to the infrared and ultraviolet fields, and even x-rays are considered as light, and the visible spectrum is only part of the electromagnetic spectrum. Human eyes are sensitive to different wavelengths of visible light. Experiments have shown that normal human eyes are most sensitive to yellow-green light with a wavelength of 555nm (nanometer), that is, the radiation of this wavelength can cause the maximum vision of human eyes, and the more deviation from the radiation of 555nm, the smaller the visibility. Light has wave-particle duality. We can think of light as either an electromagnetic wave with a high frequency or as a particle, a quantum of light, or simply a photon.

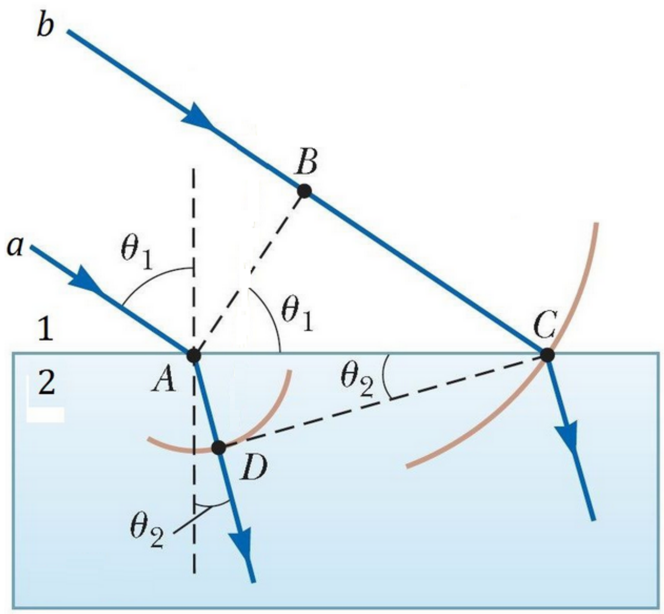
3 The nature of the light

Light bounces off water, glass, and many other surfaces. A line perpendicular to the mirror is called a normal; The Angle between the incident ray and the normal is called the incident Angle; The Angle between the reflected ray and the normal is called the Angle of reflection. In reflection, reflected light, incident light and normal are all in the same plane. Reflected light and incident light are separated on both sides of the normal line; The Angle of reflection is equal to the Angle of incidence. This is the law of light reflection. If you shine light on a mirror in the opposite direction of the reflected light, then it will be reflected back in the opposite direction of the incident light. This shows that in reflection the optical path is reversible. There are two kinds of reflection in physics: specular and diffuse. Specular reflection occurs on a very smooth surface (such as a mirror). Two parallel rays can be reflected on a reflecting object and remain parallel. Uneven surfaces, such as white paper, reflect light in all directions. This reflection is called diffuse reflection. Most reflections are diffuse. When light rays from one medium slant into another, the direction of propagation deflection, this phenomenon is called light refraction. The Angle between the refracted ray and the normal is called the refractive Angle. If the density of the incoming medium is greater than that of the original medium, the refractive Angle is less than the incident Angle. Otherwise, if less than, the refractive Angle is greater than the incident Angle. If the incident Angle is 0 and the refraction Angle is 0, it is part of the reflection. However, light refraction is also generated in the same heterogeneous medium. Theoretically, it can be emitted from one direction without generating refraction. However, since the boundary can not be distinguished and there are usually several layers instead of planes, refraction will be generated no matter what. For example, seeing the bottom of a calm lake from the shore is a first refraction, but seeing a mirage is a second refraction. Convex and concave lenses are the two most common types of lenses because of the first type of refraction. In refraction, the optical path is reversible. The phenomenon of light splitting into monochromatic light is called light dispersion. Newton first observed the dispersion of light through a prism in 1666, splitting white light into bands of color (spectra). The dispersion phenomenon indicates that the refractive index n (or propagation velocity $v = c/n$) of light in the medium varies with the frequency of light. Light dispersion can be achieved by prism, diffraction grating, interferometer, etc. White light is a compound color light composed of red, orange, yellow, green, blue, indigo, purple and other colors. Red, orange, yellow, green and other colors are called monochromatic light. The phenomenon of light splitting into monochromatic light to form a spectrum is called light dispersion. Dispersion can be achieved by using a prism or grating as a "dispersion system" instrument. After the polychromatic light enters the prism, because it has the different refractive index to each frequency light, each color light propagation direction has the different degree deflection, therefore when leaves the prism separately disperses, forms the spectrum. The phenomenon in which the refractive index of a medium varies with the frequency of light waves or the wavelength of a vacuum. When the dichromatic light refracts at the dielectric interface, the dielectric has different refractive index to the light of different wavelength, and the light of different colors are separated from each other due to the different refractive Angle. In 1672, Newton used a prism to break down sunlight into bands of colored light. This was the first experiment with dispersion. The dispersion rule is usually described by the relation between the refractive index n or dispersion rate $\frac{\mathrm{dn}}{\mathrm{d}\lambda}$ lambda and wavelength lambda of the medium. The dispersion of any medium can be divided into normal dispersion and abnormal dispersion. Let a beam of white light shine on the glass prism. After the light is refracted by the prism, it forms a color band on the white screen on the other side of the prism. Its color arrangement is red near the top corner of the prism, purple near the bottom end, and orange, yellow, green, blue and indigo in the middle. Each color in the spectrum can not be separated from other color light, called monochromatic light. Light that is a mixture of monochromatic light is called dichromatic light. In nature, the light from the sun, incandescent electric lamps and fluorescent lamps are compound color light. When light hits an object, part of it is reflected and part of it is absorbed. The light that passes through determines the color of the transparent object, and the light that reflects determines the color of the opaque object. Different objects reflect, absorb, and penetrate different colors differently, and therefore present different colors. For example, a yellow light shines on a blue object, and that object is black. Because blue objects can only reflect blue light, and not yellow light, so the absorption of yellow light, you can only see the black. But if it's white, it reflects all the colors.

4 The refraction of light

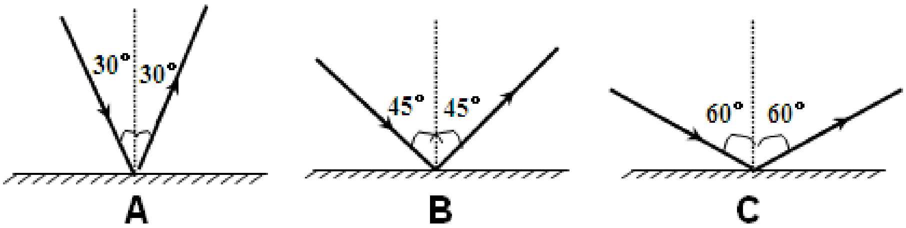
The law of refraction of light is one of the fundamental laws of geometrical optics. It is the law that determines the relation between the refracted ray and the incident ray during the refraction process of light. It was proposed by snell in 1621. When light radiates from one medium to the smooth interface of another medium, part of light is reflected by the interface, and another part of light is refracted through the interface in another medium. The refracted light obeys the law of refraction: the refracted light is in the same plane as the incident light and the normal line, and the refracted light and the incident light are on both sides of the normal line respectively. The sine of the incident Angle is proportional to the sine of the refraction Angle, which is $\frac{sina}{sinb} = n_{12}$.Where n_{12} is a constant of proportion, which is called the relative refractive index of the second medium to the first medium.

As shown on the right, a ray of light a first reaches the interface from medium 1 at time t. From the triangle ABC and ADC, we can get $sin\theta_1 = \frac{BC}{AC} = \frac{v_1\Delta t}{AC}$ $sin\theta_2 = \frac{AD}{AC} = \frac{v_2\Delta t}{AC}$ $\frac{sin\theta 1}{sin\theta 2} = \frac{v_1}{v_2} = \frac{n_2}{n_1} = n_{12}$ which is $\frac{sin\theta 1}{sin\theta 2} == n_{12}$



5 The reflection of light

The law of light reflection was proposed by French civil engineer and physicist Fresnel (1788 1827). He discovered the relationship between reflection/refraction and viewpoint Angle.Therefore, the reflection of light is also known as Fresnel reflection.If you stand by the lake and look down at the water under your feet, you will find that the water is transparent and the reflection is not very strong. If you look at the lake in the distance, you will see that the water is not transparent, but the reflection is very strong. This is the Fresnel effect.In the real world, all substances except metals have different degrees of "Fresnel effect".The law of reflection of light means that the reflected ray and the incident ray are in the same plane with the normal line. The reflected ray and the incident ray are separated on both sides of the normal line. The reflected Angle is equal to the incident Angle. It can be summarized as: "three lines coplanar, two lines separated, two angles are equal". Light is reversible. In the phenomenon of light reflection, the path of light is equal.In the special case of vertical incidence, the Angle of incidence and the Angle of reflection are all zero. And there are two kinds of reflection: specular and diffuse 1.



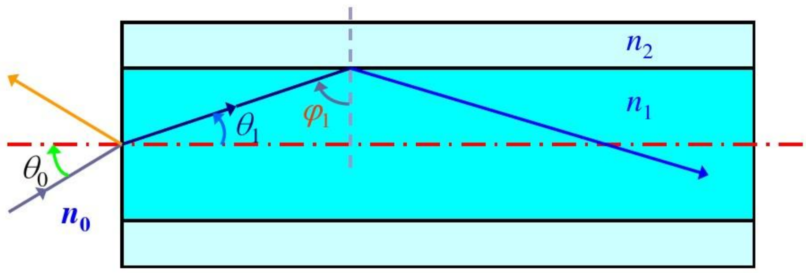
Specular reflection: parallel light rays are reflected from the interface and then shot out in a certain direction, and the reflected light rays can only be received in a certain direction (the reflecting surface is a smooth plane). 2. Diffuse reflection: parallel light is reflected from the interface in different directions, that is, reflected light can be received in different directions (the reflective surface is a rough plane or a curved surface). But both specular reflection and diffuse reflection follow the law of light reflection; Diffuse reflection is an irregular reflection caused by uneven surface. It means that there are some arcs or sharp lines on the uneven surface. Suppose a ray of light hits the surface and makes its tangent line as the reflection ray. Note: light path is reversible in light reflection.

6 The total reflection of light

Due to the refraction and total reflection of the air, there will be a "mirage" in the air. When the sea is calm, standing on the beach, we can sometimes see high-rise buildings, streets and mountains overlapping in the distance. There is a reason for this. When the atmosphere is relatively calm, the density of the air decreases with the increase of temperature. The air temperature on the sea surface is lower than that in the air, and the refractive index of the air in the lower layer is higher than that in the upper layer. We can roughly divide the atmosphere in the air into many horizontal air layers, as shown in the lower layer which has a higher refractive index. When the light from a distant scene shoots into the air, it is constantly refracted, and the incident Angle of the upper layer with a lower refractive index becomes larger and larger. When the incident Angle of the light reaches a critical Angle, the phenomenon of total reflection will occur. The light will be high in the air through the air refraction gradually return to the next higher refractive index layer. An observer near the ground can observe an image created by light from the air, which is a mirage. When light propagates to the interface of two kinds of media, reflection and refraction usually take place at the same time. If certain conditions are met, the light will no longer be refracted, but will all return to the original media, which is called total reflection. Total reflection is a special phenomenon of refraction of light. It can only occur when the incident Angle is greater than or equal to the critical Angle and the light shoots from the optically dense medium to the optically sparsely medium. Before the occurrence of total reflection, with the increase of the incident Angle, both the refractive Angle and the reflected Angle increase, but the refractive Angle increases rapidly. Under the condition that the intensity of the incident light is certain, the refracted light becomes weaker and weaker, and the reflected light becomes stronger and stronger. When the full emission occurs, the refracted light disappears, and the intensity of the reflected light is equal to the intensity of the incident light.That's why fiber optics are used today.

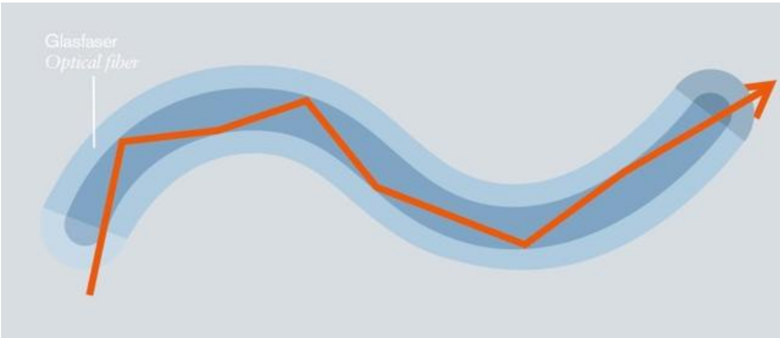
7 What is optical fiber

It has been found that light travels along a stream of fine wine ejected from the barrel. It was also found that light can travel along curved glass rods. Why is that? Doesn't the light go straight in? These phenomena have attracted the attention of dendar. Through his research, he found that this is the effect of total reflection of light. Since the density of medium such as water is greater than that of surrounding substances (such as air), that is, light shoots from water to air. On the surface, the light seems to bend in water. People later made a transparency is very high, like a spider silk degree of glass glass fiber, when the light is at a right Angle into the glass fiber, light along the winding glass fiber. It is called an optical fiber because it can be used to transmit light. In daily life, optical fiber is used for long-distance information transmission because the loss of light in the optical fiber is much lower than that of electricity in the wire. The terms fiber and cable are often confused. Most optical fibers must be covered by several layers of protective structures before use. The covered cables are called fiber optic cables. The outer protective layer and insulating layer of the fiber can prevent the damage of the surrounding environment to the fiber, such as water, fire and electric shock. The microfiber is encapsulated in a plastic sheath that allows it to bend without breaking. Optical fibre is made up of two layers of glass with different refractive indices. The inner layer is the inner core of light, with a diameter of several microns to dozens of microns, and the outer layer has a diameter of 0.1 0.2mm. The refractive index of the inner glass is 0.01 higher than that of the outer glass. According to the refraction and total reflection principle of light, when the Angle of light to the inner core and outer interface is greater than the critical Angle to generate total reflection, the light will not penetrate the interface and reflect all. Because light travels at different speeds in different substances, it is refracted and reflected from one substance to another at the interface between the two. Moreover, the Angle of the refracted light will change with the Angle of the incident light. When the Angle of the incident light reaches or exceeds a certain Angle, the refracted light will disappear and all the incident light will be reflected back, which is the total reflection of light. Different substances refract light of the same wavelength at different angles (that is, different substances have different refractive indices), and the same substance refracts light of different wavelengths at different angles. Fiber optic communication is based on the above principles. The incident light to the end of the optical fiber is not all transmitted by the optical fiber, only in a certain Angle range of the incident light can be. This Angle is called the numerical aperture of the fiber. Larger numerical aperture of fiber is beneficial to the butt joint of fiber. The numerical aperture of optical fiber produced by different manufacturers is different.



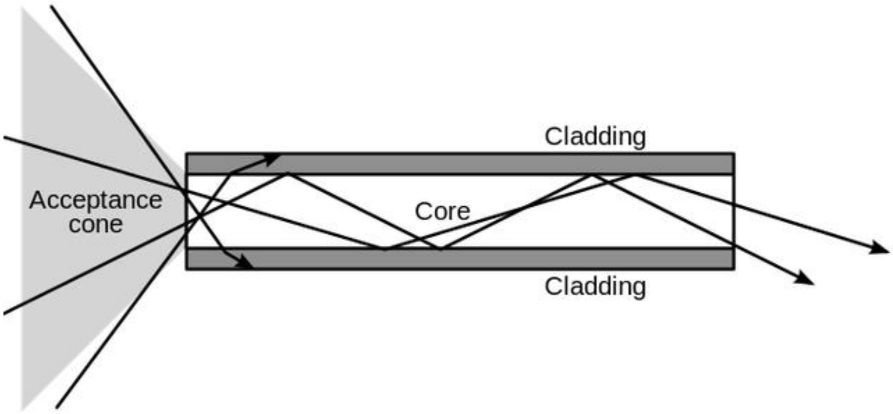
8 Functions of optical fiber

There are many types of fiber, depending on the purpose, the required function and performance also vary. 1.Quartz fiber is an optical fiber with silica as the main raw material, and the refractive index distribution of core and cladding is controlled according to different doping amount. Quartz series optical fiber, with the characteristics of low consumption and wide band, has been widely used in cable television and communication systems. The advantage of quartz glass optical fiber is low loss, when the light wavelength of 1.0 1.7 m, loss is only 1dB/km, at 1.55 m the lowest, only 0.2dB/km. 2.The operating wavelengths of the quartz series of optical fibers developed for optical communications are limited to 2 m, although they are used for shorter transmission distances. Therefore, it can work in the field of longer infrared wavelength. The developed fiber is called infrared fiber. Infrared fiber is mainly used for light energy transmission. For example: temperature measurement, thermal image transmission, laser scalpel medical, thermal processing, and so on, the penetration rate is still low. 3.Composite fiber is a kind of multi-component glass fiber made by properly mixing oxides such as sodium oxide, boron oxide and potassium oxide in SiO2 raw material. The characteristic of multi-component glass is that the softening point of multi-component glass is lower than that of quartz glass and the refractive index of core and cladding is very different. This fiber is mainly used in the medical service of optical fiber endoscopy. 4.Fluoride Fiber chloride Fiber (Fluoride Fiber) is made of Fluoride glass Fiber. This optical fiber raw material is also referred to as ZBLAN (zirconium fluoride (ZrF2), barium fluoride (BaF2), lanthanum fluoride (LaF3), aluminum fluoride (AlF3), sodium fluoride (NaF) and other chloride glass raw materials simplified into the abbreviation. The main work in 2 10 m wavelength of light transmission services. As ZBLAN has the possibility of ultra-low-loss optical fiber, the feasibility development of optical fiber for long-distance communication is under way. 5.Plastic Clad Fiber USES high-purity silica glass as the core, while plastics such as silica gel with slightly lower refractive index than quartz as the cladding step type Fiber. Compared with quartz fiber, it has the characteristics of coarse core and high numerical aperture. Therefore, easy to combine with LED light source, the loss is small. Therefore, it is very suitable for LAN and short distance communication. 6.This is an optical fiber with plastic core and cladding. Early products are mainly used for decoration and light guide lighting and optical communication in the near optical key path. The main raw materials are plexiglass, polystyrene and polycarbonate. The loss is restricted by the inherent c-h binding structure of plastics, which can reach dozens of dB per km in general. In order to reduce the loss is developing the application fluoresso series plastics. With a core diameter of 1000 m, plastic fiber is 100 times larger than single-mode quartz fiber, easy to connect and easy to bend. In recent years, along with the progress of broadband, the development of multimode plastic fiber as a graded refractive index has been paid attention to by the society. Recently, it is applied quickly in the automobile internal LAN, and it may be applied in the family LAN in the future. 7.Hollow fiber, the formation of cylindrical space, optical fiber for the transmission of light, called hollow fiber. The hollow fiber is mainly used for energy transmission and can be used for X-ray, ultraviolet and far infrared light transmission.



9 Principle of optical fiber transmission

Definition of optical fiber communication: the communication mode that takes light as the carrier of information and optical fiber as the transmission medium. To understand how fiber-optic cables work, imagine an infinite length of drinking straw or a flexible plastic tube. For example, imagine a pipe several kilometers long. Now, suppose that the inner wall of the pipe is covered with a full reflector. Then, suppose you look through one end of the pipe. At the other end, a few kilometers away, one of your friends turns on a flashlight and shines it into the pipe. Because the inside of the tube is a total reflector, the light from the flashlight will be reflected back and forth across the tube (even though the tube may be twisted), and as a result, you will see light at the other end. If your friend turns his flashlight on and off in Morse code, he can communicate with you through the channel. This is the basic principle of fiber optic cable. It is possible to make a cable from the pipe that covers the inside of the reflector, but this cable can be very thick and it is difficult to cover the inside of the pipe with a full reflector. So real fiber optic cables are made of glass. Glass is so pure that even when it is several kilometers long, light can still be transmitted (imagine glass so transparent that Windows several kilometers thick still look clear). Glass is drawn into very fine strands that are as thick as a human hair. Then, cover the bread with two layers of plastic over the glass. By wrapping the glass in plastic, a mirror is created around the glass. This reflector produces a total internal reflection, just like a total reflector covered inside a tube. You can experience this reflection in a dark room with a flashlight and Windows. If you shine a flashlight at the window at an Angle of 90 degrees, the light will pass directly through the glass. However, if you shine at a very small Angle (almost parallel to the glass), the glass will act as a mirror, and you will see beams of light bounce off the Windows and hit the walls of the house. It is at this tiny Angle that the light transmitted within the fiber is reflected, thus remaining completely within the fiber. To send telephone conversations over fiber-optic cables, people convert analog voice signals into digital ones (see how analog and digital recordings work for more information). Lasers at one end of the pipe alternately turn on and off to send each bit of data. Modern fiber optic systems with single lasers can transmit billions of bits of data per second – the laser can be turned on and off billions of times per second. The latest systems use multiple lasers of different colors to transmit multiple signals over the same fiber.



10 Principle of optical fiber transmission

In July 1966, Dr. Charles kao and Dr. Hockham, British Chinese of the British standard telecommunications research institute, pointed out according to the dielectric waveguide theory that the high loss of optical fiber is not inherent, but caused by the impurities contained in the material. It is predicted that if the content of impurities in the material is reduced, the loss of optical fiber can be reduced to 20dB/km or even less. In 1970, corning glass co., ltd. of the United States successfully developed a low-loss quartz fiber with a loss of 20dB/km, which made the fiber completely qualified as the transmission medium for the transmission of light waves and opened up a new era of optical communication.In order to realize optical fiber communication, it is important to reduce the loss of optical fiber as much as possible. Optical loss the so-called loss refers to the attenuation of optical fiber per unit length, in dB/km. The loss of optical fiber directly affects the transmission distance or the distance between relay stations. Therefore, it is of great practical significance to understand and reduce the loss of optical fiber for optical fiber communication. There are four kinds of loss in optical fiber, namely absorption loss, scattering loss, irregular loss and bending loss. A. Optical fiber absorption loss is caused by the absorption of light energy by optical fiber materials and impurities. They consume light energy in optical fiber in the form of heat energy, which is an important loss in optical fiber loss. 1. Material intrinsic absorption loss, which is caused by the intrinsic absorption of material. It has two bands, one in the near infrared region of 8 12 m, where the band's intrinsic absorption is due to vibration. The natural absorption band of another substance in the ultraviolet band, when the absorption is strong, its tail will be dragged to 0.7 1.1 m band. 2. Impurity absorption, mainly optical fiber materials containing iron, copper, chromium plasma. The higher the metal ion content, the greater the loss, as long as the strict control of the metal ion content. 3. Atomic defect absorption refers to the loss caused by atomic defects in the manufacturing process of optical fiber when glass is subjected to thermal excitation or strong radiation. B. The scattering loss of optical fiber is caused by the coupling or leakage of optical power out of the fiber core due to the micro-fluctuation of atomic density in the fiber material component or the structural defect of fiber waveguide. It is due to the inhomogeneity of the atoms or molecules of the material and the structure of the material. The refractive index of the material produces microscopic inhomogeneity which results in the scattering of transmitted light waves. This scattering is inherent in the material and cannot be eliminated. Rayleigh scattering is inversely proportional to the fourth power of the wavelength, and the loss caused by it can be calculated by the following formula: $\alpha_{SR} \approx \frac{A}{\lambda_0^4}(1 + B\Delta_0)$ Where A and B are constants related to quartz and reference materials. C. Structural irregularity loss is the part of loss caused by tiny structural fluctuations at the core cladding interface and uneven waveguide structure inside the fiber. When the structure of the fiber is irregular, the mode transformation will take place, and some of the transmitted energy will be shot out of the fiber core and become radiation mode, so that the loss will be increased. This loss can be reduced by improving manufacturing techniques. D. Bending loss is the loss caused by the bending of optical fiber axis. Any deviation of the optical fiber axis visible to the naked eye from a straight line is called bending or macro bending. Fiber bending will cause the coupling between the modes in the fiber. When the energy of the propagation mode is coupled into the radiation mode or leakage mode, the bending loss will be generated. The loss increases exponentially as the radius of curvature decreases. In the practical application of optical fiber, bending is inevitable. In order to maintain the same phase at different points on the isofacial plane, the phase velocity of optical wave needs to satisfy the following equation: $\frac{V_{px}}{V_{pl}} = \frac{R+x}{R}$ In the formula, R is the bending radius of the fiber, x is the distance from any point outside the fiber core to the fiber axis, and V is the phase velocity between x point and the fiber axis. $x = \frac{(V_{px} - V_{pl})R}{V_{pl}}$

11 Conclusions

Optical fiber communication has many advantages, such as large transmission capacity, small loss, light weight, good confidentiality and so on. If communication is like a road, then the wider the frequency band of the communication line, the more information it is allowed to transmit, and the larger the information capacity. Optical fiber has many applications in many fields, such as communication, computer LAN, and power system monitoring. With the progress of the society and the increasing demand for information, the transmission capacity of digital system is constantly increasing, and people urgently need to establish a unified worldwide communication network. In this situation, many shortcomings of the existing PDH are gradually exposed, mainly in North America, Western Europe and Asia, the three digital systems are not compatible with each other, there is no unified standard optical interface in the world, making the establishment of international telecommunications network and operation, management and maintenance are very complex and difficult.Optical fiber communication has many advantages, such as large transmission capacity, small loss, light weight, good confidentiality and so on. If communication is like a road, then the wider the frequency band of the communication line, the more information it is allowed to transmit, and the larger the information capacity. Optical fiber has many applications in many fields, such as communication, computer LAN, and power system monitoring. With the progress of the society and the increasing demand for information, the transmission capacity of digital system is constantly increasing, and people urgently need to establish a unified worldwide communication network. In this situation, many shortcomings of the existing PDH are gradually exposed, mainly in North America, Western Europe and Asia, the three digital systems are not compatible with each other, there is no unified standard optical interface in the world, making the establishment of international telecommunications network and operation, management and maintenance are very complex and difficult. Millions of kilometres of fiber-optic cables have been produced since the mid-1970s, when fiber-optic communications became a reality. Ships like the global sentinel built a glass highway around the world. So far, the ships have laid some 6.44 million kilometers of fiber under the ocean floor, enough to cross the Atlantic ocean a thousand times. In addition, the continents laid 483 million kilometers of intricate optical fiber, forming what people say is a glass communication necklace. Today, the global fibre-optic network is not only responsible for the increasing volume of network traffic, but also for the transmission of information for the world's business and banking industry, as well as connecting the world's telephone. If a Chinese had called a friend living in London more than a decade ago, the call would have been transmitted via satellite. Today, the call can be converted into a laser pulse sent over an optical fiber by simply reaching the nearest telephone system relay station. Many countries in the world are now being brought closer together by undersea cables than would have been possible even a few decades ago, let alone hundreds or thousands of years ago. Optical fiber has changed the world, the distance has died, is like this.

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