An Overview on Optical Fiber Communication

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ABSTRACT: This article examines the evolution of optical communication technologies through time, as well as its early failures. The various generations of optical fiber communication, as well as their characteristics, are then examined. Total internal reflection is discussed, as well as various kinds of fibers and their sizes and refractive index profiles, dispersion, and loss processes. Finally, the overall system of optical fiber communication is briefly discussed, as well as its benefits and drawbacks. Future optical fiber communication based on soliton is also emphasized. Optical fiber is a data transmission method that uses light pulses that travel through a long fiber, which is typically composed of plastic or glass. Metal wires are chosen for optical fiber communication transmission because signals move with less harm. Electromagnetic interference has no effect on optical fibers. The complete internal reflection of light is used in the fiber optical cable. The fibers are intended to aid in the propagation of light together with the optical fiber, depending on the power and transmission distance requirements. Long-distance transmission is done using single-mode fiber, whereas shorter distances are done with multimode fiber. These fibers' outer coating need more protection than metal wires.

KEYWORDS: Bandwidth, Optical Fiber, Group Index, Group Velocity, Dispersion.

1. INTRODUCTION

The optical fiber has represented a revolution in the world of telecommunications mainly Because of its ability to transport enormous amounts of data, including video and data, the optical fiber has marked a revolution in the world of telecommunications .Erbium-doped fibers may be used as optical amplifiers to increase the range of an optical signal. transmission. The results of these studies have allowed the spectrum to be expanded. a variety of optical fiber applications, resulting in the creation of novel technologies such as fiber optic cables The topic of this chapter is lasers and optical fiber sensors. An optical fiber is a filament-shaped optical waveguide that is usually constructed of glass[1]. a transparent substance (although it can also be made of plastic materials). An optical fiber is made up of a number of different materials. The core, cladding, and coating or buffer are the three components. Fibers may be made in a variety of ways. A usual cladding diameter is 125 m, whereas the core generally varies from 50 to 100 m. 10 to 50 meters Figure 1 depicts the fundamental construction of an optical fiber.

The core is usually composed of glass and is a cylindrical rod of dielectric material. Light propagates mostly along the fiber's core. A dielectric cladding layer is used as the cladding layer. material having a refractive index of n2 smaller than that of the core material n1[2]. The Generally, cladding is composed of glass or plastic. The cladding reduces the amount of light that escapes through the windows[3]. Reduces scattering loss at the core's surface and preserves the core by releasing it into the surrounding air[4]. It also provides mechanical strength to the fiber by preventing it from collecting surface impurities. The finish A buffer, also known as an optical fiber protector, is a layer of plastic that protects the optical fiber from physical damage. The nucleus and the cladding provide the essential conditions for an optical signal to be directed parallel to the optical fiber[5].

Total internal reflection is the mechanism of light transmission through optical fibers, which is linked to a light beam impinge on the border between two materials with differing refractive indices, as shown in Figure 1. The transmitted beam always emerges at an angle, 2, that is higher than the incident angle, 1 when light is incident from a medium with a high index (n1) to one with a lower index (n2). If we raise the magnitude of 1, we will eventually reach a point where 2 equals 90o; at this point, the angle of incidence is known as the critical angle. There is no refraction of light if the angle of incidence is greater than c, and all of the rays (radiation) are completely internally reflected toward the material with the refractive index n1.A ray must hit the core/cladding contact at an angle higher than the critical angle, c, to be effectively "trapped" inside the fiber core[6]. Snell's rule (n1 sin 1= n2 sin 2) relates the critical angle to the refractive indices of the core n1 and the cladding n2, and it may be computed as c=arcsine (n2/n1).

Any ray entering the fiber with an incidence angle of 0 between 0 and will be internally reflected along the fiber core, according to this criterion. This angle is known as the acceptance angle, and it is linked to an optical fiber's numerical aperture (NA) as follows: The refractive index of the medium surrounding the optical fiber is n0, and NA = n0 sin = (n12 - n22)1/2. Step-index fibers and graded-index fibers are the most frequent kinds of fibers utilized. The refractive index of the core is consistent throughout in the first instance, but abruptly changes (or steps) at the cladding border in the second. The core refractive index is made to change as a function of the radial distance from the fiber center in the second instance. Single-mode and multimode fibers are subcategories of both kinds of fibers. A single-mode fiber can only support one mode of propagation, while multimode fibers can support hundreds. The attenuation of an optical fiber as a function of wavelength is one of its most important properties.

Because the optical signal traveling via an optical fiber suffers the least attenuation in this area, optical communications systems function in the band centered at 1550 nm. The third window of communication is the term given to this area. New materials are now being researched for the manufacture of optical fibers that reduce signal attenuation even further for communications applications. Low attenuation, broad bandwidth, decreased weight and compactness, and immunity to electromagnetic interference are the primary benefits of optical fiber technology (EMI). The following sources provide a more detailed explanation of optical fiber qualities and properties Optical amplifiers (Erbium Doped Fiber Amplifiers, EDFAs), fiber lasers, and optical fiber sensors are among the technologies being researched and developed today. Fiber optics operate by transmitting coded data down a glass or plastic conduit through a beam of light. Engineers utilized them to transmit telephone conversations at the speed of light in the 1960s. Optical fibers are very tiny strands of glass or plastic that go through each wire. Each cable may have as few as two or as many as several hundred strands.

The strands, which are barely a tenth of the width of a human hair, can individually transmit approximately 25,000 phone calls. As a result, a cable with hundreds of strands may transport millions of calls. The light bounces back and forth between the cable pipe's walls. Like a bobsled on an ice track, each photon (light particle) bounces down the pipe. While you would anticipate light to seep through the sides of a glass pipe, the light is reflected back into the pipe at shallow angles (no more than 42 degrees). Total internal reflection is the term for this. In addition, the cable maintains the light in the pipe. The piece through which light passes is the cable's core. Cladding is the second layer of glass that wraps around the exterior of the core. Light signals are kept within the core by the cladding. In a fiber-optic communication system The optical source's intensity is modulated by the incoming electrical signal. An electro-optic modulator (or) an acousto-optic modulator may modify the optical carrier internally or externally[7]. Electro-optic modulators (KDP, LiNbO3, or beta barium borate) are often employed as external modulators nowadays. They modify light by altering its refractive index in response to an electrical signal[8].

The encoder's input electrical signal is in the form of coded digital pulses, which control the intensity of the light from the laser diode or LED and transform it into optical pulses in the digital optical fiber communication system. A photo detector, such as an avalanche photodiode (APD) or a positive-intrinsicnegative (PIN) diode, transforms optical pulses into electrical pulses in the reception stage[9]. The electrical pulses are converted into the original electric signal by a decoder.

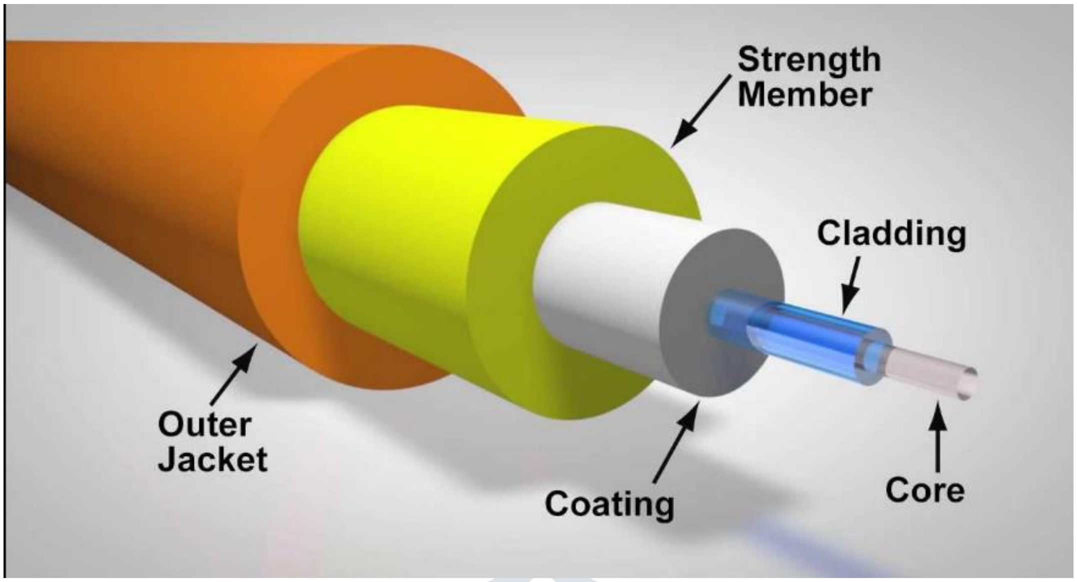

Figure 1: Diagrammatic Representation of Optical Fiber

1.1 Types Of Optical Fiber

We know that total internal reflection is used to direct light or optical communications through silica glass fibers. A typical glass fiber has a central core glass (50 m) that is surrounded by a cladding composed of a glass with a slightly lower refractive index than the core. The fiber's total diameter ranges from 125 to 200 m. Cladding is required to offer appropriate light direction, i.e., to keep light energy inside the core, as well as to give high mechanical strength and scratch resistance to the core[2]. Figure 2 shows the diagrammatic representation of step index fiber. We have two kinds of fibers based on the refractive index profile.

1.1. Step index fiber:

The refractive index of the core is uniform throughout and abruptly changes at the core cladding border in a step index fiber. The light rays traveling through the fiber are meridional rays that cross the fiber axis at each reflection at the core cladding border and propagate in a zig-zag pattern. A step-index profile is defined by a consistent refractive index inside the core and a rapid drop in refractive index at the core-cladding contact, resulting in lower refractive index cladding. A power-law index profile with a profile parameter approaching infinity corresponds to a step-index profile. Most single-mode fibers and some multimode fibers utilize the step-index profile[10].

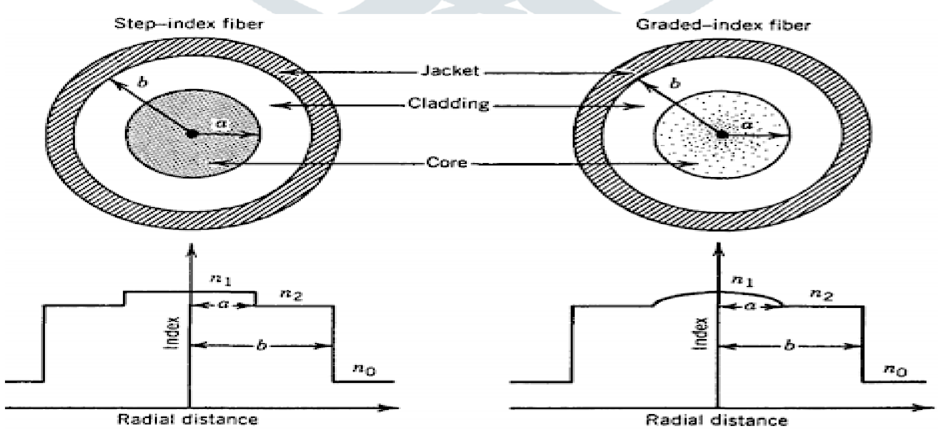

Figure 2: Diagrammatic Representation of Step Index Fiber [Google User Content]

1.2. Graded index fiber:

The refractive index of the core is made to fluctuate in a parabola fashion in a graded index fiber, with the highest value of refractive index in the core's center. The light rays that pass through it are skewed rays or helix rays that never cross the fiber axis and propagate in a helical (or) spiral pattern all around fiber direction. Figure 3 shows diagrammatic representation of graded index fiber.

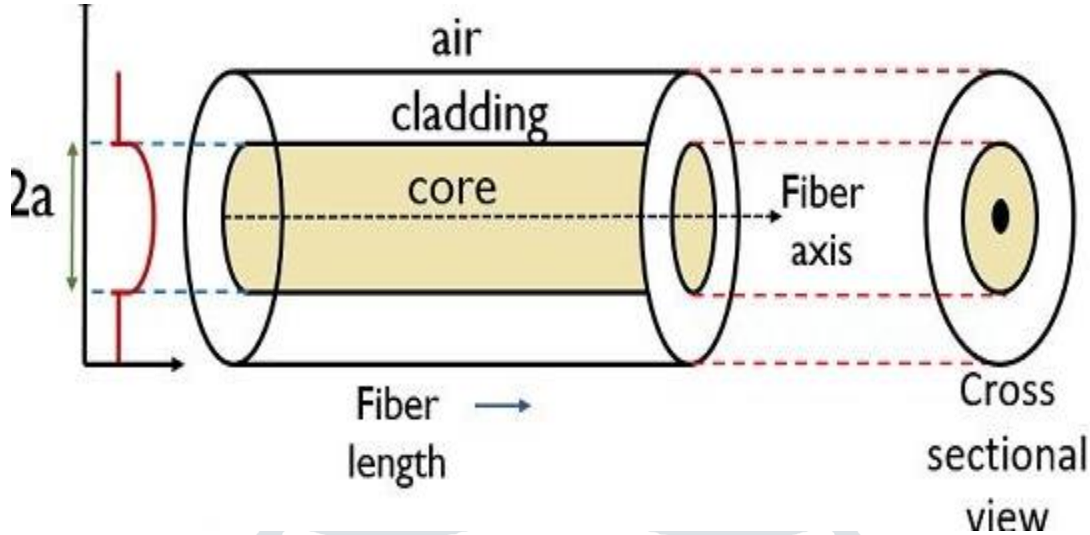

Figure 3: Diagrammatic Representation of Graded Index Fiber [Circuit Globe]

Multimode fibers and single mode fibers are distinguished by the number of modes propagating through the fiber. The mathematical notion of mode describes the characteristics of electromagnetic wave propagation in a waveguide. The nature of the electromagnetic field pattern (or) configuration along the light path inside the fiber is referred to as mode. When microwaves propagate down the z-axis, there exist transverse electric (TE) modes with Ez = 0 but Hz 6= 0 and transverse magnetic (TM) modes with Hz = 0 but Ez 6= 0 in metallic waveguides. There are hybrid modes in optical fibers that contain both axial electric and magnetic fieldsEz and Hz, in addition to TE and TM modes. EH and HE hybrid modes are the two types of hybrid modes. The *axial magnetic field Hz is relatively strong in EH modes, while* the axial electric field Ez is more strong in HE modes. Because light is linearly polarized, these modes are now referred to as linearly polarized (LP) modes.

1.3. Single mode fibers:

A single-mode optical fiber (SMF) is a kind of optical fiber that only carries one mode of light, the transverse mode. The Helmholtz equation for waves is obtained by combining Maxwell's equations and the boundary conditions, and modes are the possible solutions. These modes define how the wave propagates through space, or how the wave is distributed. Waves with the same mode but distinct frequency may exist. This is the situation with single-mode fibers, when waves of various frequencies but the same mode are dispersed in space in the same manner, resulting in a single beam of light. Despite the fact that the ray travels parallel to the fiber's length, it is frequently referred to as transverse mode since its electromagnetic oscillations are perpendicular (transverse) to the fiber's length. Charles K. Kao received the Nobel Prize in Physics in 2009 for his theoretical work on single-mode optical fibers. The G.652 and G.657 standards define the most widely used single-mode optical fibers.

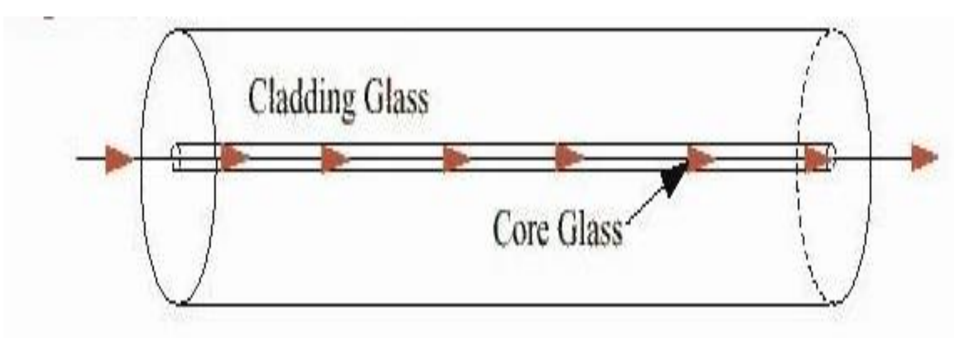

Figure 3: Diagrammatic Representation of Single Mode Optical Fiber [M2OPTICS].

1.4. Multimode fibers:

Multi-mode optical fiber is a kind of optical fiber that is mostly used for short-distance communication, such as inside a building or across a campus. Data speeds of up to 100 Gbit/s may be sent via multi-mode connections. Because of modal dispersion, multi-mode fiber has a relatively large core diameter, allowing multiple light modes to be propagated while limiting the maximum length of a transmission link. The standard G.651. Defines the most widely used forms of multi-mode optical fiber. The core diameter and relative refractive index difference are usually greater in multimode fibers than in single mode fibers. Because of self-focusing effects, signal distortion is extremely minimal in multimode graded index fiber. Because of the parabolic change in refractive index of the core, light rays move at different speeds along various pathways of the fiber. As a consequence, light beams at the outside border of the core move quicker than those in the core's center. Because of the helical route of light propagation, light rays are constantly tried to focus as they travel down the fiber, and nearly all of the rays reach the fiber's exit end at the same time. It is simple to launch light into the fiber and to fabricate the fiber. Local area networks often utilize these fibers. Figure 4 shows diagrammatic representation of multimode optical Fiber.

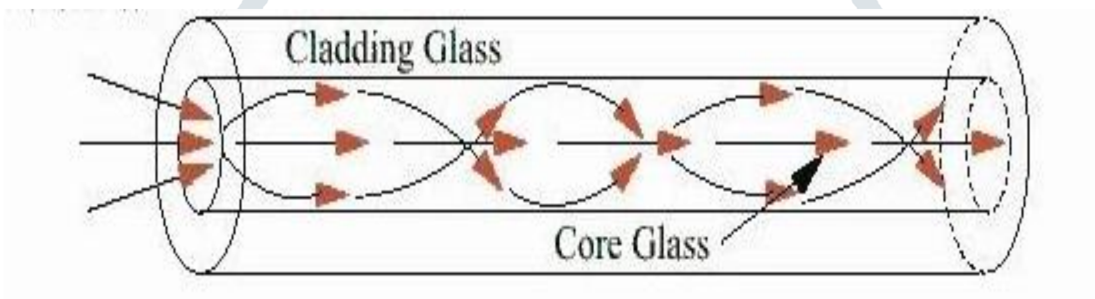

Figure 4: Diagrammatic Representation of Multimode Optical Fiber [M2OPTICS]

2. DISCUSSION

A flexible, transparent optical fiber (or fiber in British English) is produced by pulling glass (silica) or plastic to a diameter slightly larger than that of a human hair. Optical fibers are most often employed to transport light between the fiber's two ends, and they're widely utilized in fiber-optic communication, where they allow transmission over greater distances and at higher bandwidths (data transfer speeds) than electrical cables. Signals flow via fibers with less loss than through metal wires, and fibers are resistant to electromagnetic interference, an issue that metal wires suffer from. Fibers are also utilized for lighting and imaging, and they are often bundled in bundles so that they may be used to transport light into or pictures out of restricted places, such as a fiberscope. Fiber optic sensors and fiber lasers, for example, are two applications for which specially tailored fibers are employed. A core is usually surrounded by a transparent cladding material with a lower index of refraction in optical fibers. The phenomenon of complete internal reflection, which causes the fiber to function as a waveguide, keeps light in the core. Multi-mode fibers offer several propagation routes or transversal mode, while single-mode fibers allow just one mode (SMF). Multi-mode fibers have a larger core diameter and are often utilized for short-distance communication connections and applications requiring high energy transfer.

3. CONCLUSION

Many optical fiber communication links exist around the world today that do not use optical solitons. We can achieve high-quality telecommunication at a lower cost by introducing optical solitons as light pulses through fibers. Within a few years, solitons will usher in a major revolution in optical fiber communication. Despite the fact that fiber optics have been available for decades, our technology is just now catching up to fully use them. Scientists and researchers will continue to discover new methods to integrate fiber optics into our daily lives in the near future. Fiber optics will undoubtedly continue to develop as a result of its potential to enhance communication and gadgets, allowing humanity to increase their communication, medical, and military capabilities.

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