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An Overview of Optical Fibers

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ANOVERVIEWOFOPTICALFIBERS

Strictly as per the compliance and regulations of:

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I. Introduction

The science of optical fibers is a fascinating field. A great amount of research work is being carried out in all parts of the world to promote optical fiber technology. One of the most interesting developments in recent years in the field of telecommunication and data transmission systems is the use of optical bers to carry information in a way similar to that employing radiowaves and microwaves [28]. Reliable and widespread sources for transporting laser beams at a distance, optical fibers come in many forms.

II. Technical Background and Significance

Optical fibers are one of the perfect physical environment and important scientific achievements in the last century [2, 26]. They are certainly of con siderable interest because they represent the best current way to transport very high debits of digital information. The needs in this area are likely to increase very strongly in the near future [9, 25]. It is by this means that circulate over 80% of global long distance traffic information.

As early as the 1940s engineers and scientists began to consider that telecommunications in the distant future would be through optical channels [18]. The idea of using optical fibers to transmit information appeared in the early 1960s with the advent of lasers, and the advantages of transmitting information [9, 19, 25] by optical fibers are multiple compared to other communication media [12] (optical fibers are much lighter and thinner compared to the conventional copper cables, and they are cheaper than copper wires. One pair of optical fibers carries a rate of 10 times stronger than 250 pairs of copper wires). Thanks to comfort and energy saving provided by optical fibers, these last are perfect for:

- Medical applications.
- The lighting field.
- The road transport system.
- Various military applications requiring a high quality equipment.

It was in 1966 that was launched the idea of carrying optical signals (over a fiber) over long distances, but it will take years to master the manufacturing processes and to control the composition of materials which decisively influences the attenuations (losses) of the transmitted signal. It will then be possible to obtain attenuations that are small enough to make possible the transmission of signals over distances large enough to make the optical technique competitive. Starting in 1960 at 1,000 decibels per kilometer (*dB/km*), attenuation fell to 20 *dB/km* in 1975 and then to 0.2 *dB/km* in 1984.

Optical fibers are rapidly becoming the transmission medium of choice for new telecommunication [1]. They have played a key role in making possible the extraordinary growth in world-wide communications that has occurred in the last 25 years, and are vital in enabling the proliferating use of the Internet [8]. However, more and more, optical fibers are becoming very popular in a very short time and making an impact and serious commercial inroads in other fields besides communications, such as in industrial sensing, bio medical laser delivery systems, military gyro sensors, as well as automotive lighting and control [15].

Optical Fiber is new medium, in which information (voice, data or video) is transmitted with high speed, following the transmission sequence [24].

III. Features and Properties of Optical Fibers

An optical fiber (or a fiber optic cable) is a cylindrical (standard form) dielectric waveguide (made of low-loss materials), it is a thin lament of glass, assumed to be infinitely extended along its propagation axis, denoted by OZ. An optical fiber is flexible and transparent fiber which permits transmission of light waves over longer distances and at higher bandwidth

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(data rates) than other forms of telecommunications, it is used too to propagate radiation in the infra-red to visible region of the spectrum [11, 21, 24, 28].

a) Basic construction of optical fiber

An optical ber consists mainly of 4 elements (layers) [4, 6, 23, 28]:

- Core: (the innermost region of the fiber), center of the structure. It is the area for the propagation of light rays. It carries the signal.
- Cladding: (an external mantle), a zone surrounding the core, made of a material whose refractive-index is lower than the core index, so as to con ne the propagation of light rays and to keep the core clean.
- Protective coating: it is a primary buffer material used to help shield the core and cladding from physical degradation and to protect against abrasion, moisture, solvents and other contaminants.
- Jacket: additional (outer) layer which holds one or more fibers in a cable, it is used to prevent damage and to increase the strength of the fiber.

Both the core and the cladding are made of glass, but the index of refraction of the core is slightly higher than that of the cladding. The difference in materials used in the making of the core and the cladding creates an extremely reflective surface at the point in which they interface. The protective coating and the jacket do not have a direct role in light confinement. Their role, however, is to provide mechanical support and protection for the inner core and cladding layers [4]. The light is transmitted through the core but to a small extent, it travels in the cladding and so the optical clarity of the cladding is still important [6].

A typical optical fiber cable usually includes several optical fibers around a central steel cable. Various protective layers are applied, depending on the harshness of the environment where the cable will be situated.

b) Types of optical fibers

Generally, optical fibers are of two types: [28]

i. *First type: Single-mode (SMF)*

The simplest type of optical fiber is called single-mode fiber, or alternatively mono-mode fiber. It has a very thin core about 5 10 *μm* in diameter. It supports only one mode. In a single-mode fiber, all signals travel straight down the middle without bouncing o the edges. Cable TV, Internet and telephone signals are generally carried by single-mode fibers, wrapped together into a huge bundle. Cables like this can send information over 100 km (60 miles).

ii. *Second type: Multi-mode (MMF)*

Another type of optical fiber is called multi-mode fiber. Each optical fiber in a multi-mode cable is about 10 times bigger than one in a single-mode cable. This means light beams can travel through the core by following a variety of different paths, in other words, in multiple different modes. Multi mode cables can send information only over relatively short distances and are used (among other things) to link computer networks together.

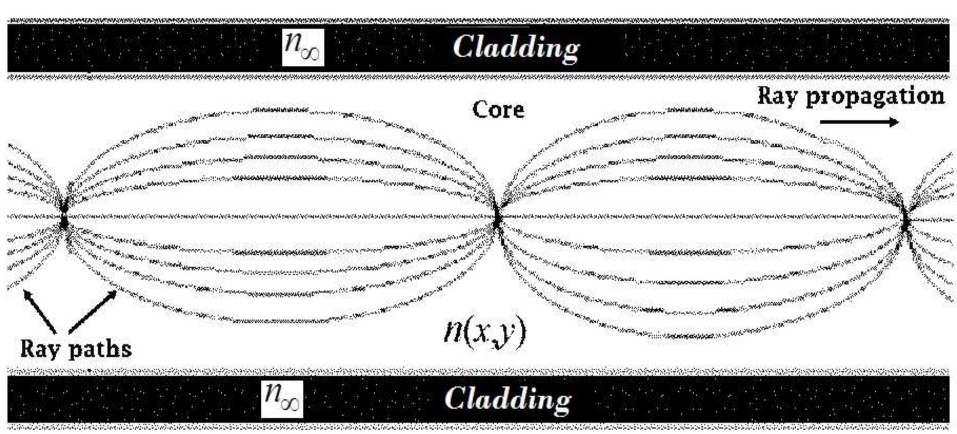

Figure 1: Light propagation in a multi-mode graded-index optical fiber (having an homogenous cladding)

Multi-mode optical fibres are dielectric waveguides which can have many propagation modes. Light in these modes follows paths that can be represented by skew rays as shown in Figure 1. The cladding has a refractive index n_∞, a parameter related to the dielectric constant, which is slightly lower than the refractive-index of the core region [13, 18].

Multi-mode fibers are no longer used in long distance (> 10 km) telecommunications due to the significant performance advantages offered by single mode systems. Many short-link applications, for which intermodal dispersion is not a problem, still make use of multi-mode fibers.

IV. Uses for Fiber Optics

Optical fiber cables are in use for telephone data since 1980 [16]. They have become in the last few years an extremely attractive method of data transfer [27]. They have a wide number of applications, they are used as:

- Light guides in medicine.
- Lighting.
- Imaging optics.
- Aerospace industry.
- Industrial tool.
- Other applications.

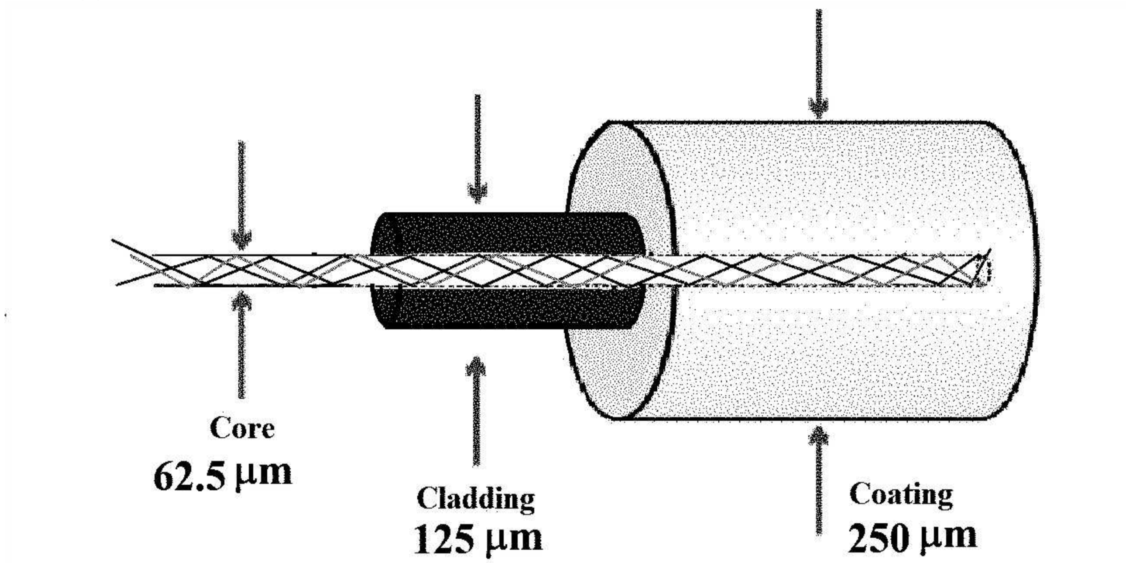

Figure 2: Geometry of a typical multi-mode optical fiber (having a circular cross section)

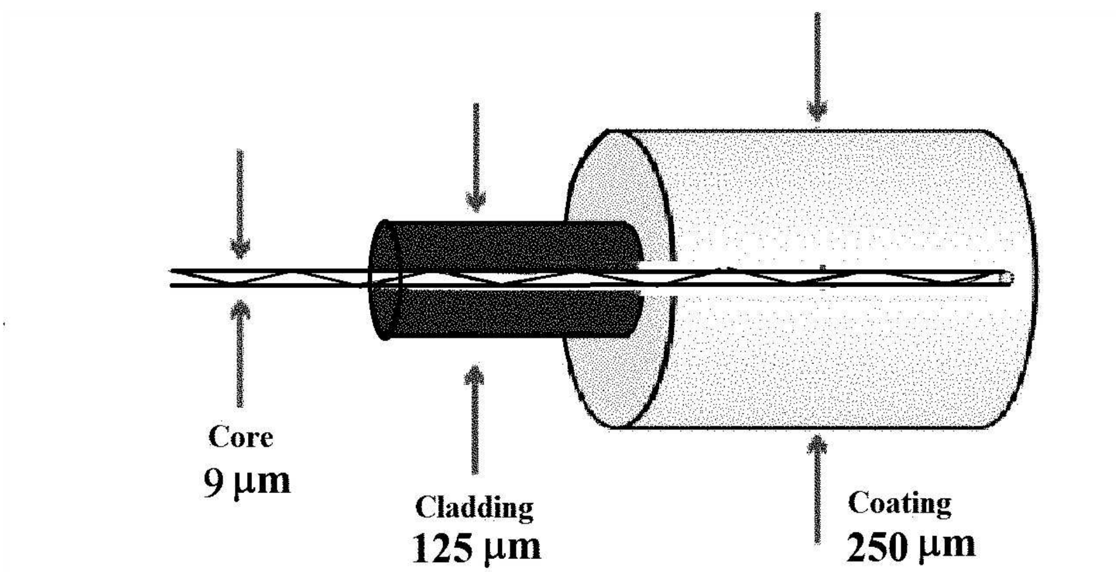

Figure 3: Geometry of a typical single-mode optical fiber (having a circular cross section)

Shooting light down a pipe seems like a neat scientific party trick, and you might not think there'd be many practical applications for something like that. But just as electricity can power many types of machines, beams of light can carry many types of information, so they can help us in many ways. We don't notice just how commonplace fiber-optic cables have become because the laser-powered signals they carryflicker far beneath our feet, deep under office floors and city streets. The technologies that use it computer networking, broadcasting, medical scanning, and military equipment do so quite invisibly [15, 17, 23, 25].

V. Refractive-Index Profile

As the refractive-index is simply a ratio of the speed of light in a material to the speed of light in free space, it does not have any units [6]. The refractive-index pro le describes the relation between the indices of the core and cladding. It refers to the variation of the refractive-index in a cross section of the optical part of the fiber. Generally, two main refractive-index pro les exist [18, 24, 26] (see Figure 2.3):

- Step-index (uniform-core): frequently used type of fiber.
- Graded-index (nonuniform-core).

The standard core diameter of step-index optical fiber is typically between 8 and 10 *µm* while the diameter of the cladding is about 125*µm*, whereas typical graded-index fibers have core diameter of 50, 62.5, 85 or 100 *µm* and a cladding diameter of 125 *µm* [5, 26]. The refractive-index changes abruptly between the core and the cladding of a step-index optical fiber [6], while the transition (of the index of refraction) between the core and cladding is gradual in a graded-index optical fiber.

The interest in graded-index optical fibers is increasing owing to their extensive possible applications. Without these components, it is difficult to imagine any further development of fiber-optical systems for transmitting information, medical and industrial endoscopy, copying technology, fast computer input-output devices, and facsimile communication [3].

Table 1: Refractive-index of some substances at 20°C [20]

Material	Refractive-index
Air	1.00029
Acetone	1.36
Pure alcohol	1.32
Amber	1.54
Crystal	1.60 to 2.00
Diamond	2.42 to 2.75
Carbon disulfide	1.628
Carbon dioxide	1.00045
Ethanol	1.361
Silicone oil	1.393 to 1.403
Benzene	1.501
Water	1.33
Emerald	1.57
Ice	1.31
Glycerine	1.47
Lapis lazuli	1.61
Opaline	1.45
Plastic	1.460
Plexiglass	1.51
Polystyrene	1.20
Ruby	1.78
Quartz	1.55 or 1.64
Sapphire	1.77
Topaz	1.61
Tourmaline	1.27
Glass	1.50
Crown glass	1.52
Glass int	1.56-1.65-1.89
Kerosene	1.44
Turpentine oil	1.47

VI. Advantages of Fiber Optics

Large technology companies such as *Google* have expanded into the fiber optic services with *Google* fiber. The optic communication components are widely applied in today's telecom field thanks to many advantages associated with using optical fibers, of which we quote:

- Dielectric benefits

An optical fiber guarantees a perfect electrical insulation between transmitter and receiver [16]. The optical fiber is completely immune to many environmental factors that affect copper cable. The core is made of glass, which is an insulator, so no electric current can flow through [7].

- *Less susceptibility to temperature fluctuations*

You can run fiber cable next to industrial equipment without any worries. Optical fibers withstand extreme temperatures better than electrical cables [16]. The optical fiber is also less susceptible to temperature fluctuations than copper and can be submerged in water [7].

- *Signal strength*

The signal strength of fiber-optic Internet does not degrade as quickly over distance. Organizations in relatively large spaces could benefit from better signal strength throughout the facility.

- *Flexibility*

Because fiber optics are so flexible and can transmit and receive light (they are used in many flexible digital cameras).

- *Ease of installation*

Optical fibers can be more easily produced and installed. Long lengths make fiber-optic cable installation much easier to be used in temporary or portable installations. Optical fiber cables can be installed with the same equipment used to install copper and coaxial cables, with some modifications due to the small size and limited pull tension and bend radius of optical cables.

- *Speed*

Fiber-optic Internet is many times faster than even the highest-speed copper Internet connections.

- *Small size*

Optical fibers are smaller in diameter than copper lines.

- *Lightweight*

Optical fibers are lightweight.

- *Non- flammable*

Because no electricity is passed through optical fibers, there is no re hazard.

- *Secure transmission*

Hackers and information thieves are a major threat in today's cyberspace. Cable tapping and signal interception can easily be per formed with basic business Internet cables. Optical fibers are the most secure medium available for carrying sensitive data, since intercepting data transmission through a fiber cable is difficult. Optical fibers are difficult to tap. As they do not radiate electromagnetic energy, emissions cannot be intercepted. As physically tapping the fibre takes great skill to do undetected. In the rare cases that fiber optic cables are tapped, visible light transmissions make it easy to identify the hacked cables.

- *Direct connection with no echoes*

Thanks to optical fibers, you have a direct connection with no echoes, while you often hear an echo on the telephone because the signal is bounced o a communications satellite.

- *Long transmission distance*

The promise of fiber optics was the possibility of increased transmission rates [6].

A fiber-optic system using a glass fiber is certainly capable of carrying light over long distances. By converting an input signal into short flashes of light, the optical fiber is able to carry complex information over distances of more than a hundred kilometers without additional amplification. This is at least five times better than the distances attainable using the best copper coaxial cables [6].

- *Cost saving*

Several miles of fiber optics cable can be made cheaper than equivalent lengths of copper wire. This saves the provider (cable TV, Internet) and money. Moreover, fiber-optic cable costs less to maintain than traditional copper lines, saving us all time and money.

- *Low cost*

Thin strands of glass, flexible enough to be coiled around a finger, and as inexpensive as copper wire, with no maintenance cost because the light-guiding index pro le is built right into the fiber structure [16]. Furthermore, the optical fiber resists most corrosive elements that attack copper cable.

VII. Inconveniences of Fiber Optics

Optical Fibers do not know many negative points.

- *Fragile components*

Optical fiber is a fragile material. Compared to copper, it requires more protection around the cable.

- *Damage Caused by Wildlife*

Many birds, for example, find the *Kevlar* reinforcement material of the optical cable cladding particularly attractive as a nesting material, so they peck the claddings to obtain the materials.

Moreover, Beavers and other rodents use exposed fiber optic cable to sharpen their teeth and insects like ants want plastic shielding in their power supply, so they are often found nibbling at fiber optic cabling.

Sharks have also been known to damage fiber optic cabling when placed underwater, especially at repetitive points. There is a plant called the Christmas Tree that treats the fiber optic cable as a root and wraps itself around the cable so strongly that the light pulses that pass through the fiber are smothered.

- *Affected by Chemicals*

Optical fibers can be affected by various chemicals, including hydrogen gas (a problem on submarine cable).

The connection of two optical fibers requires delicate polishing and perfect parallelism.

- *Opacity*

It is known that most fibers become opaque when exposed to radiation. 11

VIII. Conclusion

As an engineering discipline, fiber optics is both fascinating and challenging [4]. The shortage of copper resources accelerated the widespread use of the optical fiber communications [18].

As the technology advances, optical fibers will no doubt find wider applications in various areas of research and engineering. The field still offers a number of interesting and challenging problems to the investigator [14].

At present, the optical fibers, an important and promising material, are the only practical waveguides for optical communications [18]. They have attracted more and more attention and extended their applications to various scientific and practical aspects [22]. Fiber-optic technology won't fade away [10], today fiber optics is either the dominant medium and logical choice for every communication system, and the future will see optical fibers technology improve exponentially.

In today's network, optical fiber cable becomes more popular than before and is widely used. In the long run, optical fiber will replace copper.

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