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Review of Optical Fiber Communication

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Abstract–

Fiber optic systems are important telecommunication infrastructure for world-wide broadband networks. Wide bandwidth signal transmission with low delay is a key requirement in present day applications. Optical fibers provide enormous and unsurpassed transmission bandwidth with negligible latency, and are now the transmission medium of choice for long distance and high data rate transmission in telecommunication networks. This paper gives an overview of fiber optic communication systems including their key technologies, and also discusses their technological trend towards the next generation.

Introduction

An **optical fiber** or **optical fiber** is a flexible, transparent fiber made by drawing glass (silica) or plastic to a diameter slightly thicker than that of a human hair.[1] 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 wire cables. Fibers are used instead of metal wires because signals travel along them with lesser amounts of loss; in addition, fibers are also immune to electromagnetic interference, a problem from which metal wires suffer excessively.[2] Fibers are also used for illumination, and are wrapped in bundles so that they may be used to carry images, thus allowing viewing in confined spaces, as in the case of a fiberscope.[3] Specially designed fibers are also used for a variety of other applications, some of them being fiber optic sensors and fiber lasers.[4]

Optical fibers typically include a transparent core surrounded by a transparent cladding material with a lower index of refraction. Light is kept in the core by the phenomenon of total internal reflection which causes the fiber to act as a waveguide.[5] Fibers that support many propagation paths or transverse modes are called multi-mode fibers (MMF), while those that support a single mode are called single-mode fibers (SMF). Multi-mode fibers generally have a wider core diameter and are used for short-distance communication links and for applications

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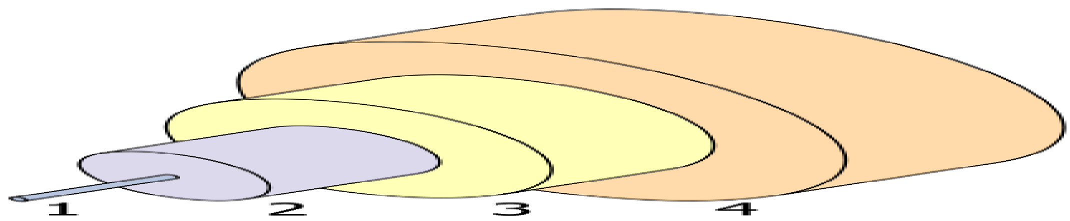

Figure 1 Optical fiber cable

Where high power must be transmitted.[citation needed] Single-mode fibers are used for most communication links longer than 1,000 meters (3,300 ft).[citation needed]

Review of Literature

Guiding of light by refraction, the principle that makes fiber optics possible, was first demonstrated by Daniel Colladon and Jacques Babinetin Paris in the early 1840s. John Tyndall included a demonstration of it in his public lectures in London, 12 years later.[9] Tyndall also wrote about the property of total internal reflection in an introductory book about the nature of light in 1870:When the light passes from air into water, the refracted ray is bent *towards* the perpendicular... When the ray passes from water to air it is bent *from* the perpendicular... If the angle which the ray in water encloses with the perpendicular to the surface be greater than 48 degrees, the ray will not quit the water at all: it will be *totally reflected* at the surface.... The angle which marks the limit where total reflection begins is called the limiting angle of the medium. For water this angle is 48°27′, for flint glass it is 38°41′, while for diamond it is 23°42′.[10][11]

In the late 19th and early 20th centuries, light was guided through bent glass rods to illuminate body cavities.[12] Practical applications such as close internal illumination during dentistry appeared early in the twentieth century. Image transmission through tubes was demonstrated independently by the radio experimenter Clarence Hansell and the television pioneer John Logie Baird in the 1920s. In the 1930s, Heinrich Lamm showed that one could transmit images through a bundle of unclad optical fibers and used it for internal medical examinations, but his work was largely forgotten.[9][13] In 1953, Dutch scientist Bram van Heel first demonstrated image transmission through bundles of optical fibers with a transparent cladding.[13] That same year, Harold Hopkins and Narinder Singh Kapany at Imperial College in London succeeded in making image-transmitting bundles with over 10,000 fibers, and subsequently achieved image transmission through a 75 cm long bundle which combined several thousand fibers.[13] Their article titled "A flexible fiberscope, using static scanning" was published in the journal *Nature* in 1954.[14][15]The first practical fiber optic semi-flexible gastroscope was patented by Basil Hirschowitz, C. Wilbur Peters, and Lawrence E. Curtiss, researchers at the University of Michigan, in 1956. In the process of developing the gastroscope, Curtiss produced the first glass-clad fibers; previous optical fibers had relied on air or impractical oils and waxes as the low-index cladding material. A variety of other image transmission applications soon followed.Kapany coined the term 'fiber optics' in an article in *Scientific American* in 1960, and wrote the first book about the new field.[16][13]The first working fiber-optical data transmission system was demonstrated by German physicist Manfred Börner at Telefunken Research Labs in Ulm in 1965, which was followed by the first patent application for this technology in 1966.[17][18] NASA used fiber optics in the television cameras that were sent to the moon. At the time, the use in the cameras was classified *confidential*, and employees handling the cameras had to be supervised by someone with an appropriate security clearance.[19]

Charles K. Kao and George A. Hockham of the British company Standard Telephones and Cables (STC) were the first, in 1965, to promote the idea that the attenuation in optical fibers could be reduced below 20 decibels per kilometer (dB/km), making fibers a practical communication medium.[20] They proposed that the attenuation in fibers available at the time was caused by impurities that could be removed, rather than by fundamental physical effects such as scattering. They correctly and systematically theorized the light-loss properties for optical fiber, and pointed out the right material to use for such fibers — silica glass with high purity. This discovery earned Kao the Nobel Prize in Physics in 2009.[21]The crucial attenuation limit of 20 dB/km was first achieved in 1970 by researchers Robert D. Maurer, Donald Keck, Peter C. Schultz, and Frank Zimar working for American glass maker Corning Glass Works.[22] They demonstrated a fiber with 17 dB/km attenuation by doping silica glass with titanium. A few years later they produced a fiber with only 4 dB/km attenuation using germanium dioxide as the core dopant. In 1981, General

Electric produced fused quartz ingots that could be drawn into strands 25 miles (40 km) long.[23]

Initially high-quality optical fibers could only be manufactured at 2 meters per second.[24] Chemical engineer Thomas Mensah joined Corning in 1983 and increased the speed of manufacture to over 50 meters per second, making optical fiber cables cheaper than traditional copper ones.[24] These innovations ushered in the era of optical fiber telecommunication.The Italian research center CSELT worked with Corning to develop practical optical fiber cables, resulting in the first metropolitan fiber optic cable being deployed in Torino in 1977.[25][26] CSELT also developed an early technique for splicing optical fibers, called Springroove.[27]Attenuation in modern optical cables is far less than in electrical copper cables, leading to long-haul fiber connections with repeater distances of 70–150 kilometers (43–93 mi). The erbium-doped fiber amplifier, which reduced the cost of long-distance fiber systems by reducing or eliminating optical-electrical-optical repeaters, was co-developed by teams led by David N. Payne of the University of Southampton and Emmanuel Desurvire at Bell Labs in 1986.

Construction Parameters

"Even with the much more resilient and robust bend-insensitive varieties, optical fiber is still glass and requires both skill and knowledge to install."

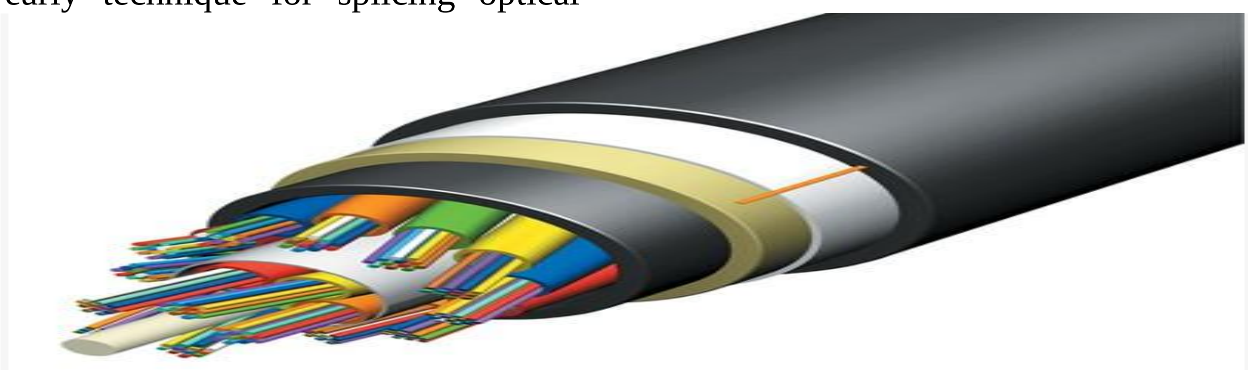

Figure 2 Construction-Optical Fibre Cable Fibre Geometric Parameters

Fibre can either be single-mode (SM) or multimode (MM). Fibre sizes are expressed by using two numbers e.g. 9/125. The first number refers to the core size in microns and the second number refers to the core and cladding size combined in microns. It is impossible to differentiate between SM and MM fiber with the naked eye. There is no difference in the outward appearances; both are 125 microns in size – only the core size differs.

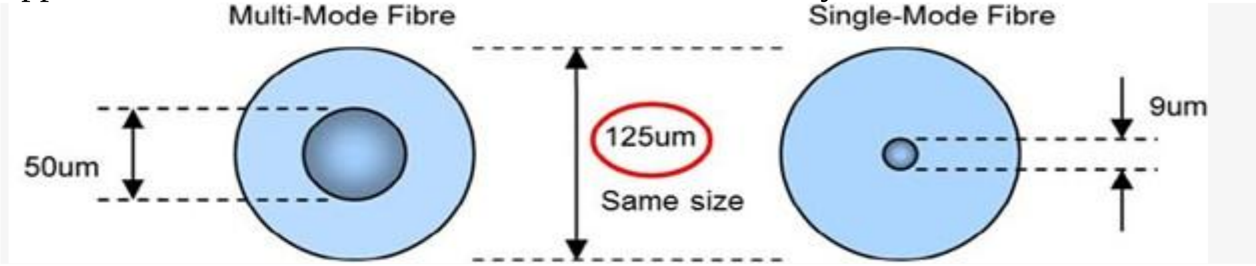

Figure 3 Fiber Geomtric parameters Fibre Construction:

Core: The optical core is the light-carrying element at the center and is usually made up of a combination of silica and germanium.

Cladding: Cannot be removed! The cladding surrounding the core is made of pure silica and has a slightly lower index of refraction (i.e. less dense) than the core. This lower refractive index causes the light in the core to reflect when encountering the cladding and remain trapped within the core.

Figure 4 Fiber core cladding and buffer coating

Buffer coating: This is removed during stripping for splicing or connectorization and acts as a shock absorber to protect the core and cladding from damage.

Cable Jackets: Polyethylene (PE) is the material of choice for use as an Outside Plant (OSP) cable jacket. The performance of raw PE can degrade rapidly through exposure to sunlight. For this purpose, Carbon Black is combined with the PE and is used to absorb the UV light and subsequently dissipates. Jacket colors other than black are used for reasons of enhancing identification.

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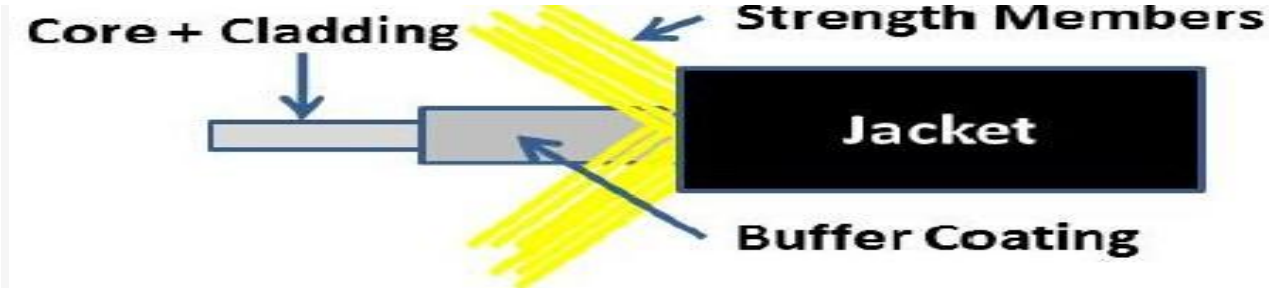

Figure 5 Cable jacket and buffer coating

Cable jackets shall be marked with manufacturer's name, month and year of manufacture, sequential meter markings, fiber type, the number of fiber's, along with a telecommunications handset symbol. Cables without these markings will not pass inspections and should not be installed.

Strength cable members

***Figure 6** Cable GYTA53*

Advantages & Disadvantages With Optical Fibres

ADVANTAGES	DISADVANTAGES
Bandwidth - Fibre optic cables have a much	**Cost** - Cables are expensive to install but last longer than

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greater bandwidth than metal cables. The amount of information that can be transmitted per unit time of fibre over other transmission media is its most significant advantage. With the high performance single mode cable used by telephone industries for long distance telecommunication, the bandwidth surpasses the needs of today's applications and gives room for growth tomorrow.

Low Power Loss - An optical fibre offers low power loss. This allows for longer transmission distances. In comparison to copper; in a network, the longest recommended copper distance is 100m while with fibre, it is 2000m.

Interference - Fibre optic cables are immune to electromagnetic interference. It can also be run in electrically noisy environments without concern as electrical noise will not affect fibre.

Size - In comparison to copper, a fibre optic cable has nearly 4.5 times as much capacity as the wire cable has and a cross sectional area that is 30 times less.

Weight - Fibre optic cables are much thinner and lighter than metal wires. They also occupy less space with cables of the same information capacity. Lighter weight makes fibre easier to install.

Safety - Since the fibre is a dielectric, it does not present a spark hazard.

Security - Optical fibres 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, fibre is the most secure medium available for carrying sensitive data.

Flexibility - An optical fibre has greater tensile strength than copper or steel fibres of the same copper cables.

Transmission - transmission on optical fibre requires repeating at distance intervals.

Fragile - Fibres can be broken or have transmission loses when wrapped around curves of only a few centimetres radius. However by encasing fibres in a plastic sheath, it is difficult to bend the cable into a small enough radius to break the fibre.

Protection - Optical fibres require more protection around the cable compared to copper

Application of Optical Fiber

The use and demand for optical fiber has grown tremendously and optical-fiber applications are numerous. Telecommunication applications are widespread, ranging from global networks to desktop computers. These involve the transmission of voice, data, or video over distances of less than a meter to hundreds of kilometers, using one of a few standard fiber designs in one of several cable designs. Carriers use optical fiber to carry plain old telephone service (POTS) across their nationwide networks. Local exchange carriers (LECs) use fiber to carry this same service between central office switches at local levels, and sometimes as far as the neighborhood or individual home (fiber to the home [FTTH]).Optical fiber is also used extensively for transmission of data. Multinational firms need secure, reliable systems to transfer data and financial information between buildings to the desktop terminals or computers and to transfer data around the world. Cable television companies also use fiber for delivery of digital video and data services. The high bandwidth provided by fiber makes it the perfect choice for transmitting broadband signals, such as high-definition television (HDTV) telecasts. Intelligent transportation systems, such as smart highways with intelligent traffic lights, automated tollbooths, and changeable message signs, also use fiber-optic-based telemetry systems. Another important application for optical fiber is the biomedical industry. Fiber-optic systems are used in most modern telemedicine devices for transmission of digital diagnostic images. Other applications for optical fiber include space, military, automotive, and the industrial sector.

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