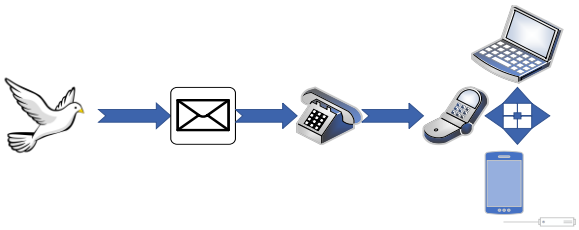
# Evaluation and Significance of Optical Fiber Communication: A Concise Review

**Shivranjani Gajjar*, Vivekanand Mishra****

* Department of Physics, C.U. Shah. University, Surendranagar, Gujarat, India
** Department of Physics, C.U. Shah. University, Surendranagar, Gujarat, India

***Abstract***

Speed and reliable networks are the prior requirements in this emerging world. Communication is exploring in a broadway every day. Digital or Analog communication, both need the best communication medium which can help to boost up the data transfer from source to destination. In this article, we have discussed the past, present, and future scenarios of optical communication and its evaluation in the current world. Also, we have discussed the basics of optical communication, their requirements, the development of optical fiber communication in a different field, and applications of optical fiber communication. Primarily, we cover the basic introduction of the earlier communication system compare with the optical communication system. Later on, the advantages of the optical communication system have been shared.



**Keywords**—Fiber Optics, Optical Fiber Communication(OFC), Optical Network, WDM.

## I. Introduction

'Communication' may define in a broadway as transferring the information from source to destination. Communication can divide in two ways according to the method of transfer like Traditional Network and Optical Network. In traditional networks, the data is converted to electrons that travel to copper cable, whereas in optical networks the data is converted to light and then transfer over fiber cable.[1] The data is in the form of electromagnetic carriers which will carry the data and transfer it to the destination using some primary processes like modulation and demodulation. In this type of communication system, the basic circuitry consists of an amplifier, oscillator, modulator, and demodulator is used for signal transfer.[2] Generally, the information data have a lower frequency/wavelength range as well as the energy range. To increase the energy, a modulation procedure must be involved during communication and a demodulator is used to get an exact signal format.[3] However, communication can also be achieved using an optical range frequency of the electromagnetic spectrum. The present scenario shows that optical communication will become the leading network system in the future for better communication.

## II. Brief History of Optical Communication

The idea of signaling system concept *Semaphore* was first developed by Chappe from France in 1791.[4] Semaphore telegraphy apparatus in which fire, light, etc was used to transmit the message. The invention of the telegraph by Samuel F. B. Morse in 1838 changes the system of communication which led to an era of electrical communication. In the electrical communication system, the range of frequencies used from the electromagnetic spectrum was the radio frequency range.[5] The use of visible frequencies to communicate between source and destination is very common for many years. The experimental demonstration of Total Internal Reflection by

Colladon(1842) gives a breakthrough idea for the concept of guiding the light wave through the medium.[6] The invention of the Photophone by Alexander Graham Bell (1880) changed the way of thinking about the communication system.[7]

Early to the nineteenth-century the data transferring rate was so low. In fact, at that time the human eye acted as a receiver the speed was limited.[7] J.L.Baird of England and C. W. Hansell's experiment in the 1920s, in which they use arrays of uncoated fiber cables for transmission of image for TV/Facsimile system. [7] A renewed interest in optical communication was stimulated in the early 1960s with the invention of the laser.[8] In 1966, Charles Kao and George Hockham working at Standard Telecommunications in the UK proposed that an optical fiber might be used as a means of communication provided the signal loss could be much less than 20 dB/km.[9]

After the invention of the optical laser, the development of optical fiber communication, it gives a very high breakthrough for transferring data. In the early century of OFC, the data transferring rate was too loose. In early 1996, the transmission capacity was reported about terabit/sec on a single fiber which launches the "tera era" perspective for OFC. All three approaches used WDM techniques. In the next five years, this capacity range was increased by 100 per decade, about 10Tb/Fiber. This was an incredible capacity and great achievement in OFC.[10]

***Optical Fiber Communication***

Optical communication involves a fiber network system to transfer information data in the form of a photon.[1]Likewise, electrical communication as an electron carries the information through the electrical cable, in the optical communication system Fiber is a medium to transfer the data and the light beam carries the information over the fiber. Glass fiber invention was done first done by a German immigrant named Herman Hammesfahr who use this patent for glass fabric[11] but it took many years to think the use of glass fiber differently. The use of fiber to guide the wave led the tremendous action in technology development.

***A. The need for Fiber Optic Communications***

In ancient communication electrical line provides a lot of capability within the 20h century. Recent development and the need for human beings show that the use of the internet will increase more in the future. Because of low transmission loss and wide bandwidth range, optical fiber is the best choice for communication. Global internet traffic has passed one zetabytes ($10^{21}$bytes) in 2016 and still growing faster.[12] Optical fiber systems give a tremendous way of transmission to increase data transmission with minimum loss. The first coaxial-cable system, put into service in 1940, was a 3-MHz system capable of transmitting 300 voice channels or a single television channel. The bandwidth of such systems is limited by the frequency-dependent cable losses, which increase rapidly for frequencies beyond 10 MHz. This drawback led to the development of microwave communication. The first microwave system operating at the carrier frequency of 4 GHz was put into service in 1948. Since then, both coaxial and microwave systems have evolved considerably and can operate at bit rates ~of 100 Mb/s. In 1975, the most advanced microwave system was put into service with an operating bit rate of 274 Mb/s. A severe considerably and can operate at bit rates ~100 Mb/s. The microwave communication drawback of such high-speed coaxial systems is their small repeater spacing (~1 km), which makes the system relatively expensive to operate. Microwave communication systems generally allow for a larger repeater spacing, but their bit rate is also limited by the carrier frequency of such waves. A commonly used figure of merit for communication systems is the bit-rate–distance product, BL, where B is the bit rate and L is the repeater spacing. In 1970, for communication BL ~ 100(Mb/s) -km was available but there was a fundamental limitation.[13] It was realized during the second half of the twentieth century that an increase of several orders of magnitude in the BL product would be possible if optical waves[14] were used as the carrier.[13]To transfer the data through the fiber is a medium/carrier which can help low loss transformation. And for that, we need light waves such as the type that can act as a beam source and which can help improved total internal reflection as it is a basic principle or say the requirement to guide the source. Such a problem was also solved after the invention of the Laser. The basic difference between microwave communication and Optical communication is the range of frequencies. For microwave communication frequency range is ~1 GHz whereas the optical carrier frequency range is about ~200 THz. Compare

to traditional network, because of some requirement i.e., long haul transmission system with low loss, compact and least weight transmitters and receivers, increased span of transmission, increased bit rate-distance product etc., OFC is mostly prefer for communication system nowdays.[15]

## III. OPTICAL FIBER SYSTEM

At the beginning of the use of optical fiber, communication was too lossy(~100dB/Km) for long-distance communication. However, this loss was overcome after 1970 about 0.2dB/Km.[1] In this section, we will discuss the basics of the OFC system and the affecting parameters of fiber during communication.

### *A. Fiber Optics*

Fiber is generally made of glass material in the shape of a coaxial which can be used as a waveguide[16] for data transfer. The fiber cable is cylindrical with centered dielectric material with clad having a slightly lower refractive index than the core. This can help to guide a light source through the fiber cable. The optical fiber can be classified in two ways: Single Fiber cable in which single fiber is to be installed into a jacket while another is Multi-Mode Fiber in which many fibers are to be installed into the jacket. A different kind of material is used to develop fiber, for example, silica ($SiO_2$), Polystyrene as a core, and Polymethyl Methacrylate Core are known as All Plastic Fiber. Another example of fiber is Plastic Clad Silica (PCS) in which the silica core is surrounded by low refractive index transparent polymer as clad. The diameter of optical fiber is about 70μm to 0.003 inches. A typical fiber cable structure can be shown in figure-1. There are two types of propagation in fiber: Single-mode fiber and Multimode fiber. For optical fiber depends on the dimensions of cable core and cladding, they are further classified in different i.e., multimode step-index in which diameter of the core is larger than cladding, while in single-mode step-index fiber core diameter is smaller then cladding layer. Another mode is graded-index fiber in which the refractive index profile changes from core to cladding.[17] Generally, in the OFC system, single-mode fiber is preferably used as it has comparatively easy to achieve a high-speed transmission rate.

### *B. Optical Fiber Communication System*

The OFC system can be classified in two ways: guided and unguided. [13] As the name implies a guided optical fiber system the- transmitted beam remains confined. Whereas in the unguided optical system the emitted pulses spread out in the space. Generally, a guided optical system is used in the broadcasting approach whereas unguided cannot be used in broadcasting applications. Figure-2 shows the block diagram for OFC. In OFC, three basic components are used for transmission: Transmitter, Transmission medium, and Receiver. The transmitter consists of a light source that can be modulated according to an electrical input signal to produce a light beam which is then transmitted to the transmission medium. Generally, this beam is generated in the form of a pulse and transfer to the receiver over optical fiber. The optical source, which can provide electric-optical conversions such as semiconductor laser or light-emitting diode (LED), is used in an OFC system. The receiver consists of a detector like a photodiode, which can help optical-electrical conversion after receiving the data from the optical cable. Some other devices like Phototransistor and Photoconductor can also be used as a detector. When pulses are transmitted through the fiber due to some circumstances the pulses spread out in the fiber. This is known as a dispersion in fiber and which is dependent on the amount of wavelength.

The achievement of OFC in every field of communication helps a lot to improve lightwave technology.[18] The OFC development can be understood based on development from the beginning to the recent year. This is divided into five-generation according to the order of development year. Table-1 shows the five generations of the lightwave system.[18][7]

Recent development focus on low loss and enhancement of the data rate of the fiber system. Having a tremendous capacity one can use OFC employ in advanced techniques of networking. One of the methods is used to develop a selective network system, Wavelength Division Multiplexing(WDM) method gives a very good breakthrough for the better optical communication system. WDM optical networks[19] are used to send many light beams of different wavelengths simultaneously down the core of an optical fiber. However,

sending different wavelength in fiber cable also cause dispersion in a fiber network, but this can be overcome using different optical amplifier [20]cascading to a WDM network system. Moreover, many other developments led OFC to the next level of generation including the Dence Wavelength Division Multiplexing (DWDM) system to enhance the capacity, dispersion-compensating fibers, use of photonic switching architectures. All these developments aim at achieving fiber attenuation as small as 0.16 dB/km (at 1550 nm), data transmission rates over 2 Gbps.[7] Soliton,[17] a special pulse shape, retains its shape as it propagates through the fiber. Soliton provides a solution for dispersion in the fiber. Soliton achieves speeds of 80Gb/s over distances of 10000km.[1]

### *C. Application of optical fiber communication*

OFC can be used in many areas of communication. The local speed rate for networking can be boosted up at a very high level using the optical fiber network system. The use of an optical fiber system may costly, but it gives a very reliable, secure network system for transferring the data. However, optical fiber cable is the most commonly used nowadays in the telecommunication system.

The telecommunication system is further classified into two sections based on their distance, i.e.; Long- Haul and Short Haul.[13] OFC also gives a huge role in Public network applications like telecommunication systems for example local access networks, SONET, ATM in which optical fiber system architecture is used. General telephones of Indiana which has a 3-mile link between two switching centers in fort Wayne, Indiana, carrying 5000 telephones in just 14 fiber. A similar system was installed in San Angelo, Texas, before the end of 1981.[22] Like this many, more companies replace their old copper wire technology with optical fiber technology.

In the military application, optical fiber system for communication helps to achieve security, survivability, etc., for example, mobile, Communication links like torpedo and missile guidance which are an example of a long-haul communication system.

Another excellent application of optical fiber system is in the development of optical sensors[23] in which the interferometry system are employed to develop optical system e.g.; single-mode fiber interferometric sensors. Optical sensors[24][25] become so useful in every field like defense, security which may be the future of developing a device that can use in sensitive element detection.[26], [27]

Computer applications: Modern computer system consists of many interconnections because that transmission rate sometimes becomes low in case of an electrical connection for transmission. One can resolve this problem using the terminal of the optical fiber system. The early design by IBM research operators at 200 Mbits-1 optical serial sub-systems. Another application in this area is in the Local area network.[8]

## FUTURE CHALLENGES AND CONCLUSION

High-speed data transferring rates led to the active development of optical fiber communication. The historical approach shows that fiber optics will be the future of advanced technology in every field of communication. Furthermore, optical fiber communication also becomes part of local data transferring devices. Although, there are many challenges in the network system in which fiber optics is used, like traffic congestion control, wavelength routing for the survivable network,[1], [28] which is the next interest of research in the field of electronics and communication.

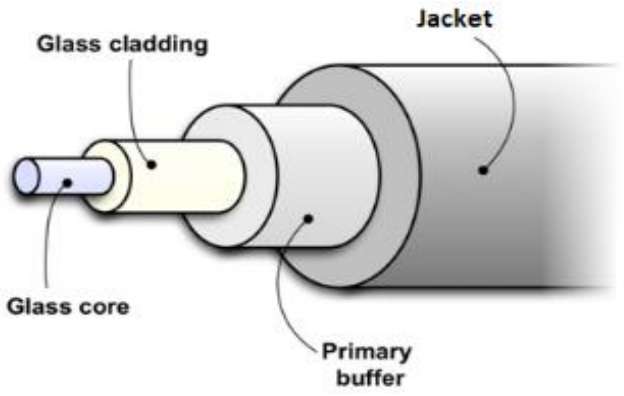



Fig. 1 Optical Fiber Cable

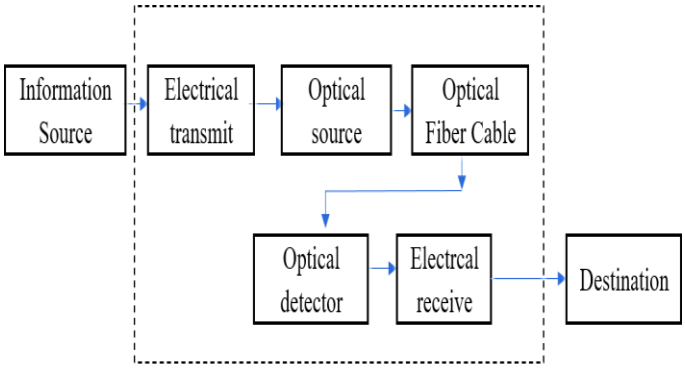



Fig. 2 Block Diagram of the Optical Fiber Communication system
(Image courtesy: Optical Fiber Communication By John M. Senior [7]

| **Generation Wavelength** | Wavelength (μm) | Fiber Type | Bit Rate | Fiber Losses (dB/km) | Repeater Spacings |
|---|---|---|---|---|---|
| 1st (1970s) | 0.85 | Multimode (graded core) | 2-45Mbps | ≥1 | ≈ 10 Km |
| 2nd (Early 80s) | 1.3 | Multimode (graded core) | 45-90 Mbps | 0.5-1.0 | ≈ 40 Km |
| 3rd(Late 80s) | 1.55 | Single Mode | ≥ 1.7 Gbps | =0.3 | ≈ 60-70 Km |
| 4th-(Early 90s) | 1.45-1.62 (Typical 1.55) | Single Mode (Dispersion shifted) | 2.4 Gbps | ≈ 0.2 | ≈ 80 Km |
| 5th(in 2000s) | 1.50-1.57 (Typical .55) | Single mode (dispersion shifted/soliton) + Fiber Amplifier | ≥ 2.4 Gbps | 0.1-0.2 | ≥ 100 Km |

Table-1 Five generations of the lightwave system

## REFERENCES


[1] C. S. R. Murthy and M. Gurusamy, *WDM optical networks : concepts, design, and algorithms*. Prentice Hall PTR, 2002.

[2] D. Roddy and J. Coolen, *Electronic Communications*, Fourth Edi. Pearson Publication.

[3] V. K. Mehta and R. Mehta, "V. K. Mehta, Rohit Mehta-Principles of Electronics-S. Chand & Co Ltd (2008).pdf." S. Chand & Company, p. 792, 2008, doi: 8121924502.

[4] *Handbook of Optical Fibers and Cables, Second Edition*. Taylor & Francis, 1996.

[5] G. Keiser, "OPTICAL FIBRE COMMUNICATION BY KEISER." McGRAW-Hill Series.

[6] "Jean-Daniel Colladon - Wikipedia." https://en.wikipedia.org/wiki/Jean-Daniel_Colladon (accessed Sep. 27, 2020).

[7] H. Hamam and S. Guizani, *Optical Fiber Communications*, vol. 1. 2011.

[8] J. M. Senior, *Optical Fiber Communications Principles and Practice*, vol. 31, no. 2. Pearson Publication, 2007.

[9] S. Kumar and M. J. Deen, *FIBER OPTIC COMMUNICATIONS*. Wiley & Sons.

[10] A. K. Dutta, N. K. Dutta, M. Fujiwara, and H. Kogelnik, *WDM Technologies: Optical Networks*. 2004.

[11] B. S. Finn, *City of Light: The Story of Fiber Optics (review)*, vol. 43, no. 1. 2002.

[12] R. Hui, *Introduction to Fiber-Optic Communications*. Elsevier Science, 2019.

[13] G. P. Agrawal, *Fiber-Optic Communications Systems, Third Edition.*, vol. 6. Wiley & Sons, 2002.

[14] JOACHIM PIPREK, *Semiconductor Optoelectronic Devices*. ACADEMIC PRESS, 2003.

[15] V. S. Bagad, *Optical Fiber Communications*. Technical Publications, 2009.

[16] M. Ghandehari, "Optical Waveguides," *Smart Sensors, Meas. Instrum.*, vol. 28, pp. 19–26, 2018, doi: 10.1007/978-3-319-70715-0_2.

[17] V. Alwayn and I. Cisco Systems, *Optical Network Design and Implementation*. Cisco Press, 2004.

[18] "Lightwave System Components." https://optiwave.com/resources/applications-resources/lightwave-system-components/ (accessed Sep. 27, 2020).

[19] H. Nain, U. Jadon, and V. Mishra, *Evaluation and analysis of non-linear effect in WDM optical network*. 2016.

[20] U. Jadon, H. Nain, and V. Mishra, *NRZ vs RZ: Performance analysis of SMF with different laser sources at 10 Gbps*. 2016.

[21] J. R. TAYLOR, *Optical solitons- theory and experiment*, vol. 21, no. July. Cambridge University Press, 1973.

[22] A. Al-Azzawi, *Fiber Optics: Principles and Practices*. CRC Press, 2017.

[23] M. Bass and E. W. Van Stryland, *Fiber Optics Handbook Fiber, Devices and Systems for Optical Communications*. McGraw-Hill Professional.

[24] A. Gandhi, V. Mishra, and D. Mehta, "Fiber-Optic Sensors: Technology & Applications," vol. 9, no. 1, pp. 304–320, 2018.

[25] P. N. Patel, V. Mishra, and A. S. Mandloi, "Optical Biosensors : Fundamentals & Trends," *J. Eng. Res. Stud.*, vol. I, no. I, pp. 15–34, 2010.

[26] M. Dr.Vivekanand and Ugale Sunita.p, *FIBER-OPTIC COMMUNICATION SYSTEMS AND COMPONENTS*. NEW DELHI. WILEY INDIA PVT. LTD., NEW DELHI, 2012.

[27] S. P. Ugale and V. Mishra, "Optimization of reversible LPFG for sensing application," *Optik (Stuttg).*, vol. 125, no. 1, pp. 111–114, 2014, doi: 10.1016/j.ijleo.2013.06.056.

[28] O. Gerstel, "On the future of wavelength routing networks," *IEEE Netw.*, vol. 10, no. 6, pp. 14–20, 1996, doi: 10.1109/65.546354.