ROOTINDEXING
JOURNAL ABSTRACTING AND INDEXING SERVICE
INTERNATIONAL ADVANCE JOURNAL OF ENGINEERING, SCIENCE AND MANAGEMENT (IAJESM)
July-December 2023, Submitted in July 2023, iajesm2014@gmail.com, ISSN -2393-8048
Multidisciplinary Indexed/Peer Reviewed Journal. SJIF Impact Factor 2023 =6.753

Different Types of Optical Fibre Technology: An Overview

Bhishma Dev Bera, Research Scholar, Department Of Physics, Cmj University, Jorabat, Meghalaya, India.
Dr. Prince Bansal (Assistant Professor) Research Guide,Department Of Physics, Cmj University, Jorabat, Meghalaya,India

INTRODUCTION

One is able to maximise the use of the bandwidth that is made available by the optical fibre since it is feasible to multiplex onto a single optical fibre a number of channels that operate at different wavelengths. This allows for maximum utilisation of the capacity. This kind of transmission is referred to as wavelength-division multiplexing, or WDM for short. The acronym stands for "wavelength-division multiplexing." On the other hand, long-haul WDM systems have issues due to the fact that the long fibre collects a huge amount of dispersion, and the different channels contribute a great number of optical powers, which raises the fibre's nonlinearity. Both of these factors contribute to the fact that the nonlinearity of the fibre is increased. The difficulty of the system to work correctly is exacerbated by the presence of both of these conditions. In the process of forecasting pulse propagation in optical fibres, the use of the Nonlinear Schrodinger Equation (NLSE) is a typical and normal part of the process. This is done on a consistent basis as part of the practise. In order to perform the transmission of a huge quantity of data at a high bit rate, the NLSE serves as a basis for strengthening currently existing fibre lines and proposing new fibre communications systems. This is done via the NLSE's foundational function. This structure was first established by the NLSE, an organisation. Examining the transmission of short pulses may be done in a number of ways, one of which is by inserting higher order terms into NLSE. This is done in particular to account for Raman scattering, which is an effect that can be caused by the transmission of short pulses. Examining the propagation of brief pulses is possible in a number of different ways, and this is one of those ways. Working in the Fourier domain is another option; however, the component that originates from the nonlinear section of the polarisation in Maxwell's equation will result in convolution integrals that are tough to handle both analytically and computationally. Working in the Fourier domain is one of the approaches that may be taken. One of the possibilities that might be taken into consideration is doing work in the Fourier domain. If you want to avoid these difficulties, one choice you have is to carry out your job in the Fourier domain. This is only one of the options you have. It would seem that the split-step frequency domain approach is the most preferred option at this time due to the stability and robustness of the solution, the efficiency of the solution, and the conceptual clarity of the solution. This is the case since split-step frequency domain techniques are more efficient than other solutions. On the other hand, in order to get a high frequency domain resolution, the time window that is used in the Fourier transform has to have a size that is suitably big. This is the case irrespective of whether or not the aforementioned benefits really exist. Therefore, whether dealing with short pulses or noise-contaminated signals that need a tight sample interval, a considerable amount of sampling data must be processed concurrently. This is the case whether dealing with the former scenario or the latter scenario. This is true regardless of whether one is discussing the first case or the second scenario. This is true regardless of whether you are working with the first scenario or the second one as your basis for analysis.

The term "fibre optics" refers to a kind of technology that sends data in the form of light pulses across long distances using strands of glass or plastic fibre rather than traditional wires. The term "fibre optics" refers to this category of technological advancement. When bundled together in a fiber-optic cable, optical fibres, each of which is approximately the same width as a single human hair, have the ability to send more data over greater distances and at a quicker pace than is possible with other types of transmission media. This is because optical fibres are about the same width as a single human hair. By using this technical innovation, a fiber-optic internet connection, in addition to telephone and television service, is made accessible to residential and commercial buildings. This service may also be provided.

Optical Fibre Technology Employing a Multimode Structure We observe the following in nonlinearity:

Since the beginning of their existence, optical fibres have been studied and developed for potential use as a medium that is suitable for the transmission of optical pulses. This line of research and development continues to this day. This development has been taking place ever since the idea of the fibres themselves was conceived for the first time. Due to the fact that a significant portion of this study has been focused on the transmission of low-energy pulses for the purpose of communication, fibres have been optimised for singlemode guiding with minimal propagation losses. This is because to the fact that this research has been conducted. These losses are exclusively constrained by the inherent material absorption of silica glass in the near infrared portion of the spectrum, which is around 0.2 decibels per kilometre. This is the only element that can explain for these losses, thus it is important to keep this in mind. There was a resurgence of interest in the area of nonlinear fibre optics as a direct result of the related increase in the transmission length that was available. This occurred as a direct consequence of the accompanying rise in the transmission length that was available. This interest was shown to exist, for example, by early investigations on the stimulated Raman Effect and optical solitons. These studies provided evidence that this interest was there. Since the invention of fibre amplifiers, the power of fibre-coupled lasers that are currently on the market has increased by a significant amount. The power of some fibre lasers already exceeds kW levels when operating in continuous wave (cw) mode, and their peak outputs reach MW when all-fiber systems are operating in pulse mode. The introduction of fibre amplifiers has made it practicable to achieve this level of power boost. The present fibre technology is being stretched to its breaking point as a result of these improvements, which necessitates the creation of fibres with larger mode areas and higher damage thresholds in order to keep up with the demand. However, since it is becoming more difficult to satisfy these constraints using fibres that only support a single optical mode, the use of fibres that support a large number of optical modes is becoming an increasingly prevalent practise. The fact that commercial Ti:sapphire fs lasers have now reached the GW range is proof that non-fiber-based laser systems are able to deliver far greater peak outputs than those that are based on fibre. In other words, lasers that are based on fibre are limited in their ability to provide higher peak outputs.

Fiber is used in the production of nonlinear fibre optics, fibre lasers, and fibre optics. a kind of fibre that is not active

Optical fibres are identified by the moniker "optical fibres" since they are the fundamental components of fibre optics. They are categorised as cylindrical waveguides and throughout the production process, they are often fabricated using a diverse assortment of glasses. It is possible to manufacture optical fibres that are hundreds of kilometres in length using fused silica, which is the kind of glass that is used the most often these days. This length is the longest length that is currently attainable.

The majority of optical fibres that are used in laser technology include a medium known as the cladding that surrounds the core of the optical fibre. The cladding, which surrounds the core of these optical fibres and has a lower refractive index than the core itself, is what these optical fibres are called. Both the core and the cladding of an optical fibre that has a step index have the same value for their respective refractive indices. Step index fibres are one kind of optical fibre. Because of this, the step-index optical fibre has improved performance. In spite of the fact that the intensity distribution may extend beyond than the core, the majority of the light travels inside the core area because the core acts as a guide for the light as it is transmitted through the fibre. For clarity, the core functions as a guide for light as it travels through the fibre, which serves its primary purpose. It is possible for the optical power to be maintained inside the optical fibre due to the guiding and the relatively low propagation losses, even if there is a substantial distance between the two ends of the optical fibre. This is because the propagation losses are quite low.

Fibre lasers

An optical fibre can become an active fibre that can serve as a gain medium in the creation of ultrafast fibre lasers by doping the core of the fibre with rare-earth ions, such as ytterbium, erbium, or thulium, for instance. In fibre, fibre lasers, and nonlinear fibre optics, a single pass through aYb-doped fibre can result in a small signal gain of up to >30 dB. As a result, there is a high optical alignment tolerance and the complexity of creating opto-mechanical systems is reduced. Ultrafast fibre lasers are a common tool in many areas of optical science and technology, including modern ophthalmology, optical microscopy, laser micromachining, optical communication, and precision metrology.

The emission range of mode-locked Yb-fiber lasers typically lies between 1020 and 1060 nm. The bulk of SMFs exhibit positive group-velocity dispersion (GVD) over the entire range of wavelengths. On the other hand, the production of femtosecond pulses frequently necessitates the control of the entire cavity dispersion, necessitating the use of devices that may produce negative GVD. These components could be two bulk gratings or a fibre Bragg grating. The pulses from aYb-fiber mode-locked laser range in duration from sub-ps to less than 10 ps and correspond to several modes of mode-locking, including dissipative soliton, similariton, stretched-pulse, and soliton. The magnitude of net cavity dispersion and the sign of the dispersion both affect how long these pulses last. The linear cavity, the ring cavity, the figure of eight, and the figure of nine are a few different cavity configurations that can be used in aYb-fiber laser.

Non-linear fibre optics

The massive peak power produced by ultrafast pulses as they move through the core of an optical fibre, which has a nominal diameter of several microns, results in a change in the material's refractive index, which in turn induces nonlinear fiber-optic phenomena. An illustration of this concrete response could be the growth of the material polarisation.

$$P = \chi^{(1)}E + \chi^{(2)}EE + \chi^{(3)}EEE$$

where (n) denotes the susceptibility of the nth order at wavelengths of optical light. "order the susceptibility." Glass is a material that has a totally eradicated second-order susceptibility, making it an optically isotropic substance. The many different kinds of nonlinearities that will be covered in this article are able to be represented in terms of the real and imaginary parts of the third-order nonlinear susceptibility that will be located in Eq. These parts can be either real or imaginary. The real component of the susceptibility is linked to the refractive index, whereas the imaginary component is related to a temporal or phase delay in the reaction of the material, which can lead to either a loss or a gain depending on the circumstances. For instance, the nuclear contribution to stimulated Raman scattering (SRS) or the electrostrictive stimulated Brillouin effect (both of which result in loss or gain) may be characterised in terms of the imaginary component. Both of these effects result in loss or gain. whereas the four-wave mixing is linked with the real component of t, the of a (3) susceptibility is related with the imaginary portion of t. Frequency conversion is the end result of a phenomena known as four-wave mixing, which is an entirely electrical and very instantaneous process.He has a susceptibility of three.

The susceptibility is related with the imaginary portion of t, whereas the four-wave mixing is tied with the real part of t. The phenomenon known as four-wave mixing is a process that is wholly electrical and takes place almost instantaneously. The final consequence of this process is the conversion of frequencies. (n2 = 2.6 × 10−26cm2/W). However, the light-fiber nonlinear interaction is further strengthened by the contributions of two additional fibre parameters: the mode field area (MFA) Ae f f and the effective length Le f f. These two parameters are determined by the following::

$$A_{eff} = \frac{\left\{\int_{-\infty}^{+\infty} |A(x,y)|^2 dxdy\right\}^2}{\int_{-\infty}^{+\infty} |A(x,y)|^4 dxdy}$$

$$L_{eff} = \frac{1}{\alpha}(1 - e^{-\alpha L}),$$

where the field distribution is denoted by A(x, y), and the loss coefficient is denoted by. MFA of standard SMFs, such as HI1060, is around 80 m2 in size. Le f f represents the effective length of the propagation path when loss is taken into account.
Using the following ratio, we are able to do a comparison between the nonlinearities of bulk media and silica fibres:

$$\frac{I_f L_{eff}(fiber)}{I_b L_{eff}(bulk)} = \frac{\lambda}{\pi r_0^2 \alpha},$$

Where If is the intensity (power per unit area) of the fibre, and Ib is the intensity (power per unit area) of the bulk. r0 is the mode field radius of the fibre, and is the wavelength of the light travelling through the fibre. According to Eq., having a small mode field radius and a low loss can significantly increase the ratio, and hence, the optical nonlinearities. For instance, if we select the wavelength to be 1 micrometres and a fibre with a normal loss of 0.2 decibels per kilometre, the nonlinear increase merely owing to the small core can be on the scale of 108. This is because the small core has a greater ability to concentrate light.
The GVD is yet another essential measure that is utilised in the field of nonlinear fibre optics. GVD has a wide range of effects, particularly with nonlinear wavelength conversion; these effects may be grouped under the following three subheadings:

1. It is the factor that decides how the phase matching works in parametric nonlinear systems.
2. It brings about a mismatch between the group velocities (temporal walk-off, lower phase-matching band width), which, in turn, reduces the effective interaction length for extremely short pulses.
3. It extends the duration of the pulses that are being transmitted, which reduces the pulse peak power and, as a consequence, weakens the nonlinear interaction.

Fiber-optic nonlinear effects can be a significant drawback for high-energy pulse amplification and delivery in fibres because high peak intensities result in a large number of fiber-optic nonlinear effects that distort both the optical pulse and the optical spectrum. This is due to the fact that high peak intensities create several nonlinear effects in fiber-optic systems. As a direct result of this, reducing the effects of these nonlinearities as much as possible is a crucial component of the process of developing ultrafast fibre laser systems.
CPA, or chirped-pulse amplification, is typically utilised in high-energy (more than 1 J), ultrafast Yb-fiber amplifiers in order to protect against the potentially harmful effects of nonlinearity. Before seeding weak pulses into a Yb-fiber amplifier, which is then followed by a compressor to compress the stretched and amplified pulses to the transform-limited duration, weak pulses in a typical Yb-fiber CPA system are first temporally stretched to last between 100 and 1000 picoseconds.
Fiber-optic nonlinearities, on the other hand, are particularly useful for a large number of applications. These applications include wavelength conversion, spectrum broadening and pulse compression, the generation of supercontinuum, and many more. In point of fact, the implementation of all-fiber integrated sources is dependent upon the utilisation of fiber-optic nonlinearities in order to produce the next generation of ultrafast sources for clinical applications. This is necessary in order for the next generation of ultrafast sources to be developed. Because of this, the production of these dependable and space-saving fiber-based sources requires an in-depth understanding of both the benefits and the downsides that are

connected with nonlinear effects.

Optical Fibres Employed for the Purpose of Defence:

Fibre optics are utilised for the purpose of data transmission when the application calls for a very high level of data security, such as that which is required in the aerospace and military industries. These are employed in the wirings of aeroplanes, as well as in hydrophones for use in SONAR and seismic research. Additionally, these are utilised in the investigation of seismic activity.

The benefits of fibre optic cable compared to copper and coaxial wire

In recent years, it has been obvious that fibre optics is slowly replacing copper cables as an effective means of communication signal transmission. This shift occurred because copper cables were found to be less reliable than fibre optics. In addition to providing the backbone for a variety of network systems, they bridge the great distance that exists between various local phone systems. Other users of the system include cable television services, colleges and universities, business buildings, manufacturing facilities, and electric utility firms. The copper cable system and the fibre optic system are quite comparable. The information is sent down fibre lines using light pulses instead of electrical pulses, which are used to send information down copper lines. The difference between the two is that fibre optic uses light pulses. Examining the individual components that make up a fibre optic chain will help one have a better comprehension of the system's operation in relation to systems that are built on wires. Traditional copper or coaxial connections do not give the same benefits as fibre optic transmitters and receivers connected by fibre optic cable do. We are going to talk about some of the benefits of using a fibre optics system rather than a copper cable system.

Bandwidth: Fibre optic cables offer a tremendous bandwidth, with transmission speeds running at up to 40 Gbps currently and over 100 Gbps likely to be operational in the near future. 1 gigabit per second is able to carry more than 30,000 audio calls on the telephone at the same time when compressed. Over a distance of 10 kilometres, coaxial cables with a diameter of up to 8 centimetres may transfer data at speeds surpassing 1 gigabit per second. Copper's prohibitively expensive price tag is the primary thing holding the project back.

Interference: Electromagnetic interference (EMI), radio frequency interference (RFI), lightning, and high-voltage switching have no effect whatsoever on fibre optic cables. They do not experience any problems associated with capacitive or inductive coupling. There is no EMI or RFI emission from fibre optic connections. Interference may be a problem for copper wires, depending on the material they're made of and the shielding they have surrounding them. Copper wires, which can be impacted by electromagnetic interference (EMI) and radio frequency interference (RFI) through inductive, capacitive, and resistive coupling. Copper cable, like any other cable, releases electromagnetic radiation, which has the potential to interfere with cables that are laid next to it.

The Qualities That Define an Optical Fibre Optic Transmission System

The ability of fibre optics, which is the science of light transmission via very tiny glass, to have an advantage over copper conductors might be attributed to the fact that fibre optics is a science. The following is a list of some of the features of transmission via optical fibre optics:

Wavelength: Light signals are sent over a glass fibre that is just about the thickness of a human hair. To prevent light from leaking out of the cores, a material known as cladding is wrapped around each one. The cladding is coated with extra material or a buffer, which protects the fibre from being damaged by moisture and from being exposed to physical harm. When selecting a wavelength for transmission, the objective is to deliver the most data over the greatest distance while experiencing the least amount of signal loss possible. Attenuation refers to the weakening of a signal while it is transmitted from one location to another. The wavelengths 850, 1300, and 1550 nanometers (nanometers) are the three most common ones utilised for fibre optic transmission. Due to the fact that these wavelengths experience the least amount of attenuation within the fibre, they are utilised within the field of fibre optics.

There is a one-to-one correspondence between the length of a wave and the rate of its attenuation. When waves are longer, there is less of an attenuation effect.

Attenuation is the process that occurs as light moves through optical fibres and causes the optical signal power to decrease. This allows for a greater transmission distance since it allows the light to travel a longer distance. For each foot, kilometre, or thousand feet, etc., it is measured in units of DBs, which stands for decibels. Values typically range from a few tenths of a dB/km for single-mode fibres operating at 1550 nm to a value of 10 dB/km for step-index fibres operating at 850 nm. Due to the fact that it defines the distance between repeaters that must be kept in order to keep signal levels at acceptable levels, attenuation is the single most critical element in determining the cost of fibre optic communications systems.

1. Bandwidth (n.)

The amount of data that can be carried by an optical fibre is measured by its bandwidth. In other terms, it refers to the quantity of data that can be transported in a certain length of time, as well as the range of frequencies that are used to communicate the data. Additionally, it can relate to the range of frequencies that are used to send the data. The speed at which data can be carried across fiber-optic networks as well as the frequency range over which data can travel without experiencing any attenuation contribute to the large bandwidth of these networks. In most cases, it is denoted as the product of the data frequency and the distance travelled, which is commonly denoted as MHz-km or GHz-km.

2. Spreading out

When an optical signal travels through an optical fibre, a phenomenon known as dispersion causes the pulse to get stretched out across a longer distance. When dispersion reaches a particular degree in the optical fibre communication system, the optical signal will become distorted, which will then lead to intersymbol interference because of the overlapping of the front and rear pulses. Dispersion in optical fibres places a cap on both the bandwidth and the distance that may be achieved by fiber-optic communications.

REFERENCES

1. AA Ivanov, and AM Zheltikov. Powerful wavelength-tunable ultrashort solitons in a solid-core photonic-crystal fiber. Optics letters, 34(6):851–853, 2009.
2. Agraval, G. P. (2007). Maxwell´s Equations. In Nonlinear Fiber Optics, 4ª edição. Burlington, USA: Academic Press.
3. Agrawal G. P., ‘Nonlinear Fiber Optics’, Academic Press, USA, (2005).
4. Agrawal, G. P. (2005) Light wave Technology, Telecommunications Systems, Wiley-Interscience
5. Andres Gil Molina, Alexander Perez Ramirez “Nonlinear Fiber-Optics with Incoherent Sources” January 2014 DOI:10.1364/LAOP. 2014.LTh2C.1
6. Arleth Manuela Gonçalves “Pulse Propagation in Optical Fibers” In Nonlinear Fiber Optics, 4ª edição. Burlington, USA: Academic Press. 2010
7. Auro M. Perego, Sergei K. Turitsyn, KestutisStaliunas “Amplification through losses in nonlinear fiber optics” 2018 International Conference Laser Optics (ICLO) DOI: 10.1109/LO.2018.8435202
8. Bhuvaneshwari, M. &ShaziaHasan, Dr &Razak, Dr. (2018), “Study on soliton pulse and its characteristics for fiber optic communication.” International Journal of Engineering & Technology. 7. 2845-2847. 10.14419/ijet.v7i4.17860.