Optical Fibre Splicer

(Job Role)

Qualification Pack: Ref. Id. TEL/Q6400
Sector: Telecom

Textbook for Grade 10

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171076

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एन सी ई आर टी
NCERT
राष्ट्रीय शैक्षिक अनुसंधान और प्रशिक्षण परिषद्
NATIONAL COUNCIL OF EDUCATIONAL RESEARCH AND TRAINING

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Foreword

The National Education Policy (NEP) 2020 envisions an education system that is deeply rooted in India's cultural heritage and achievements, while also preparing students to effectively engage with the challenges and opportunities of the twenty-first century. This aspirational vision is built upon the National Curriculum Framework for School Education (NCF-SE) 2023, which outlines a comprehensive approach to education across various stages. In the early stages, the NCF-SE fosters the holistic development of students by focusing on the five dimensions of human existence, known as the *pañchakośhas*, creating a solid foundation for further learning.

High-quality vocational textbooks play a vital role in bridging practical skills and theoretical knowledge. These textbooks must balance direct instruction with opportunities for hands-on experience, helping students apply what they learn in real-life settings. The National Council of Educational Research and Training (NCERT) is providing such high-quality teaching–learning resources. A team of experts, educators, and practitioners have collaborated to develop these vocational textbooks to ensure students are well-prepared for the demands of their chosen fields.

It is against this backdrop that Pandit Sunderlal Sharma Central Institute of Vocational Education (PSSCIVE), Bhopal, a constituent of the NCERT has developed learning outcome based on modular curricula for vocational subjects from Grades IX to XII. This has been developed under the centrally sponsored scheme of Vocationalisation of Secondary and Higher Secondary Education of the Ministry of Education, erstwhile Ministry of Human Resource Development.

This textbook has been developed as per the learning outcome based on curriculum, keeping in view the National Occupation Standards (NOSs) for the job role and to promote experiential learning related to the vocation. This will enable the students to acquire necessary skills, knowledge and attitude.

I acknowledge the contributions of the book development team, reviewers, and all institutions and organisations for supporting towards the development of this textbook.

The NCERT welcomes suggestions from students, teachers and parents, which would help us further improve the quality of the material in subsequent editions.

In addition to textbooks, it is important to encourage students to explore other learning resources, such as school libraries, and engage in practical scientific and technical work. Teachers and parents play a vital role in guiding students as they apply their learning outside the classroom.

I am grateful to all who contributed to the development of this vocational textbook and look forward to receive feedback from its users to make future improvements.

DINESH PRASAD SAKLANI
Director
National Council of Educational
Research and Training

New Delhi
December 2024

About the Textbook

The telecommunication industry comprises all telecommunications, telephone companies and internet service providers and plays a crucial role in the evolution of mobile communications and the information society. The telecom industry in India is growing exponentially and is the second largest in the world with a subscriber base of over 1.2 billion. The telecommunication sector comprises companies that make communication possible on a global scale, whether it is through the phone or the internet, through airwaves or cables, or through wires or wireless. These companies have created the infrastructure that allows data in words, voice, or video to be sent anywhere in the world. The largest companies in the sector are wireless operators, satellite companies, cable companies and internet service providers.

The telecommunications sector evolved from the telegraph, the first mechanical device meant for telecommunication. The technology has improved the communication speed tremendously over a period of time. At one time, telecommunications required physical wires connecting homes and businesses. In contemporary society, technology has gone mobile; digital and wireless technology is becoming the primary form of communication.

The telecommunication sector consists of three basic sub-sectors: telecom equipment (largest), telecom services (second largest), and wireless communication. Wireless communication is the fastest-growing area in this sector. The sector's biggest challenge is to keep up with people's demand for faster connections.

Optical Fibre Splicer is responsible for ensuring efficient splicing of the optical fibre cables and supports in optical fibre installation and in carrying out fibre testing using Optical Time Domain Reflectometer (OTDR) and power meter. This job requires the individuals to work in a field set-up and be able to handle situations under pressure. They should have basic written and oral communication skills and should be able to apply practical judgement to successfully perform the assigned responsibilities.

The textbook has been developed by the Textbook Development Committee to make it a useful and inspiring teaching–learning resource material for vocational students. Adequate care has been taken to align the content of the textbook with the National Occupational Standards

(NOSs) for the job role, so that the students acquire the necessary knowledge and skills as per the performance criteria mentioned in the respective NOSs of the Qualification Pack (QP).

The textbook has been reviewed by experts so as to make sure that the content is not only aligned with the NOSs, but also is of high quality. The NOSs for the job role of Optical Fibre Splicer covered through this textbook are as follows:

1. TSC/N6400 undertakes splicing of optical fibre
2. TSC/N6401 installation and commissioning of Optical Fibre Cable (OFC)

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The National Council of Educational Research and Training (NCERT) expresses its gratitude to all the members of the Project Approval Board (PAB) and officials of the Ministry of Education (MoE), Government of India, for their cooperation in the development of this textbook. The Council also extends gratitude to all the contributors and the Telecom Sector Skill Council (TSSC) for sharing expertise and valuable time by positively responding to the request for the development of this textbook.

The Council also acknowledges the contribution of the Review Committee member for carefully evaluating and giving suggestions for the improvement of this textbook.

The Council would also like to thank Rajesh Khambayat, *Joint Director*, Pandit Sunderlal Sharma Central Institute of Vocational Education (PSSCIVE), Bhopal for providing support and guidance in the development of this textbook.

We are thankful to the *course coordinator* Deepak D. Shudhalwar, *Professor* (CSE) and *Head*, Department of Engineering and Technology, PSSCIVE, NCERT, Bhopal for developing and organising the content for this textbook.

The efforts of Abhinav Kumar Dwivedi, *Assistant Professor* in Media and Entertainment (Contractual), Gaurav Sharma, *Graphic Artist* (Contractual), and Rajesh Kahar, *DTP Operator* (Contractual), PSSCIVE, Bhopal, and Avinash Kumar Shakyavar, *Sr. Production* and *Post Production Faculty*, Maya Academy of Advance Cinematics, Bhopal are thankfully acknowledged for drawing, designing and editing graphics. Ajai Mathew, *Assistant Professor*, Department of Electronics and Communication Engineering, Amal Jyothi College of Engineering, Kanjirappally, Kottayam also deserves thanks for providing the photographs used in the textbook, from his college department.

The Council is grateful to Saroj Yadav, *Professor* and *Dean* (A), NCERT, and Ranjana Arora, *Professor* and *Head*, Department of Curriculum Studies, for their sincere efforts in coordinating the review workshops for the finalisation of this textbook. The Council acknowledges the copy-editing and valuable contribution of Alpana Saha, *Assistant Editor* (Contractual) and proofreading inputs of Lomesh Giri, *Proofreader* (Contractual) in shaping this textbook. The efforts of Pawan Kumar Barriar, *DTP Cell Incharge* and Upasana, *DTP Operator* (Contractual), Publication Division, NCERT, for flawless layout design, are also acknowledged.

The Council is grateful to the Ministry of Education for the financial support and cooperation in realising the objective of providing a quality textbook for Indian vocational students.

Contents

THE CONSTITUTION OF INDIA

PREAMBLE

WE, THE PEOPLE OF INDIA, having solemnly resolved to constitute India into a [1]**[SOVEREIGN SOCIALIST SECULAR DEMOCRATIC REPUBLIC]** and to secure to all its citizens :

JUSTICE, social, economic and political;

LIBERTY of thought, expression, belief, faith and worship;

EQUALITY of status and of opportunity; and to promote among them all

FRATERNITY assuring the dignity of the individual and the [2][unity and integrity of the Nation];

IN OUR CONSTITUENT ASSEMBLY this twenty-sixth day of November, 1949 do **HEREBY ADOPT, ENACT AND GIVE TO OURSELVES THIS CONSTITUTION.**

1. Subs. by the Constitution (Forty-second Amendment) Act, 1976, Sec.2, for "Sovereign Democratic Republic" (w.e.f. 3.1.1977)
2. Subs. by the Constitution (Forty-second Amendment) Act, 1976, Sec.2, for "Unity of the Nation" (w.e.f. 3.1.1977)

Unit 1

Optical Fibre Splicing

Fibre optics is essential to our telecommunication infrastructure. Optical Fibre Cable (OFC) is ideal for high-speed communication because OFCs use light to transmit data. In the recent era, mostly copper cables have been replaced with optical fibre cables because of the high speed of the transmission. There can be several occasions when we require to join the two optical fibre cables. In such situations, optical fibre splicing is required to join two fibre optic cables together. Optical fibre splicing is a common method used to repair broken cables, extend the length of a cable run, or join different types of fibres. Splicing is faster and more efficient than connectorisation for joining fibres. Splicing is essential for maintaining telecom networks that connect people around the world. It is also used in Local Area Networks (LAN) that connect computers in offices. Fusion splicing and mechanical splicing are the two most common ways of joining together optical fibres permanently.

To perform fibre optic splicing, we need some basic tools and equipment, such as fibre strippers, cleavers, cleaners, splicers, and protection sleeves. Fibre strippers remove the outer coating and buffer from the fibre, exposing the glass core and cladding.

This unit covers the optical fibre communication, splicing of optical fibre and the tools and equipment required for splicing.

Chapter 1

Optical Fibre Communication

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One day Nitya got a chance to visit the Indian Space Research Organisation (ISRO). There she came to know about the advanced technologies, which are being used in the field of space science. She also came to know about the application of optical fibre technology, which is being used in spacecraft and satellites. She studied and observed the utilisation of optical fibre communication in different sectors. She came to know that the present age technology is the result of many brilliant inventions and discoveries. In the field of communication, our increasing ability to transmit more information, quickly and over longer distances, is the result of these innovations. Communication technology has expanded in the sectors, such as health, education, defence, finance, agriculture, space science, telecommunication, media, entertainment and aviation.

Communication technology has travelled a long distance from an era of copper wire transmission to optical fibre cable technology. Optical fibre cables are the backbone of optical fibre communication. An optical fibre cable is a glass or plastic fibre that carries data in the form of light. Today, optical fibre cable is the fastest means of communication, as it transfers data at the speed of light. In this chapter, you will understand the technology behind optical fibre communication and its applications.

Fig.1.1: Nitya with her father visiting the Indian Space Research Organisation

Communication

Communication refers to the transfer of information from one end to another end. Information can be in the form of voice, electrical signals, electromagnetic waves, digital data, and light. For example, a conversation between two friends can also be called as *communication*. In our day-to-day life, one uses various communication technologies such as mobile communication, data communication, optical communication, voice communication and mobile communication.

Mobile Communication: It is used for the transmission of signal and provides services to mobile phones.

Data Communication: It is used in computer networking for the transmission of data between computers.

Optical Communication: It is used for long-distance communication. In most cases, it is used to provide high-speed internet service.

Fig. 1.2: Signal transmission between the mobiles

Fig. 1.3: Transfer of data between computers

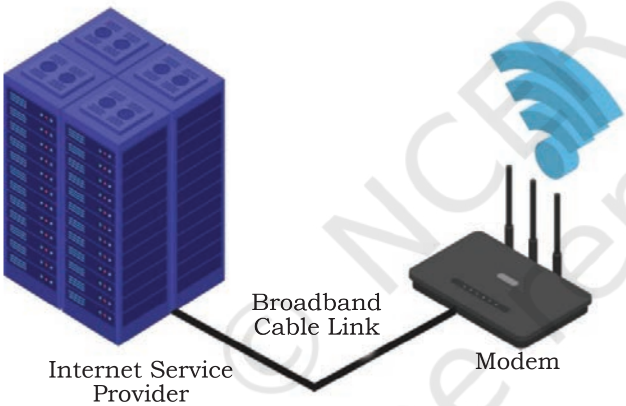

Fig. 1.4: Optical fibre cable used in broadband cable link

Fig. 1.5: Voice communication over landline phones via telephone exchange

Voice Communication: It is used in landline phone and Public Switched Telephone Network (PSTN).

Satellite Communication: It is used in space technology, defence, media, weather forecasting and meteorology.

Fig. 1.6: Satellite communication

Basic Optical Fibre Communication

In general, an optical fibre communication network has three sections namely transmitter, optical fibre cable, and receiver as shown in Figure 1.7. For example, when a person 1 places a call to person 2, signals are first

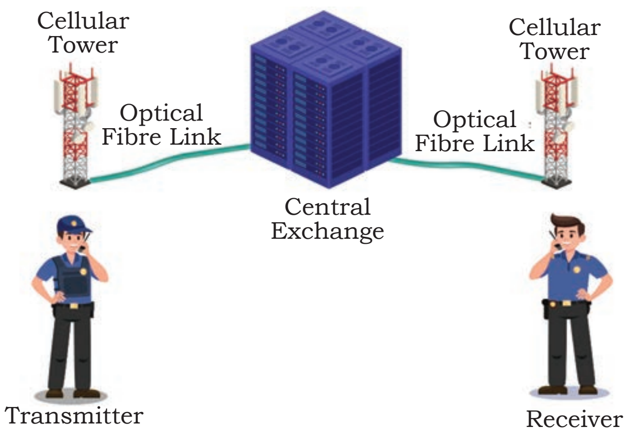

Fig.1.7: Sections of optical fibre communication

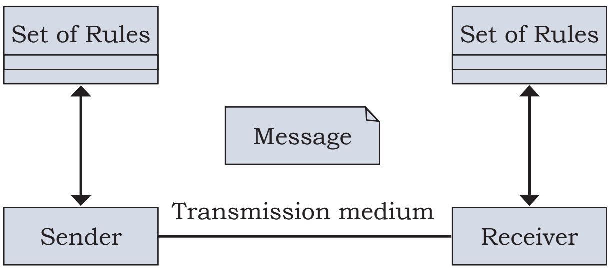

Fig.1.8: Data transfer process

forwarded to the nearby cellular tower (transmitter). Then signals will transfer to the central exchange using optical fibre cables. From the central exchange it will be forwarded to the nearby concerned cellular tower (receiver) using optical fibre cables. In this way, the call is attended by person 2.

Data from the sender to the receiver is transferred. To connect sender and receiver a medium is required. This medium can be wired or wireless. The wired medium has a physical link, whereas the wireless medium has a non-physical link.

Wired media defines communication using wires and cables. Some of the wires and cables are twisted pair cables, coaxial cables and optical fibre cables as shown in the Figure 1.9 (a), (b), (c).

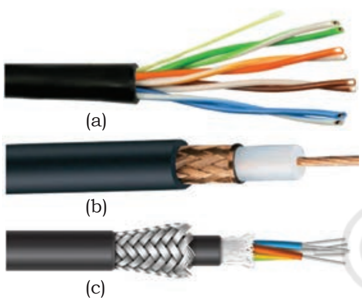

Fig.1.9: (a) Twisted pair cable (b) Coaxial cable (c) Optical fibre cable

In wireless media communication, link is established wirelessly and the air acts as a medium. Antennas mounted on the towers are used to transfer the signal in wireless communication. Figure 1.10 shows various kinds of antennas, such as the cell site antenna and microwave antenna mounted on the towers.

Therefore, optical fibre cable is a replacement for copper wire that is used in wired communication.

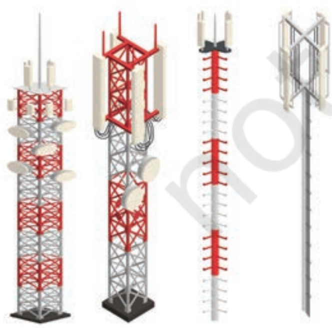
Fig.1.10: Antenna mounted on the tower

Optical Fibre Cable

Optical fibre cables have very thin and long fibres like human hairs. These fibres are made up of glass or plastic. The light propagates from one end to another through these glass/plastic fibres. Figure 1.11 shows a signal transmission through copper cable and optical fibre cable.

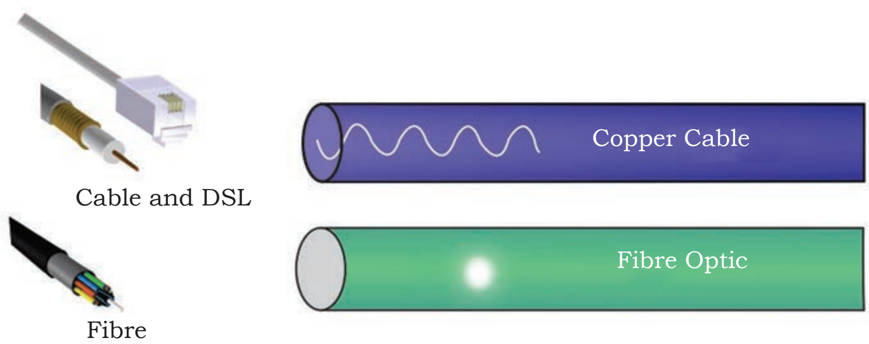

Fig.1.11: Copper cable carrying electrical current and optical fibre carrying light signal

Structure of an Optical Fibre Cable

Optical fibre cable (OFC) is made up of glass or plastic fibre, coated with several layers. The various layers in optical fibre cable are shown in Figure 1.12. The structure of an optical fibre includes the following parts:

(a) Core
(b) Cladding
(c) Buffer
(d) Strength Member
(e) Jacket

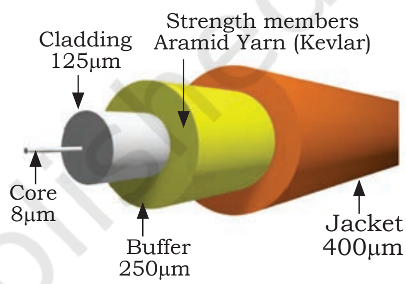

Fig.1.12: Diameter of various layers in an optical fibre cable

(a) Core: It is the thin and innermost part of an optical fibre cable. Figure 1.13 (b) shows the side view of the core in optical fibre cable. It is made up of glass. Through this, signal travels from one end to another in the form of light.

(b) Cladding: It is the outer layer of an OFC, which surrounds the core. It reflects the light back into the core. It helps to trap the light in the core using *Total Internal Reflection*. This concept will be discussed later. Figures 1.13 (a) and 1.13 (b) show the front and side view of cladding in OFC.

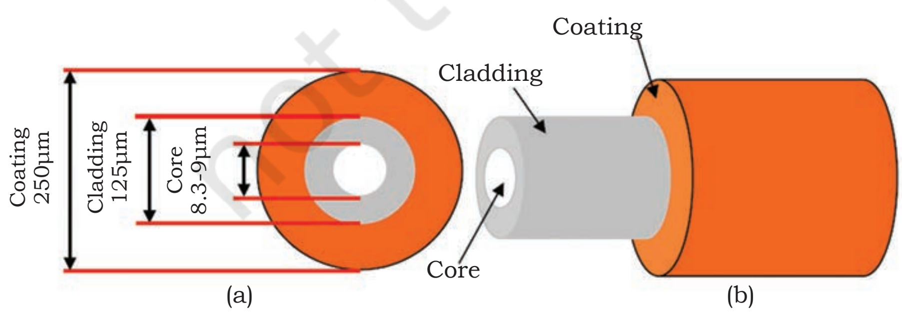

Fig.1.13: (a) Cross-sectional view of single-mode optical fibre cable (b) Side view of single-mode optical fibre cable

Core and cladding of optical fibre are available in variety of sizes. Table 1.1 represents various core and cladding diameters.

Table 1.1: Size of core and cladding diameter in different optical fibre cables

	Single-mode Optical Fibre (Diameter in µm)	**Multimode Optical Fibre-Step Index** (Diameter in µm)			**Multimode Optical Fibre-Graded Index** (Diameter in µm)		
Core	8–9	32.5	60	600	50	32.5	85
Cladding	125	125	140	1200	125	125	125

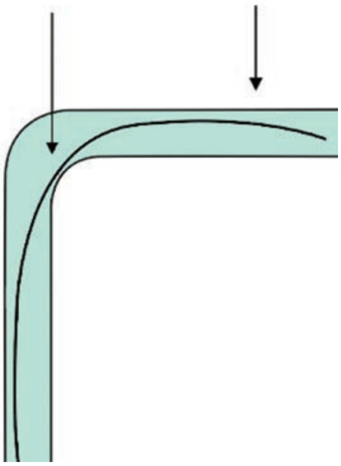

Fig.1.14: Loose tube buffer

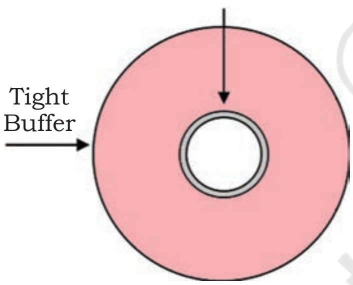

Fig.1.15: Tight buffer

(c) Buffer: As you know, the core is the portion of OFC through which light travels and the cladding helps in trapping the light into the core. However, it is necessary to provide protection to the core and cladding from external and environmental damage. The buffer is one such protective layer. It is made up of a hard-plastic coating. Buffer can be of two kinds: loose-tube buffer or tight buffer.

Loose-tube Buffer: It consists of a buffer layer that has a diameter much larger than the diameter of the fibre. It allows the fibre to move smoothly into the buffer. An optical gel is filled in the buffer to protect the fibre from water. These are designed to be installed in harsh environments, such as dense forests, and areas prone to heavy rainfall. A typical loose-tube buffer is shown in Figure 1.14.

Tight Buffer: It consists of a buffer layer in which optical fibres are attached tightly. In other words, it does not allow fibre to move smoothly into the buffer. They are mostly used for the indoor installation of optical fibre cables (Figure 1.15).

(d) Strength Member: In extreme environmental conditions, hard plastic layer of buffer in OFC is not sufficient. In order to increase the strength of the OFC, additive material is used. They increase the tensile strength of OFC. Figure 1.16 shows that the strength member is placed between the buffer and jacket. It also protects the fibre against stretching and excessive bending. Materials like aramid yarn, and fibreglass are used as a strength material.

Aramid Yarn: It is a man-made synthetic fibre. It is lighter, flexible, and fire-resistant. Aramid yarn is called *Kevlar*. Typical aramid yarn in optical fibre cable is shown in Figure 1.16.

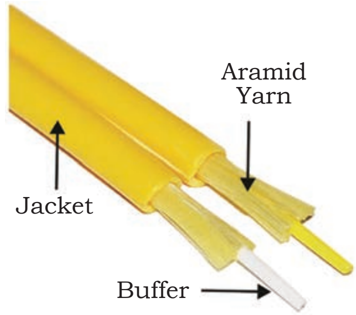

Fig.1.16: Aramid yarns in optical fibre cable

Fibre Glass: It is made up of extremely fine fibres of glass. They are used to protect optical fibre cables from heavy external physical loads. Figure 1.17 shows typical fibre glass.

Fig.1.17: Fine fibre of glass

(e) Jacket: It is a protective layer over the strength material of an optical fibre cable. This part protects the fibre from the adverse outside environment, including sunlight, snowfall, and rainfall. The jacket is made of plastic material, such as Polyvinyl Chloride (PVC), Polyethylene, and Polyvinyl Di Fluoride (PVDF). Optical fibre cables may have a number of fibres, on each fibre separate jackets are used. There are known as *inner jackets* and the common outer jacket is known as a *sheath,* as shown in Figure 1.18.

Fig.1.18: Sheath as an outer layer of cable with multiple jackets on the fibre

Table 1.2 illustrates the material used to manufacture the various layers, such as the core, cladding, strength member, buffer, and jacket of an optical fibre cable.

Table 1.2: Material used to manufacture layers of optical fibre cable

Layers	Materials
Core	Glass or Plastic
Cladding	Glass or Plastic
Strength Member	Stranded steel, Kevlar, Nylon
Buffer	Only glass, Glass and polymers, Only polymer
Jacket	Polyethylene, Polyvinyl Chloride, Polyurethane, Polyester Elastomers

NOTES

Assignment 1

Match the following layers and material of optical fibre cable with their correct feature:

S. No.	Optical Fibre Cable Layer and Coating	Feature
1.	Loose-tube buffer	It has a slightly lower refractive index than that of the core.
2.	Strength member	The outermost jacket contains multiple layers of jacket and strength members.
3.	Polyvinyl Chloride (PVC)	It is a piece of strong thread running through the jacket.
4.	Core	It has an inner diameter much larger than the diameter of the fibre.
5.	Cladding	The buffer layer is applied directly over the fibre.
6.	Tight buffer	It is a type of jacket used for indoor cable runs.
7.	Steel jackets	It is the thin glass centre of the fibre where the light travels.
8.	Polyethylene	This material is used as a jacket for outdoor.
9.	Sheath	It helps to increase a cable's tensile strength.

Applications of Optical Fibre Cable

Optical fibre cables have revolutionised the world of digital communication. As optical fibre communication offers high speed and security, they are used in every sector. The major areas are Internet Service Providers (ISP), telephone exchange, computer networks, health, defence and aerospace.

1. **Internet Service Provider (ISP):** OFCs offer high bandwidth, hence, it is suitable for transmitting large amounts of data at very high speeds. This optical fibre technology is, therefore, widely used by ISPs.
2. **Telephone Exchange:** OFCs are used in telephone exchanges. The presence of OFCs in the exchange gives additional benefits to the user. It provides a faster path to connect the users at different ends with better voice quality and services.

3. **Computer Network:** It is a system, in which multiple computers are connected to each other to share information and resources. This sharing of information and resources is easier, more secure and faster because of the presence of OFCs in the network.
4. **Health:** OFCs are widely used in medical equipment, pharmaceutical industries, and medical research institutes. For example, OFCs are used to provide illumination in endoscopy.
5. **Defence and Space:** To fulfil a high level of data security in the field of defence and aerospace, OFC is a right choice to be used for high-speed transmission of data and a secured network.

Concept of Light Propagation

You have seen a variety of objects in the world around us. However, you are not able to see anything in a dark room. Things become visible on lighting up the room. What makes it visible? During the daytime, the sunlight helps us to see objects. An object reflects the light that falls on it. This reflected light reaches our eyes and enables us to see things. Figure 1.19 illustrates how a person can see the objects.

Fig.1.19: Reflection of light ray into the eyes

In our daily lives, we have so many examples of reflection and refraction of light, such as image formation by a mirror because of reflection of light and the colours of the rainbow and twinkling of stars because of refraction of light.

(a) (b) (c)

Fig. 1.20: (a) Reflection in a mirror (b) Rainbow due to refraction of light (c) Twinkling of stars due to the refraction of light

Nature of Light: Light exhibits both wave and particle nature.

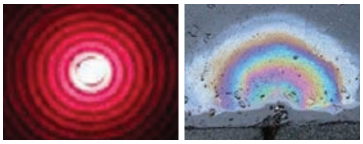

Fig.1.21: Wave nature of light

(a) Wave Nature of Light: In wave nature, light acts like an electromagnetic wave, which travels at the speed of light 'c' in a vacuum. For example, if one mixes the oil in water, one could be able to see the wave nature of light as shown in Figure 1.21. Figure 1.22 shows the electromagnetic wave in which 'E' is the electric field, and 'B' is the magnetic field.

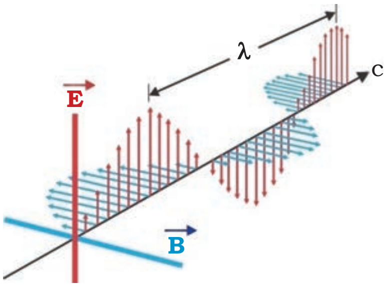

Fig.1.22: Light as an electromagnetic wave

On the basis of the light propagation, a pattern of waves can be further classified as transverse and longitudinal waves (Figure 1.23). When a wave oscillates perpendicular to the direction in which it is traveling, such waves are called *transverse waves*. The wave pattern of transverse wave is shown in Figure 1.24.

Fig.1.23: Transverse wave propagation pattern in the water

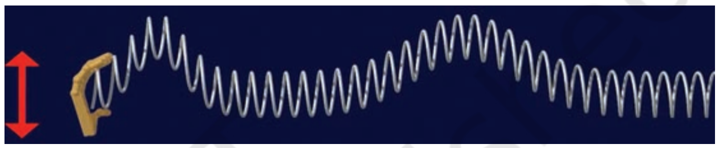

Fig.1.24: Propagation pattern of transverse wave

If you throw a stone in still water, waves are formed. The pattern followed by the wave in water is transverse in nature. This example illustrates how a transverse wave travels in a medium.

When the wave oscillates in the same direction in which it is traveling, it is called a *longitudinal wave*. Longitudinal wave is shown in Figure 1.25.

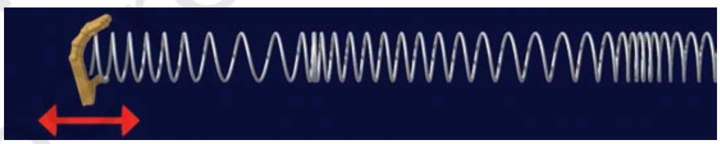

Fig.1.25: Propagation pattern of longitudinal wave

Sound waves are examples of longitudinal waves. When sound travels through a medium, such as solid, liquid or gas, it travels because of the vibration in the adjacent particles in the medium. Energy from the source will pass to the particles, from there it will reach the ear as shown in Figure 1.26. Thus, you can say sound waves are longitudinal in nature.

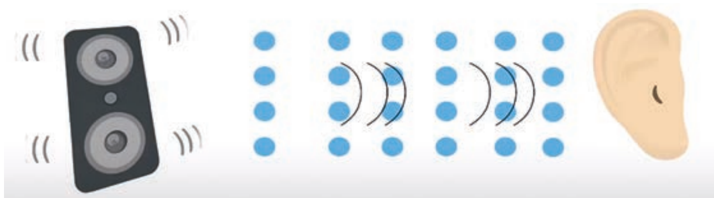

Fig.1.26: Sound traveling in the air

Know More...

Waves have two important characteristics, i.e., wavelength and frequency.

Wavelength: Distance covered by the one complete cycle of the wave is called as *wavelength*. It measures in metre.

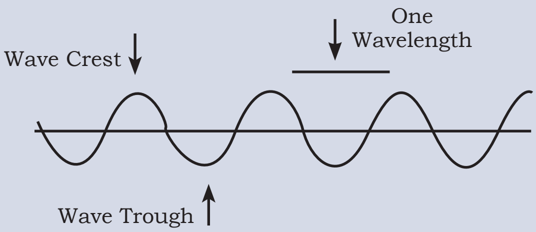

Fig.1.27: Wavelength

Frequency: Number of cycles in one second is termed as *frequency*. It measures in Hertz.

The time-period (T) of a waveform is for one full cycle, i.e., 0° to 360°. The relationship of frequency (f) and time period (T) is given by the equation.

$f = 1 / T$

$T = 1 / f$

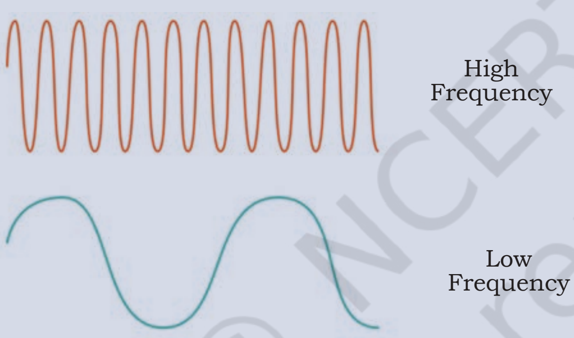

Fig. 1.28: High and low frequency

> **Note:** Wavelength and frequency are inversely proportional to each other. Hence, higher the frequency, lower will be the wavelength and vice versa.

Speed of Light: The speed of light in a vacuum is approximately 3×10^8 m/sec. It takes approximately 8.3 minutes to reach the Earth's surface from the Sun.

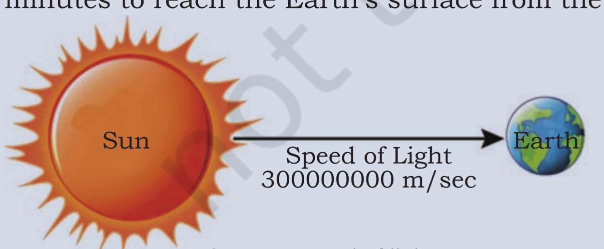

Fig.1.29: Speed of light

Electromagnetic Spectrum: It is the range of all electromagnetic waves, such as visible light waves,

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microwaves, radio waves, X-rays, gamma rays, and infrared rays. The visible light is the portion of the electromagnetic spectrum that is visible to the human eyes. The visible region includes seven colours. Sunlight is an example of visible light.

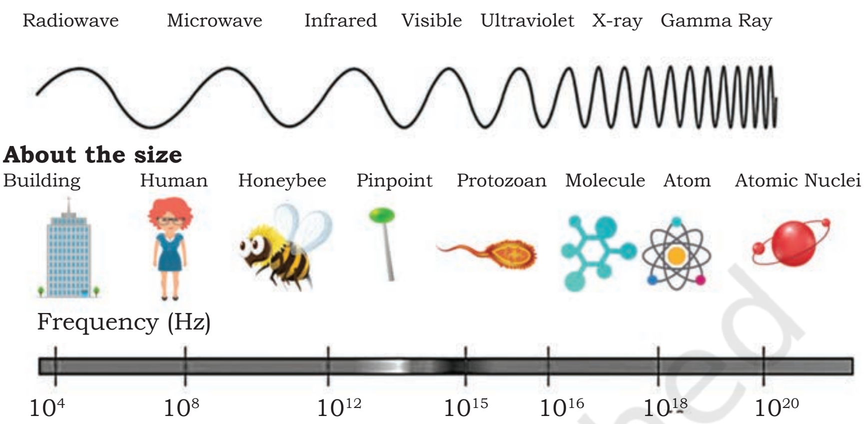

Fig. 1.30: Electromagnetic spectrum

In Figure 1.30, observe that the different waves have different wavelengths. For example, a radio wave can have a maximum wavelength equal to a tall building. In the same way, gamma rays can have a maximum wavelength equal to nuclei of an atom. Likewise, you can interrelate the other images with a wavelength of different waves. Frequency bands and their applications are listed in Table 1.3.

Table 1.3: Applications in various frequency bands

Frequency Bands	Applications
Radio waves	They are used in radio and television signals broadcasting.
Microwaves	They are used in satellite communication, military equipment, and microwave ovens.
Infrared radiation	They are used in remote controls, heat-sensitive thermal and imaging cameras, and night vision cameras.
Visible light	They are used in traffic signals, vehicle headlamps, indicators and many more.
Ultraviolet	They are used in hospitals for cleaning the bacteria, microbes, and living microorganisms present on the surgical equipment.

X-rays	They are commonly used in X-ray machines to check fractures in bones inside human body.
Gamma rays	They are used to kill cancer cells.

(b) Particle Nature of Light: In particle nature, energy carried by light is in the form of separate bundles of energy, these are called *photons*. Figure 1.31 shows that sunlight consists of photons.

Light travels in a straight line. The speed of light depends on the medium through which it passes. If it passes through the polished surface, then it bounces back known as *reflection,* and if it passes from one medium to another, say from air to water it bends, known as *refraction.*

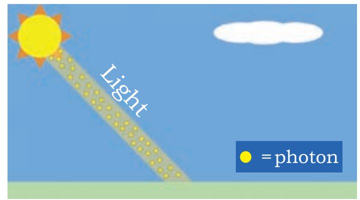

Fig.1.31: Particle nature of light

Reflection: A highly polished surface, such as a mirror, reflects light falling on it, as shown in Figure 1.32. The image is seen in the mirror, because the light from the polished surface of the mirror reflects and reaches your eyes. Reflection occurs when the rays of light bounce back in the same medium after reflection.

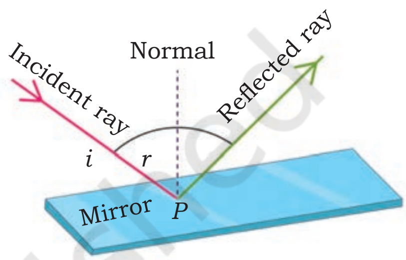

Fig.1.32: Reflection of light through mirror

The incoming light ray is called the *incident ray*. The light ray bouncing back into the same medium is called the *reflected ray*. The normal is an imaginary line perpendicular to the surface. The angle of incidence is measured between the incident ray and the normal. The angle of reflection is measured between the reflected ray and the normal as shown in Figure 1.33.

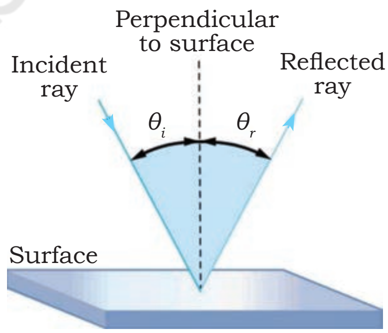

Fig. 1.33: Reflection of light

Let us recall the laws of reflection of light.

(i) The angle of incidence is equal to the angle of reflection, and

(ii) The incident ray, normal and reflected ray, all lie on the same plane.

These laws of reflection are applicable to all types of reflecting surfaces including spherical surfaces.

Practical Exercises

Activity 1

Demonstrate to prove the laws of reflection through a plane mirror.

Material Required

Soft board, white sheet of paper, optical pins, mirror, pencil, protractor and ruler.

Procedure

1. Place the paper on the board and fix it.
2. Place the mirror vertically on the white sheet of paper and trace its edge.
3. Draw a line at right angle to the edge of mirror that will act as normal 'ON'.
4. Starting with an angle *i* of 30˚, draw an incident ray and place two pins, P and Q along it.
5. Observe the reflected ray using a mirror and mark the position of as R and S. Fix the pins at the respective points.
6. Remove pins R and S and join the dots by drawing a straight line.
7. Measure and record angle 'R'.
8. Repeat the procedure 4, 5, 6 and 7 for angles incidence angle *i* = 35˚, 40˚, 45˚, 50˚ and 55˚.
9. Note down the values in the table. Carefully observe the result as:
   (i) The angle of incidence equals the angle of reflection.
   (ii) Incident ray, reflected ray and the normal at the point of incidence lie in the same plane.

   Hence, the laws of reflection proved.

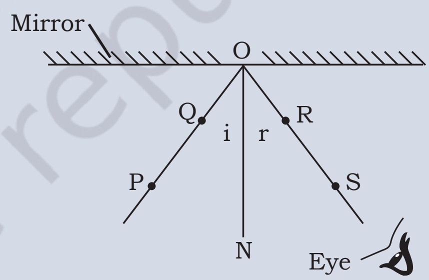

Fig.1.34: Set up for law of reflection

Fig.1.35: Bending of pencil in the glass

Fig. 1.36: Lemon in the glass

Refraction: Light travels in a straight line in a transparent medium. What happens, when light enters from one transparent medium to another? Is it still moving in a straight path or it has changed its direction? Recall your day-to-day experiences. Have you seen a pencil, partly immersed in a water glass? It appears to be displaced at the interface of air and water as shown in Figure 1.35.

You may have seen that a lemon kept in a water glass appears bigger than its actual size as shown in Figure 1.36, when viewed from the side of the glass.

These observations indicate that light does not travel in the same direction, when it travels through different mediums. It appears that when travelling obliquely from one medium to another, the direction of propagation of light changes in the second medium. This phenomenon is known as *refraction of light*. It is illustrated in Figure 1.37.

Assignment 2

1. Place a coin at the bottom of a bucket filled with water.
2. Observe the coin and try to pick up the coin in the first attempt. Did you succeed in picking up the coin?
3. Repeat the activity. Why did you not succeed in doing it in first attempt?
4. Ask your friends to do this. Compare your experience with their experience.

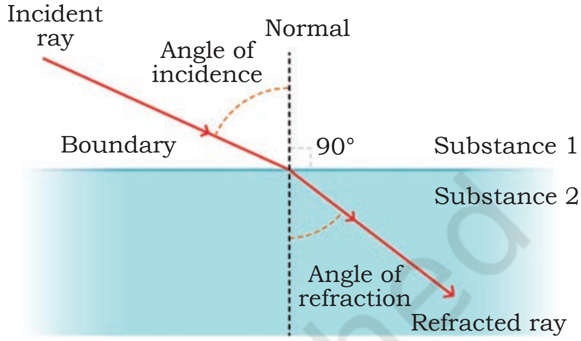

Fig.1.37: Refraction of light

Laws of Refraction

(i) The incident ray, refracted ray and normal all lie on the same plane.

(ii) The ratio of the sine of the angle of incidence to the sine of the angle of refraction is a constant. This law is also known as *Snell's law of refraction*.

If '*i*' is the angle of incidence and '*r*' is the angle of refraction, then

$$\frac{\sin i}{\sin r} = \text{constant}$$

This constant is called the *refractive index*. Let us study the 'refractive index' in detail.

Note: For the case of $\theta_1 = 0$ (i.e., a ray perpendicular to the interface), the solution is $\theta_1 = 0$ regardless of the values of refractive index n_1 and refractive index n_2. It means a ray entering a medium perpendicular to the surface, is never bent.

Refractive Index: It determines the speed with which a light beam travels in a medium. The refractive index of a material is dimensionless.

$n = c/v$, where, '*c*' is the speed of light in vacuum, and '*v*' is the speed of light in the medium.

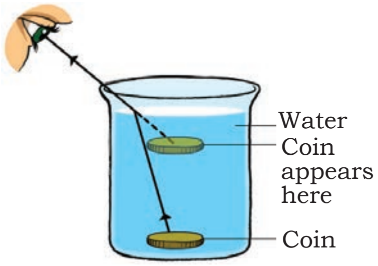

Fig.1.38: Observe the coin in the glass beaker

As you know a ray of light that travels from one transparent medium into another, will change its direction in the second medium. The bending of light will depend upon the extent of the refractive index of the medium. The speed of propagation of light varies in various mediums. It turns out that light propagates at different speeds in different mediums. Light travels faster in vacuum with a speed of 3×10^8 m/s. In the air, the speed of light is only marginally less as compared to that in vacuum. It reduces considerably in glass or water.

The refractive index of several mediums is given in Table 1.4. From Table 1.4, you can see that the refractive index of water is 1.33. It means that the ratio of the speed of light in air and the speed of light in water is equal to 1.33.

Consider an example, if a coin is placed in a beaker containing water. The coin will look upward at its exact position as shown in Figure 1.38. This is due to changes in the refractive index of air and water.

Table 1.4: Refractive index of some material

Material	Refractive Index	Material	Refractive Index
Air	1.00	Turpentine oil	1.47
Ice	1.31	Glycerine	1.47
Water	1.33	Rock salt	1.54
Alcohol	1.36	Ruby	1.71
Kerosene	1.44	Diamond	2.42

Example: The speed of light in a medium is 2×10^8 m/s. What is the refractive index of that medium?

Solution: $n = c/v = 3 \times 10^8 / 2 \times 10^8 = 1.5$

The refractive index of the material is 1.5 and it is unitless.

Assignment 3

1. A ray of light traveling in air enters into water. Does the light ray bend towards the normal or away from the normal? Why?
2. Light enters from air to glass having refractive index 1.50. What is the speed of light in the glass? The speed of light in vacuum is 3×10^8 m/s.
3. Suppose, you have kerosene, turpentine oil and water. In which of these does the light travel fast? Use the information given in Table 1.4.

4. The refractive index of diamond is 2.42. What is the meaning of this statement?
5. A medium is having a refractive index of 2.5. Determine the speed of light in the medium.

Total Internal Reflection

When light hits an interface between two different mediums, it may behave in different ways. Typically, the light partially refracts and partially reflects.

Consider an example of glass and air as shown in Figure 1.39. Figure 1.39 shows three rays of light A, B and C. Glass has a higher refractive index than air. When light travels from the medium of glass to the second medium of air, then it bends away from the normal. Light ray 'A' shows the first case of refraction. Light ray 'B' shows that the refracted ray becomes parallel to the surface of the glass at a particular angle called the *critical angle*. Now, at any angle greater than this critical angle (θ_c) the light will be reflected inside the glass only as shown by light ray 'C'.

When the light travels from one medium to another, say from water to air as shown in Figure 1.39, then the incident angle (θ_1) is less than the critical angle (θ_c) the light is transmitted through the air. But if light travels at an incident angle (θ_1) greater than the critical angle (θ_c), it will not pass through the air. Instead, it will be reflected to the first medium, i.e., water. Hence, this phenomenon is known as *Total Internal Reflection*.

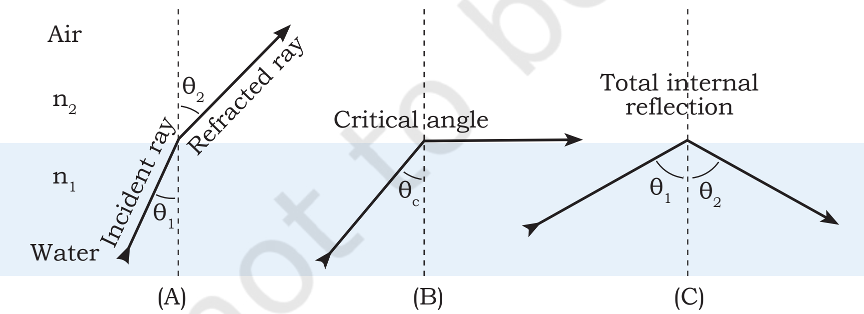

Fig.1.39: Concept of total internal refraction at air and glass interface

The concept of total internal reflection is used in optical fibre communication. The propagation of light in the fibre occurs by the method of total internal reflection.

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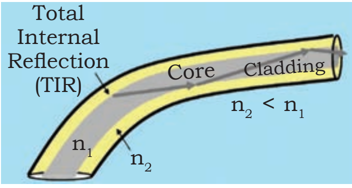

Fig.1.40: Propagation of light in the core of fibre cable using total internal reflection

Figure 1.40 shows the propagation of light through an optical fibre cable. This propagation is due to total internal reflection in the core.

The refractive index of the core is larger than that of the cladding. Due to the difference in the refractive indices of the core and the cladding, light is confined in the core. But the angle of light entering the fibre must be greater than the critical angle, and then only the total internal reflection takes place. Because of this total internal reflection, light passes through the glass fibre up to a longer distance.

Table 1.5: Refractive index of core and cladding

	Single-mode Optical Fibre	Multimode Optical Fibre
Core	1.45	1.425–1.480
Cladding	1.44	1.417–1.460

Some of the important terms used to illustrate the propagation of light inside the fibre are: numerical aperture, acceptance angle and acceptance cone of the fibre.

Numerical Aperture (NA)

It is the light-collecting ability of an optical fibre. More the NA, the more efficient the fibre will be. It is also known as a *Figure of merit*. The NA is related to the refractive index of the core (n_1), cladding (n_2) and outer medium (n_0) as

$$\text{NA} = \frac{\sqrt{n_1^2 - n_2^2}}{n_0}$$

If the medium is air, then $n_0 = 1$, then

$$\text{NA} = \sqrt{n_1^2 - n_2^2}$$

Let us see how to measure the numerical aperture in practical activity 2.

Practical Exercises

Activity 2

Demonstrate to measure the numerical aperture of Optical Fibre Cable (OFC).

Material Required

Optical Fibre Trainer (OFT) kit, optical fibre cable, screen, connecting wires, NA measurement unit, frequency generator.

Procedure

1. Prepare the set-up to measure the numerical aperture as shown in Figure 1.41.
2. Connect the power supply to the OFT kit, and make all the connections.
3. Connect one end of the OFC to the OFT kit and other end to the numerical aperture jig.
4. Vertically, hold the white screen with four concentric circles (10, 15, 20 and 25mm diameter) such that the optical fibre axis is perpendicular.
5. Maintain a suitable distance to make the red spot emitted from the optical fibre coincide with the 10cm circle. Note that the circumference of a circle must coincide with the circle.
6. Record L, the distance of the screen from the fibre end and note the diameter W of the spot.
7. Compute the numerical aperture using a formula, NA=sin $\theta = W/\sqrt{(4L^2 + W^2)}$ where θ is called the *acceptance angle,* it is the maximum angle of incidence at the input end of the optical fibre. So, the optical ray can just propagate within the optical fibre.
8. Tabulate the reading and repeat the experiment for 15mm, 20mm, and 25mm diameter too.

S. No.	Length (mm)	Diameter of the Spot (mm)	Numerical Aperture (NA)	Acceptance Angle (Degree)
1.	9	10	0.4	23.5
2.	14	15	0.4	23.5

9. The numerical aperture of an optical fibre cable is 0.4 mm.

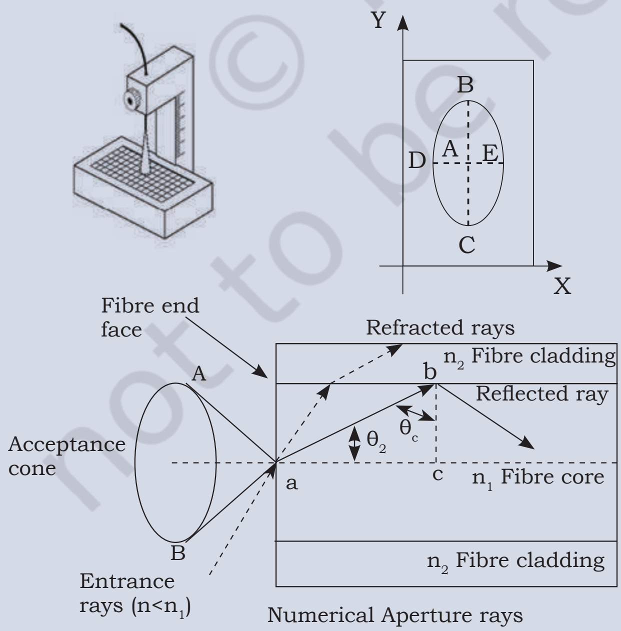

Fig.1.41: Set up to measure the numerical aperture

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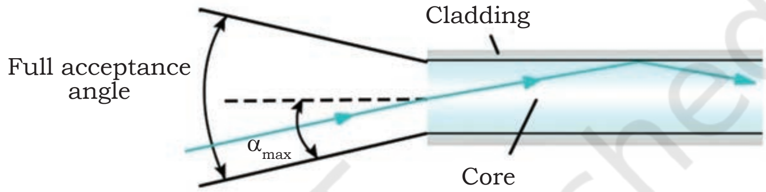
Acceptance Angle

It is the maximum angle made by the light ray with the fibre axis, so that light can propagate through the fibre after total internal reflection.

Relation between NA and acceptance angle, NA = sin α

Acceptance Cone

It is the cone in which light incident at an acceptance angle or less than the acceptance angle and then the light can propagate through the fibre after total internal reflection. The propagation of light through the optical fibre cable is shown in Figure 1.42.



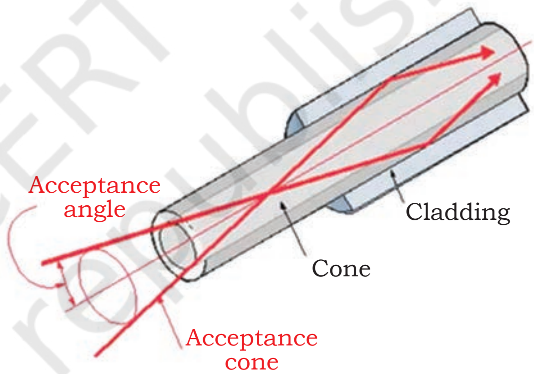


Fig. 1.42: Light propagation through the optical fibre cable

Classification of Optical Fibre

Optical fibres can be classified based on the materials used and modes of propagation of light. "Mode" refers to the number of paths for the light rays within the OFC.

Material-Based Classification: On the basis of the material optical fibres are classified into two types: Glass fibres and Plastic fibres.

1. **Glass Fibres:** Most of the optical fibres are made up of glass. The glass contains a material known as *silica*. Silica is made from the sand.
2. **Plastic Fibres:** Plastic-made fibres are obtained from polymers like Poly Methyl Metha Acrylate (PMMA),

Polyethene (PE), Polystyrene (PS). These are useful in a harsh environment, where greater strength is required.

Transmission Mode-based Classification: When the light is guided through the optical fibre, it exhibits certain modes. These modes can be thought of as rays of light. Modes of the fibre are classified into two types, namely, single-mode and multimode fibres, as shown in Figure 1.43. Multimode fibres are further classified as step index and graded index.

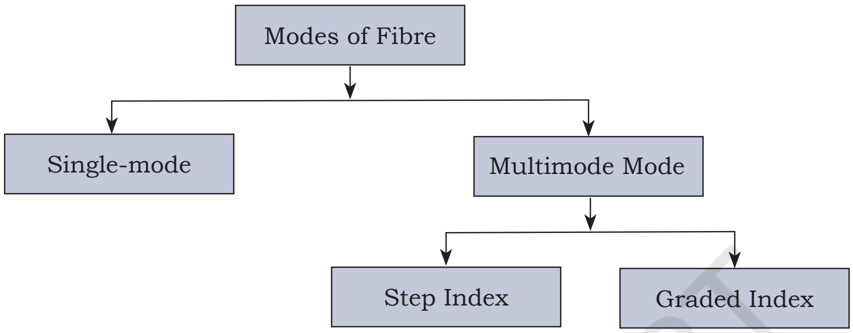


Fig. 1.43: Classification of optical fibre based on transmission mode

1. **Single-mode Fibre:** In this, only one light ray is used to send the data for transmission as shown in Figure 1.44.

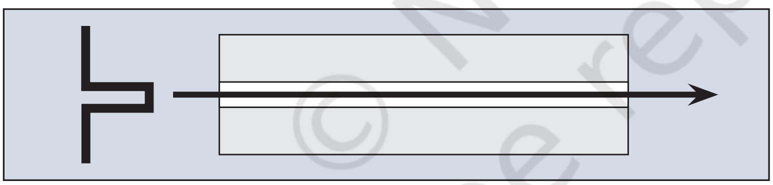


Fig. 1.44: Single-mode optical fibre cable

2. **Multimode Fibre:** It allows more than one ray to propagate along the fibre. The multiple modes from a light source move through the core in different paths as shown in Figure 1.45.

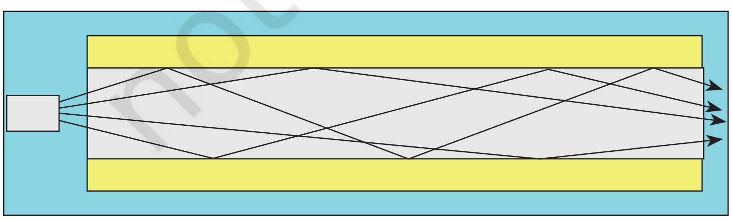


Fig. 1.45: Multimode optical fibre cable

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Practical Exercises

Activity 3

Identify single-mode and multimode fibre.

Material Required

Optical fibre cable, LASER source, optical connector, plain white sheet.

Procedure

1. Connect the LASER light using optical connector to one end of OFC.
2. Focus the other end of OFC on white paper.
3. Observe the diameter of LASER light coming out of the fibre. If the diameter is too broad, then it is multimode fibre or otherwise if the diameter is too small, then it is single-mode fibre.

Assignment 4

Suppose, you have LED light source and you want to pass the light through the fibre cable. What type of fibre you will use and why? How much light is propagated through the fibre end. Use both single-mode and multimode fibre and compare the result. Similarly, use a LASER light and observe the result for the same.

Multimode fibres are further divided into the step index and graded-index multimode fibre.

(a) Step-index Fibre: In this, a refractive index of the core and cladding is in the form of the staircase. It means that there is a sudden change in the refractive index of the core and cladding.

In such fibre, light rays propagate in a zigzag manner inside the core as shown in Figure 1.46.

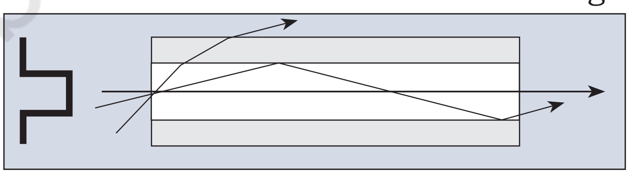

Fig.1.46: Optical signal in step index fibre

(b) Graded-index Fibre: In this, the core itself has several layers. The layer, which is close to the axis of optical fibre, has a more refractive index as compared to the next layers. Alternatively, if you move from the axis of optical fibre toward the cladding within the core, the refractive index decreases as shown in Figure 1.47. Finally, at the interfacing point of core cladding, the light will be reflected in the core.

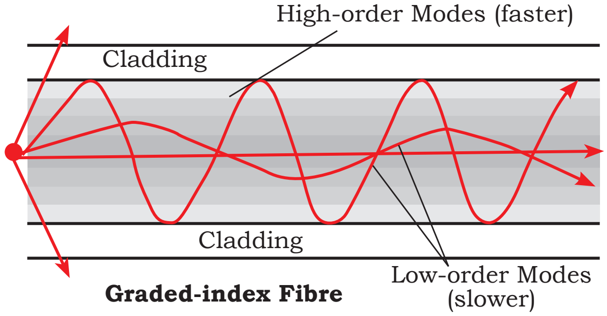

Fig.1.47: Optical signal in graded-index fibre

Table 1.6: Comparison of single-mode and multimode

S. No.	Single-mode	Multimode
1.	Only a single light ray passes through the core of the fibre.	More than one light ray travels along with the fibre core.
2.	The core diameter of single-mode fibre is about 8–6 micrometre (µm). Whereas, the cladding diameter is about 125 micrometre (µm).	The core diameter of multimode fibre is about 50 micrometre (µm) and 62.5 micrometre (µm). Whereas, the cladding diameter is about 125 micrometre (µm).
3.	Single-mode fibres are used for long distance communication 50 to 60 km.	Multimode fibres are used for short distance communication such as buildings or campuses up to 10–15 km.
4.	Single-mode fibre has a higher bandwidth and less attenuation.	Multimode fibre has lower bandwidth and higher attenuation.
5.	Single-mode fibre allows less dispersion.	Multimode fibre allows more dispersion.
6.	LASER (Light Amplification by Stimulated Emission of Radiation) beam is used to pass the light in the fibre.	LED (Light Emitting Diode) is used to pass the light in the fibre.
7.	It is suitable for WAN (Wide Area Network), MAN (Metropolitan Area Network), campus etc.	It is suitable for LAN (Local Area Network).

Losses in Optical Fibre Cable

Losses in optical fibre may occur at the time of transmission. Due to a decrease in the intensity of the light or spreading of the light in different directions, the signal carrying information or data may become weak and not able to transmit the data at a faster rate. This is because of the degraded signal. This degradation of a signal may occur due to attenuation and dispersion. Figure 1.48 shows the signal degradation in optical fibre cable.

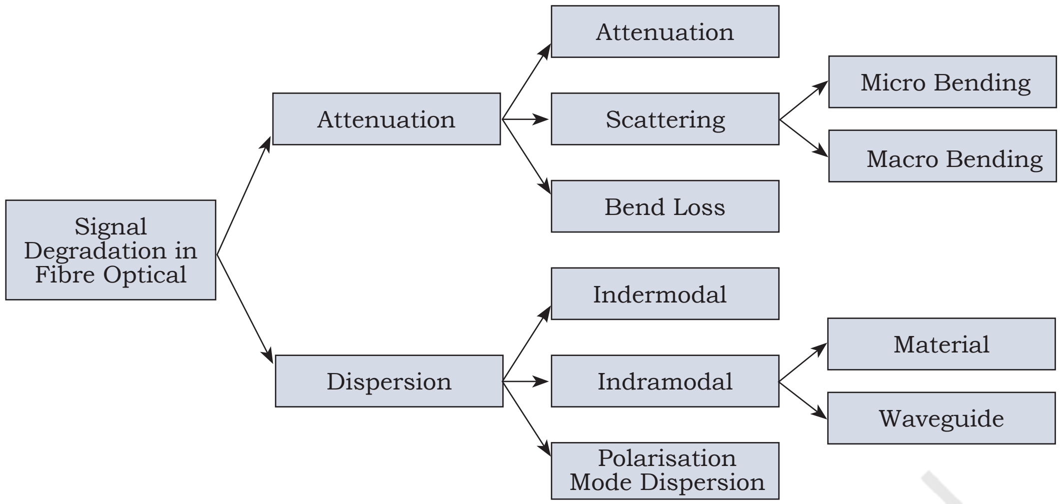

Fig.1.48: Signal degradation and its classification in optical fibre communication

In OFC, several types of losses can occur; some of them are explained below:

(a) Attenuation: The strength of the light signal goes on decreasing as it travels along the length of the fibre as shown in Figure 1.49. Attenuation is measured in a logarithmic unit of decibel (dB). Consider an example, the light signal is in the form of digital, i.e., '0's and 1's and when it is weakened, it becomes difficult to distinguish between the 0's and 1's. The bits are sometimes so weakened that bit '1' appears to be a '0' bit. Hence, to rectify this problem of attenuation a device known as an amplifier or repeater is required to regain the strength of the signal. The attenuation is caused due to the absorption, scattering loss, and bending loss in optical fibres.

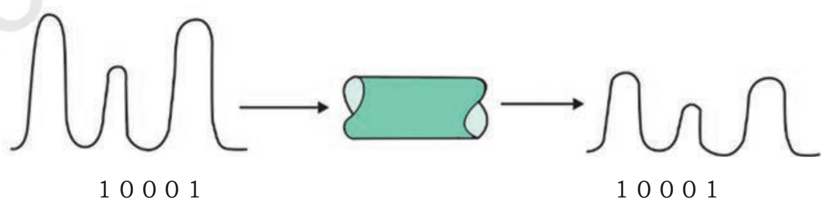

Fig.1.49: Reduction in strength of the optical pulse

Consider an example, a signal is transferred from one end of fibre to the other end. Measure the signal strength at the first end, and at another end as shown in Figure 1.50. Compare and observe the difference.

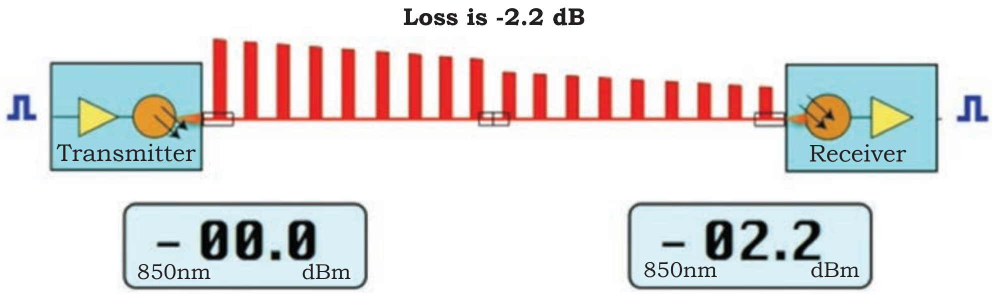

Fig. 1.50: Attenuation loss at transmitter and receiver ends of optical fibre cable

(b) Absorption: In OFC, absorption of light can happen because of the fibre material used. The fibre material absorbs light and this absorbed light energy is converted into heat radiation, due to the presence of impurities in the fibre material. This heat radiation will get wasted.

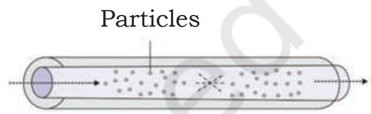

Fig.1.51: Scattering of light in optical fibre cable

(c) Scattering: It defines light, and is dispersed in all directions. This dispersion is caused due to structural imperfections in the optical fibre material (Figure 1.51).

(d) Bend Loss: Incorrect handling of optical fibre is one of the common problems that can result in loss in optical fibre, like bend loss. When OFC is bent, it causes a loss of light in the fibre. There are two types of bends namely micro bending and macro bending. Typical, micro bending and macro bending losses are shown in the Figure 1.52.

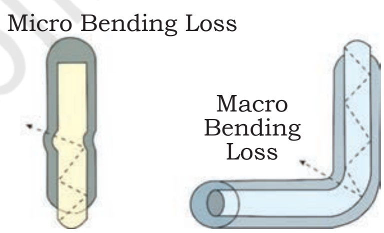

Fig.1.52: Macro and micro bending loss in optical fibre cable

Practical Exercises

Activity 4

Demonstrate to calculate macro bending loss in optical fibre cable.

Material Required

Optical fibre, LASER, connector, optical power metre.

Procedure

1. Connect a LASER light at one terminal of OFC using a connector.
2. Make sure that the OFC does not have any bend. Connect an optical power metre at the other end of OFC. Observe and note the reading.
3. Now, bend the OFC and again connect the optical power metre. Observe and note the reading.

4. Compare the two noted readings. You will observe a change in the two readings. Reading taken during the bending of the cable is much lesser. This defines the macro bending loss.

Dispersion: It refers to the spreading of the light pulse, as they travel into the fibre. Overlapping of the two signal pulses at the output of the fibre end creates an error at the receiver output in the transmission channel. It limits the information carrying capacity of the fibre. Typical, spreading of a digital pulse in the OFC is shown in Figure1.53.

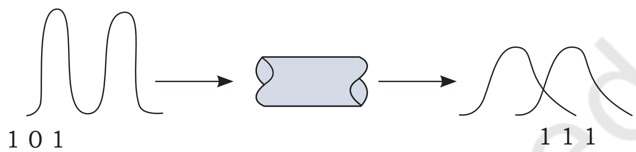

Fig.1.53: Dispersion of pulse in the optical fibre cable

Dispersion is classified as:

(a) Intermodal Dispersion

(b) Intramodal Dispersion

(a) Intermodal Dispersion: It occurs in multimode fibre. When a number of light pulses are injected into the fibre, some of them do not reach simultaneously at the end of the fibre. In multimode OFC, each ray of light has a different wavelength travel. Therefore, each ray will travel at a different speeds inside the fibres and reach the fibre end at different times. However, sometimes there is an overlapping of the rays at the fibre output. Because of this, the ray spreads and it will be then difficult to distinguish rays at the output of the fibre. For example, if transmitting the three pulses, i.e., the first pulse represents 1, the second pulse represents 0, third pulse represents 1 at the input of OFC. After sometime, when bits reach the output, then at the end of fibre, it is received as 111 (Figure 1.54).

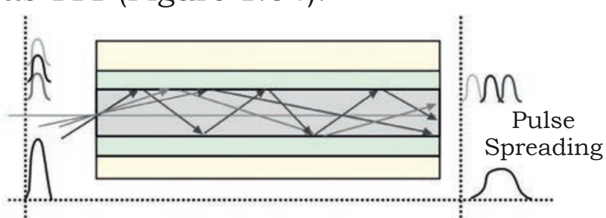

Fig.1.54: Intermodal dispersion in the multimode optical fibre cable

(b) Intramodal or Chromatic Dispersion: It is also known as *chromatic dispersion*. Intramodal dispersion mainly occurs in single mode fibre. Basically, word 'chroma' represents colour. Intramodal dispersion occurs because a light pulse is made up of different wavelengths, each traveling at different speeds in the fibre. For example, white light is composed of seven colours and when it passes through the fibre, blue light travels faster and red light travels slower. Typical, intramodal dispersion is shown in Figure 1.55.

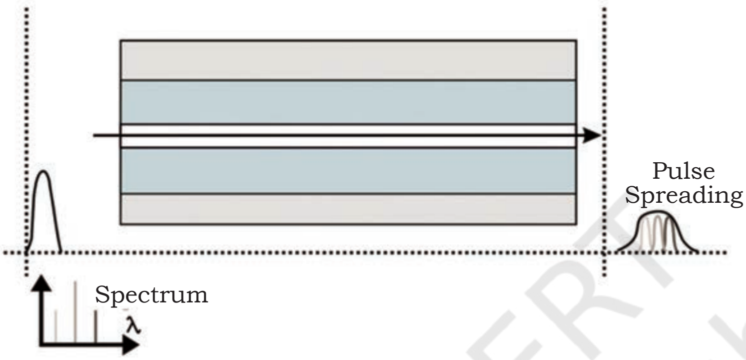

Fig.1.55: Intramodal or Chromatic dispersion in optical fibre cable

Intramodal is divided into two parts, namely material dispersion and waveguide dispersion.

Material Dispersion: Dispersion is due to the dispersive nature of the glass material. For example, when white light passes through prism it will split into seven colours as shown in Figure 1.56. Prism highlights the role of glass in dispersion. This dispersion is called *material dispersion*.

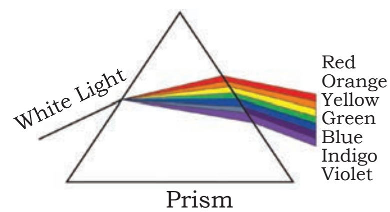

Fig. 1.56: Splitting of white light into seven colours by glass prism

Waveguide Dispersion: This type of dispersion mostly occurs in single mode fibre. In this dispersion, 80 per cent of the input optical power signal propagates in the core of the optical fibre cable, whereas remaining 20 per cent of the input optical power propagates in the cladding of OFC. The amount of optical power signal penetrating the cladding depends upon the wavelength of the applied optical power signal. This means that the more the wavelength of the applied optical power signal, the more will be the penetration in the cladding of OFC. Typical waveguide dispersion is shown in Figure 1.57.

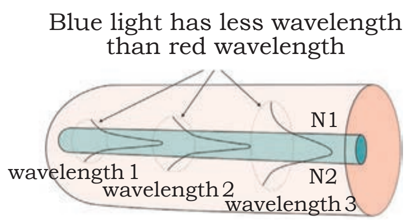

Fig.1.57: Waveguide dispersion in the core of optical fibre cable

Practical Exercises

Activity 5

Study the dispersion of white light using a prism.

Material Required

Dark room, light source, white plain paper, prism.

Procedure

1. Take a prism, clean its faces. Placed it on the white plain paper. Prism on the white surface is shown in Figure 1.58.

Fig. 1.58: A prism on a plain surface

2. Now, turn ON the light source and place it in such a way that light incident on one of the faces of prism. Light ray incident on the prism's face is shown in Figure 1.59.

Fig. 1.59: Incident light ray on the prism

3. In a dark room, observe that white light incident on a face of prism is divided into seven colours as shown in Figure 1.60.

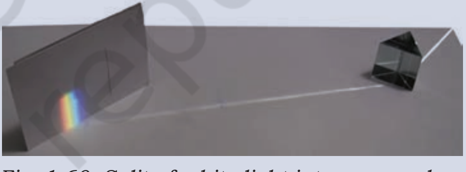

Fig. 1.60: Split of white light into seven colours

CHECK YOUR PROGRESS

A. Multiple Choice Questions

1. Which of the following pattern is followed by electric and magnetic field in electromagnetic waves?
(a) They are parallel to one another
(b) They are at right angles to one another
(c) They are randomly oriented to one another
(d) They are unrelated
2. Which of the following nature of light?
(a) Neither a wave nor a particle
(b) Primarily a wave
(c) Have the characteristics of both a wave and a particle
(d) Primarily a particle

3. Which of the following forms of electromagnetic wave has a lower frequency than the other three?
(a) Infrared light (b) Visible light
(c) Gamma rays (d) Microwaves

4. Refraction of light is characterised by a change in its
(a) Colour as it passes from one medium into another
(b) Speed as it passes from one medium into another
(c) Frequency as it passes from one medium into another
(d) Direction within a single medium

5. If a beam of light passing from medium A to medium B bends toward normal, what cfan we say?
(a) Medium A is denser than medium B.
(b) Medium A has a higher refractive index than medium B.
(c) Medium A has a lower refractive index than medium B.
(d) Both mediums A and B have the same refractive index.

6. The critical angle is the angle of incidence for which the angle of refraction is
(a) 180° (b) 0°
(c) 45° (d) 90°

7. Which of the following describes the four components of an optical fibre cable?
(a) Core, cladding, coating, buffer
(b) Fibre, buffer, strength member, jacket
(c) Core, buffer, jacket, coating
(d) Fibre, buffer, strength member, coating

8. A bundle of fibres running through a buffer with room to move around inside, is called
(a) Loose tube buffer (b) Spacer buffer
(c) Random buffer (d) Tensile buffer

9. Which of the following is the benefit of using tight-buffered fibres?
(a) Stretch more without breaking
(b) Take up less space in a cable
(c) Run for short distances outside the cable
(d) Carry a signal further

10. What relation does the electric and magnetic waves and the direction of travel have in light?
(a) They are parallel to one another
(b) They are at right angles to one another
(c) They are multiples of one another
(d) They are unrelated

B. Fill in the Blanks

1. Refraction at the air–water interface leads to ____________ of light.

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2. If light passes through the glass to air and the angle of transmitted light is greater than the critical angle, then it leads to ____________.
3. White light coming from the sun is composed of ____________ colours.
4. Phenomena of total internal reflection take place in ____________ cable.
5. Light through the optical fibre propagates inside the core at a speed of ____________.

C. State whether True or False

1. If white light is passed through the prism, then the light splits into seven colours.
2. Total internal reflection is a method, which allows the light to pass through the cladding part of the fibre.
3. In optical fibre cable, the diameter of the core is larger than the cladding.
4. The buffer coating is made up of steel.
5. The buffering layer protects the core and cladding of the optical fibre cable.
6. The speed of light becomes larger when it travels from rarer medium to the denser medium.
7. The speed of light will be reduced, when it travels from a denser to rarer medium.

D. Short Answer Questions

1. What is the role of buffer coating in optical fibre cable?
2. What is the electromagnetic spectrum?
3. Explain the term Total Internal Reflection.
4. What measures must be taken to restore the weak signal?
5. List various layers used in the manufacturing of optical fibre cable.

Chapter 2

Splicing of Optical Fibre Cable

Optical Fibre Cable (OFC) is the fastest transmission medium used in communication. In general, for any communication there is a requirement of transmitter, transmission medium, and receiver. In optical communication, we use OFC. For long distances, you need a long OFC. So, there is a felt need of joining the OFCs. In an electrical network, the wires are joined by soldering. Connecting OFCs is analogous to joining electrical wires. Splicing is the process of joining two OFCs. In splicing, the broken fibre ends are joined permanently. It is the noble name of 'soldering'. In this chapter, you will learn to understand the process of splicing and the equipment required for splicing.

Splicing

Optical Fibre Cables are widely used in communication networks. They act as veins of a communication system. An OFC is made up of glass. If these cables are broken or damaged, it is required to join them. The specialised technique used to join the damaged OFCs is called *splicing*. Various steps of splicing are shown in Figure 2.1.

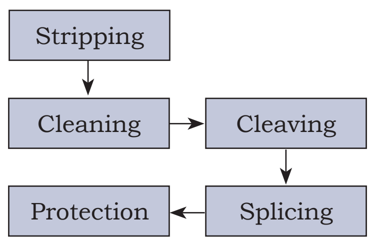

Fig. 2.1: Steps for performing splicing

Factors Affecting the Optical Fibre Cables

In the communication network, OFCs are mostly installed underground. Several factors can damage the underground OFCs. To repair these damaged OFCs splicing has to be performed. Some of the factors affecting the OFCs are namely water, rodents, lightning, infrastructural construction, ice crush, and many more.

Fig. 2.2: Damaged optical fibre cables

Fig. 2.3: Damage in the splice enclosure due to water

Fig. 2.4: Damage in the fibre cable due to rodents

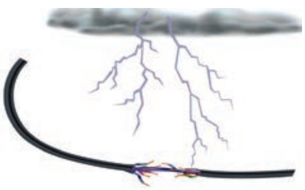

Fig. 2.5: Damage in fibre cable due to lightning

Fig. 2.6: Damage of the fibre cable due to construction

Fig. 2.7: Damage of the fibre cable due to ice crush

Water: It is very harmful for the OFC. Water slowly reduces the strength of coatings on the OFC. Water may enter into the OFC through splice joints. This may damage the OFCs as shown in Figure 2.3.

Rodents: They are often responsible for extensive damage to the OFCs. Even metal armoured cables can be cut by them as shown in Figure 2.4.

Lightning: When lightning strikes the ground, it will look for the least resistive path. Due to moisture in the soil, these high amounts of charges bypass the OFCs and are sunk into the ground. This action will cause major damage to the outer coating of the OFCs as shown in Figure 2.5.

Infrastructural Construction: It is the biggest cause of damage to the underground cables. As you know, OFCs are installed beneath the earth's surface. Therefore, at the time of digging, caution has to be taken on-site. Figure 2.6 shows the damage of OFCs while digging.

Ice Crush: In a cold place, water that enters a splice joint converts into ice as shown in Figure 2.7. It damages the internal structure of OFCs.

Type of Splicing

Splicing can be performed in two ways:

(i) Fusion splicing and

(ii) Mechanical splicing

If splicing is done mechanically, it is called *mechanical splicing*, and if it is done electrically, then it is called *fusion splicing*. Fusion splicing is most commonly used. It is done by heating the ends of the fibre using an electric arc. It is useful to join the fibre ends permanently. This method has a lower attenuation loss of 0.1dB/km. In mechanical splicing, the joint is temporary and has a loss between 0.2–0.72dB/km, which is more than that of the fusion splicing.

Assignment 1

1. Suppose, you have a broken OFC of 1 metre length. To join it, perform the stripping of OFC and then, perform precise cleaving. State the advantage of precise cleaving over cutting the fibre ends using blades of the knife.

2. Label each part of the splicing machine along with its use in fusion splicing.
3. Perform the fusion splicing of the cleaved fibre ends. Also, place the protection sleeve above it and fix it on the joined fibre ends. Note the time required to join the fibre ends and check its performance for any loss of light by passing the light into the spliced OFC.

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Losses in Splicing

When joining the two OFCs, their cores must be properly aligned. The OFC splice loss occurs mostly due to the following points:

Poor Connectivity: It is a joined optical fibre that causes a splice loss. For example, if the light source wavelength is 1,310 nm, misalignment by 1μm results in approximately 0.2 dB of loss, as shown in Figure 2.8.

Fig. 2.8: Splice loss due to poor connectivity

Bending of Optical Cable: Due to excessive bending of OFC, light in the OFC may be diverted, which will cause a loss of light. Avoid the increasing bending angle of OFC as shown in Figure 2.9.

Fig. 2.9: Splice loss due to axial run-out

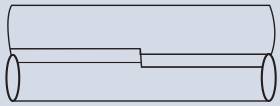
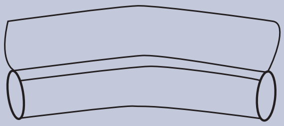
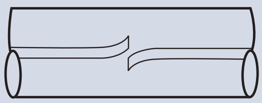
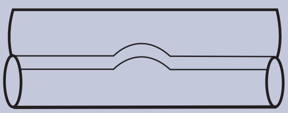
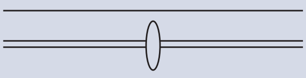
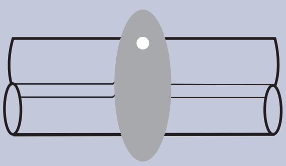
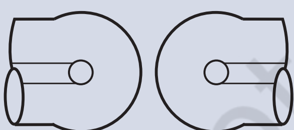
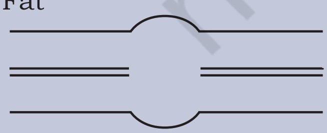
Gap: An end gap between optical fibres causes a splice loss as shown in Figure 2.10.

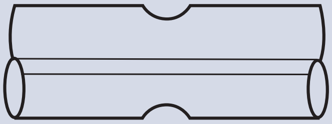
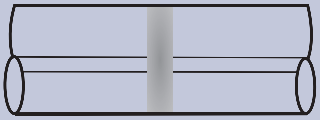
Fig. 2.10: Splice loss due to gap

Reflection: At the terminal of OFC, due to a change in the refractive index there is a loss of light. This loss is in the form of reflection because some of the light is again returned to the OFC.

Splice Problem Troubleshooting: Table 2.1 gives some common symptoms, causes, and remedies to rectify the problems.

Table 2.1: Common symptoms, causes, and remedies

Symptoms	Causes	Remedies
Core axial offset  *Fig. 2.11*	Dust on the V-groove of the fusion splice machine or fibre clamp.	Clean V-groove and fibre clamp.
Core angle  *Fig. 2.12*	a. Dust on the V-groove of the fusion splice machine or fibre clamp. b. Bad fibre ends face quality.	a. Clean V-groove of fusion splice machine and fibre clamp. b. Check if fibre cleaving is done properly.
Core step  *Fig. 2.13*	Dust on the V-groove of fusion splice machine or fibre clamp.	Clean V-groove of fusion splice machine and fibre clamp.
Core curve  *Fig. 2.14*	a. Bad fibre ends face quality. b. The pre-fuse power is too low or the pre-fuse time is too short.	a. Check if fibre cleaving is done properly. b. Increase pre-fuse power and pre-fuse time.
Bubbles  *Fig. 2.15*	a. Bad fibre-end and face quality. b. Pre-fuse power is too low or pre-fuse time is too short.	a. Check if fibre cleaving is done properly. b. Increase pre-fuse power and pre-fuse time.
Combustion  *Fig. 2.16*	a. Bad fibre end and face quality. b. The presence of dust is still there after cleaning fibre or cleaning arc.	a. Check if fibre cleaving is done properly. b. Cleaning the fibre ends thoroughly or increasing the cleaning arc time.
Separation  *Fig. 2.17*	If electrodes are contaminated. Electrodes and the fusion current are very high.	Increase pre-fuse power and pre-fuse time.
Fat  *Fig. 2.18*	Auto feed too fast, incorrect current.	Increase pre-fuse power and pre-fuse time.

Thin  *Fig. 2.19*	This type of problem is present when the current is high and the feed rate is very low. Contaminated electrodes, pre-fusion time span is also too long, pre-fusion current is too high, gap too wide.	Maintain the current and feed rate.
Line  *Fig. 2.20*	Fusion current is very low, pre-fusion time is very short.	Maintain the current and feed rate.

CHECK YOUR PROGRESS

A. Multiple Choice Questions

1. A permanent joint formed between two different optical fibres is known as
   (a) Fibre splicing (b) Fibre connector
   (c) Fibre attenuator (d) Fibre dispersion
2. Which of the following is a major part of fusion splicing?
   (a) Electric arc (b) Heating
   (c) Fusion (d) Manual joining
3. Which of the following defines the term cleaving?
   (a) Cutting the fibre edges
   (b) Polishing the fibre ends
   (c) Cleaning the fibre
   (d) Joining of the fibre
4. The loss of light in fusion splicing compared to mechanical splicing is
   (a) Equal (b) Greater
   (c) Less (d) Accurate
5. Mechanical splicing is also known as
   (a) V-groove splice
   (b) Elastic tube splice
   (c) Rotary splice
   (d) Fusion splice
6. Which of the following joint can be formed using mechanical splicing?
   (a) Temporary joints (b) Permanent joints
   (c) Loosely joints (d) Partially joints

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7. Comparing mechanical and fusion splicing, one see
   (a) Fusion splicing is more accurate than mechanical splicing
   (b) Mechanical splicing is more accurate than fusion splicing
   (c) Both mechanical and fusion splicing is accurate
   (d) Mechanical splicing and fusion splicing are inaccurate
8. Which of the following is responsible for core diameter mismatch loss?
   (a) The diameter of the transmitting core is greater than that of the receiving core
   (b) The diameter of the transmitting core is less than that of the receiving core
   (c) The diameter of the transmitting core is not precisely aligned with the diameter of the receiving core
   (d) The diameter of the receiving core is at the low end of the acceptable size range
9. Which of the following is responsible for core cladding, diameter mismatch loss?
   (a) The cladding diameter of the transmitting fibre is larger than the cladding of the receiving fibre
   (b) The cladding diameter of the transmitting fibre is smaller than the cladding of the receiving fibre
   (c) The cladding diameters of the fibres do not match
   (d) The cladding diameters of both fibres are slightly larger than normal
10. Which of the following loss occurs, if there is a mismatch between the cores of two fibres?
    (a) Concentricity loss (b) Centrality loss
    (c) Lateral offset loss (d) Slip loss
11. If the transmitting and receiving cores are slightly oval, the splice may experience
    (a) Symmetrical loss (b) Asymmetrical loss
    (c) Oval loss (d) Cylindrical loss

B. Fill in the Blanks

1. In mechanical splicing, the joint is temporary and has loss between __________ to __________ dB/km.
2. In fusion splicing, the joint is permanent and has loss of __________ dB/km.
3. The technique to join two optical fibre cables are called as __________.

4. Moisture in __________ may damage the optical fibre cable.
5. There may be separation in optical fibre cables caused due to contamination in __________.

C. Short Answer Questions

1. What is splicing?
2. What are the factors that can damage the optical fibre cable?
3. What are the basic methods used for splicing?
4. List the two problems, with their cause and remedy, that occur at the time of splicing.
5. List the common loss in the optical fibre cable.

Notes

Chapter 3

Optical Fibre Tools and Equipment

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Tools and equipment are the backbone for commissioning the installation of Optical Fibre Cable (OFC). They play an important role in setting up the cable as per the plan. Handling the tools and equipment in the correct way ensures the correct installation and repairing of the OFC. The equipment helps to identify the faults occurred in the OFC. It is recommended to keep the complete set of tools required for digging, installation, splicing, connecting, testing, and troubleshooting. The toolkit primarily consists of a splicing machine, test equipment, cable-handling tools, termination/splicing tools, and consumables. In this chapter, you will understand the various tools and equipment used in the installation of OFCs.

Toolkit and Equipment

Fig.3.1: Optical fibre tool kit and testing equipment

Tools and equipment are essential for cable laying, installation, testing, and splicing of OFCs. Tools are the same for different cables, but may vary in size and shape as per their brands. Refer to the manual for the appropriate size of tool for OFC installation. Keep the toolkit clean. It contains essential tools for carrying out the termination, and polishing of OFC at the work sites. It is portable and equipped with various tools and accessories used for termination work. Some of the tools are: Kevlar cutter, round cable stripper, polishing products, connector cleaner and wipes, epoxy products and test equipment, such as Compact 200X Microscope with 2.5 mm and 1.25 mm universal adapter. In addition, it also includes accessories used to clean and polish the

ST/SC/FC/LC/MU connectors. A typical optical fibre termination toolbox is shown in Figure 3.2.

Fig.3.2: Optical fibre termination toolbox

Cable Cutting and Stripping Tools

Rotary Cable Slitter: It is used to cut the outer jacket of the cable. The blade of the jacket slitter can be adjusted from 0.187–2.75 inches. Adjust the blade of the slitter according to the thickness of the outer jacket of the cable. Then, place it on the mark point. Rotate the slitter around the cable, and then, slide it towards the end point of the cable. A typical rotary cable slitter is shown in Figure 3.3.

Fig. 3.3: Rotary cable slitter

Practical Exercises

Activity 1

Demonstrate cable stripping using rotary cable slitter.

Material Required

Rotary cable slitter, OFC

Procedure

1. Take a piece of an OFC and rotary cable slitter.
2. Set the blade of rotary cable slitter in accordance with the thickness of the jacket of OFC.
3. Place the OFC in the slot of rotary cable slitter and then tighten the slitter knob.
4. Rotate the slitter in circular direction in such a way that only jacket of OFC should be cut.
5. Move the slitter in the outward direction.
6. After removing the jacket, inspect the fibre for any damage.

Armoured Cable Cutter: It is used with larger-diameter, metallic-armoured cables for cutting the outer jacket and armour of the cable. The depth of the cutting blade is generally correct for cutting the outer jacket and armour without harming the inner jacket or fibres in a metallic-armoured cable. Cut the armour just like tubing, making several revolutions around the cable, and tightening the cutters with each revolution (Figure 3.4).

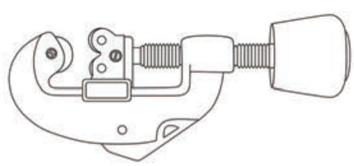


Fig. 3.4: Armoured cable cutter

Practical Exercises

Activity 2

Demonstrate the cable stripping using armoured cable jacket stripper.

Material Required

Armoured cable cutter, OFC

Procedure

1. Take a piece of OFC and armoured cable cutter.
2. Open the universal cable jacket stripper and adjust its blade, according to the diameter of the OFC.
3. Place the OFC in the slot of universal cable jacket stripper and then close the universal cable jacket stripper.
4. Move the stripper in the outward direction in such a way that only jacket of OFC is strip down.
5. After removing the jacket, inspect the fibre for any damage.

Fig.3.5: Optical fibre stripper

Fibre Stripper: It is a tool used to strip the cladding, and buffer coating of the optical fibres and remove the jacket of the fibre. It can be used for fusion splicing and direct termination works. It has three slots namely large, medium, and small used to strip the jacket, buffer, and cladding layer, respectively (Figure 3.5).

Practical Exercises

Activity 3

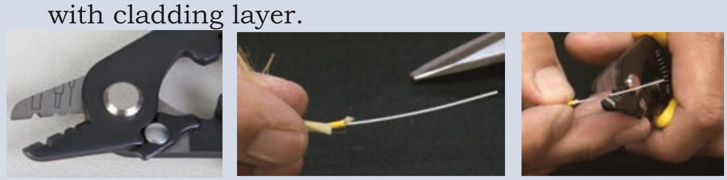
Demonstrate OFC stripping using optical fibre stripper.

Material Required

Optical fibre stripper, OFC

Procedure

1. Take an optical fibre stripper. Firstly, place the fibre in the large slot of stripper in order to remove the jacket of fibre.
2. Place the optical fibre in the middle slot of stripper, as shown in Figure 3.6(c). It will strip the buffer layers, left with cladding layer.



(a) (b) (c)

Fig. 3.6: (a) Three slots of optical fibre stripper (b) Buffer layers of OFC (c) Stripped fibre is placed in middle slot of optical fibre stripper

3. Clean the cladding of an optical fibre using tissue paper poured into isopropyl solution, as shown in Figure 3.7.

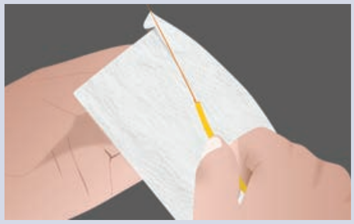
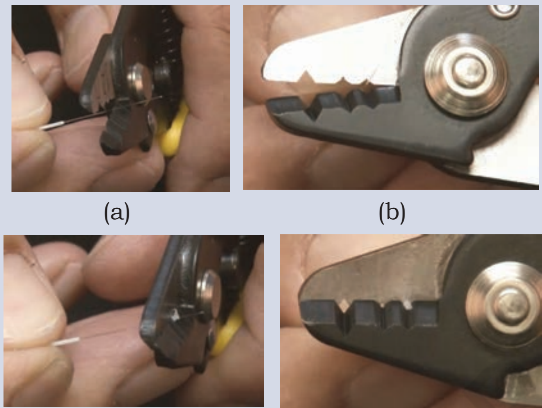


Fig. 3.7: Cleaning the optical fibre using tissue paper

4. Again, place the same fibre in the small slot. This will remove the cladding of the optical fibre, as shown in Figure 3.8.



(a) (b) (c) (d)

Fig. 3.8: (a) Placing cladding portion of OFC in little slot (b) Side view of placing the OFC in small slot (c) Squeeze the stripper removes the cladding (d) Side view of cladding removable in stripper

5. Observe the core and cladding layers. Visualise the difference in diameter of core and cladding.

Buffer Tube Stripper: It is used to strip the jacket and buffer coating of the OFC. It can support OFC with up to 1/8 inch in diameter. In addition, it is equipped with adjustable blades, which can be adjusted to strip the jacket or buffer coating of the OFC to provide nick-free stripping. A typical buffer tube stripper is shown in Figure 3.9.

Fig.3.9: Buffer tube stripper

Practical Exercises

Activity 4

Demonstrate cable stripping using buffer tube stripper.

Material Required

Buffer tube stripper, OFC

Procedure

1. Take an OFC and buffer tube stripper.

2. Open the buffer tube stripper according to the diameter of OFC.

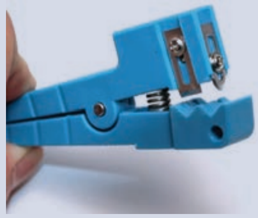


Fig. 3.10: Open the buffer tube stripper

3. Place the OFC in the slot of buffer tube stripper and then close the buffer tube stripper.

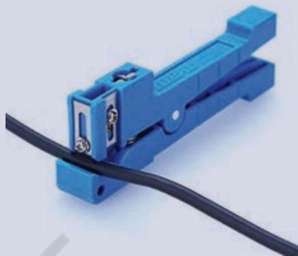


Fig. 3.11: Placing the cable in the buffer tube stripper

4. Move the stripper in the outward direction in such a way that only buffer of OFC is strip down.
5. After removing the jacket, inspect the fibre for any damage.

Fig.3.12: Fibre cleaver

Fibre Cleaver or Precision Cleaver: It is used to cut optical fibre to provide a clean and precise end face for optical splicing to minimise optical loss. It is equipped with a high-quality durable blade, which can provide cleaving up to 48,000 times before the replacement blade. A typical fibre cleaver is shown in Figure 3.12.

Practical Exercises

Activity 5

Demonstrate the use of precision cleaver.

Material Required

OFC, precision cleaver

Procedure

1. Strip of its outer layer of sample OFC using optical fibre stripper.
2. Clean the stripped fibre using tissue paper dipped in isopropyl alcohol.
3. Now, take the precision cleaver and open its cap as shown in Figure 3.13.

Fig. 3.13: Precision cleaver

4. Horizontally, place the stripped optical fibre inside the precision cleaver slot as shown in Figure 3.14.

Fig. 3.14: Fibre placed in the slot of precision cleaver

5. Adjust the blade of the precision cleaver to cut the stripped fibre cable.
6. Close the cap of precision cleaver, as soon as one closes the cap of precision cleaver, it will cut the stripped optical fibre in a direction perpendicular to the axis of fibre.

Fig. 3.15: Closing the cap of cleaver

7. Again, open the cap of precision cleaver. Check the end terminal of stripped fibre.
8. Similarly, repeat the same procedure for the other end of the fibre cable to perform its cleaving.

Fig 3.16: Scribe

Scribe: It is a sharp, hard crystal used to scratch or mark the point on the fibre for cleaving. It is used in the termination of fibre to remove the excess fibre from the connector ferrule before polishing. A typical scribe is shown in Figure 3.16.

Optical Fibre Crimp Tool: It is used to perform the crimping at the terminal of the cable. The crimping tool provides the proper compression force on the crimp sleeve required to ensure the retention of the connector on the cable. A typical crimping tool is shown in Figure 3.17.

Fig 3.17: Crimping tool

NOTES

Practical Exercises

Activity 6

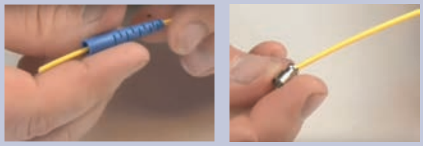
Demonstrate crimping of OFC using a crimping tool.

Material Required

Optical fibre crimper, OFC, SC connector, crimp

Procedure

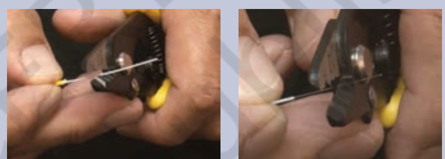
1. Take a piece of OFC, and insert the boot of the SC connector. Then, insert the crimp into the cable as shown in Figure 3.18.



(a) (b)

Fig. 3.18: (a) Insert the boot in the OFC (b) Insert the crimp in the OFC

2. Now, make a mark on the cable and strip its jacket, buffer and cladding using an OFC stripper as shown in Figure 3.19.



(a) (b)

Fig. 3.19: (a) Placing the buffer layers for stripping in the stripper's middle slot (b) Place the cladding layers for stripping in the stripper's little slot

3. Clean the fibre using isopropyl solution.
4. Take the bare fibre and insert it inside the ferrule as shown in Figure 3.20.

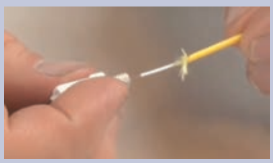


Fig. 3.20: Inserting the bare fibre inside the ferrule

5. Slide and fit the stripped fibre end inside the ferrule as shown in Figure 3.21.

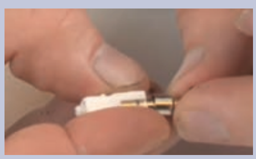


Fig. 3.21: Inserting stripped fibre inside a ferrule

6. Using a crimper, perform the crimping on the ferrule as shown in Figure 3.22.

Fig. 3.22: Crimping using the crimper

7. Slide the boot over the crimped portion.
8. Now, cut the extra Kevlar of fibre around the ferrule.
9. Cover the ferrule using outer housing as shown in Figure 3.23.

Fig. 3.23: Connecting outer housing to the inner body

10. Observe and check the functionality of the connector.

Nose Plier: It is used for grabbing and pulling pull-cords, or ripcords. Grab the pull cord firmly with the pliers, roll the cord around the jaws, and pull back along the cable to slit the cable open. Do not pull at 90 degrees to the cable. This will break the pull cord. A typical nose plier is shown in Figure 3.24.

Fig 3.24: Nose plier

Aramid Yarn (Kevlar) Scissors: Super sharp scissors are specially made for cutting the tough Kevlar fibres used as strength members in OFC. They are made up of hard stainless steel or ceramic to stand at the time of repetitively cutting the Kevlar fibres. These scissors should be used only for cutting aramid yarn (Kevlar). To use the Kevlar scissors, you should make a bunch of all the aramid yarn together, twist them to give the shape of rope, and then cut all the fibres at once. The scissors blades should cut through in 1 to 2 snips. A typical Kevlar scissors are shown in Figure 3.25.

Fig 3.25: Kevlar scissors

Practical Exercises

Activity 7

Demonstrate the use of optical fibre Kevlar scissors.

Material Required

Optical fibre Kevlar scissors, OFC

Procedure

1. Take an OFC, hold it properly in such a way that some of the portion of cable is left as shown in Figure 3.26.

Notes

Fig. 3.26: Optical fibre cable

2. Take a Kevlar scissors carefully, cut the fibre as shown in Figure 3.27.

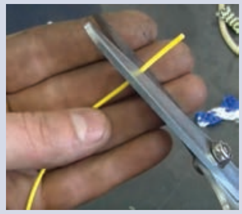


Fig. 3.27: Cutting the fibre using Kevlar scissors

3. Check sharpness of terminals (Figure 3.28).

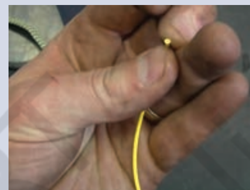


Fig. 3.28: Check sharpness of terminals

4. Use the Kevlar scissors to cut the Kevlar of the fibre as shown in Figure 3.29.

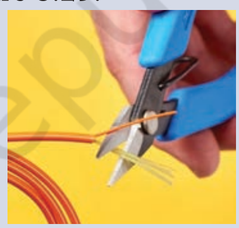


Fig. 3.29: Cutting the Kevlar of fibre using the Kevlar scissors

Optical Fibre Polishing Tools

These tools are used to facilitate the termination of the optical fibre connectors. Optical fibre polishing tools are used in the final stage of the optical fibre connector termination. To achieve the optimal result, the newly terminated optical fibre connector will require polishing to avoid high attenuation loss and low return loss.

Optical Fibre Polishing Film: It is used to polish the end face of the optical fibre connectors for better optical fibre connection and low optical loss. These are available in different sizes and with two types of materials: aluminium oxide or silicon carbide material as shown in Figure 3.30. The polishing plates, pads and mats provide the necessary surface support for the optical fibre connector polishing work to be carried out.

Polishing Plate: It provides a work surface for the polishing work of the optical fibre connector.

Polishing Pad: It can provide a cushioned surface support to carry out the polishing works and to prevent the polishing film from being stripped off.

Polishing Mat: It is used as a working mat for the optical fibre connector to polishing work and as a working surface for optical fibre stripping. As the polishing mat is black in colour, the fibre scraps can be easily spotted and picked up.

Polishing Puck: Insert the connector into this polishing tool, lay on polishing paper. Need one for 2.5mm ferrule connectors (ST/SC/FC) and one for 1.25mm ferrule connectors (LC).

Optical Fibre Polishing Disc: It is a tool made of highly precise machined metal or plastic material to carry out polishing work to the optical fibre connector. It comes with different types to support optical fibre connector types, such as FC, LC, SC, and ST. It can support the polishing of the optical fibre connectors with the end faces types, such as the physical contact and angled physical contact. A typical optical fibre polishing disc is shown in Figure 3.31.

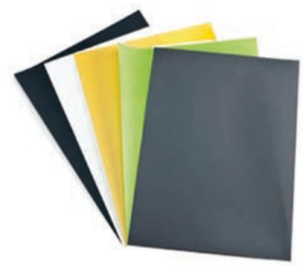


Fig.3.30: Optical fibre polishing film

Fig. 3.31: Optical fibre polishing disc

Optical Fibre Cleaning Tools

For an optimal optical fibre connection, the optical fibre connectors and other optical accessories to be used must be free from dust particles or other impurities. The optical fibre cleaning tools and supplies are designed to be deployed in the cleaning of these accessories to prevent scratching.

Connector Cleaner: It is a cleaning media used to remove impurities from the end face of the optical fibre connector. A rubber pad is located under the cleaning media to prevent scratching. A typical connector cleaner is shown in Figure 3.32.

Fig. 3.32: Connector cleaner

Optical Fibre Swabs: These are optical fibre cleaning tools used to remove impurities, such as dirt or oil from the ferrules of the optical fibre connectors. There are optical fibre swabs, which are 1.25mm and 2.5mm, respectively, to provide more targeted cleaning to remove contamination. It can be used wet or dry to clean up impurities. A typical optical fibre swab is shown in Figure 3.33

Fig.3.33: Optical fibre swabs

Fig. 3.34: One-click ferrule mate cleaner

One-Click Ferrule Mate Cleaner: It can be deployed to remove contamination at the ferrules of the optical fibre connectors as well as the alignment sleeves of the optical fibre adapters. Cleaning can be done by inserting the nozzle of the one-click ferrule mate cleaner into the optical fibre adapters. If the area is hard to reach, the nozzle can be extended. The cleaning reel is rotated automatically to ensure a new cleaning surface is available for each cleaning to prevent contamination. A typical one-click ferrule mate cleaner is shown in Figure 3.34.

Fig. 3.35: Isopropyl alcohol

Isopropyl Alcohol: It is used to clean fibres and connectors during splicing, termination and testing. A typical isopropyl alcohol is shown in Figure 3.35.

Fig. 3.36: Wipes

Wipes: It is used to clean up and dry off optical fibres. It is very cheap and is used to clean the jelly, which is around the core and cladding. Dry wipes are taken with a few drops of isopropyl alcohol above it and then it will clean up the fibre. A typical wipe is shown in Figure 3.36.

> **Note:** Do not touch the wipes with dirty hands or wet hands. Dispose of the used wipes in bin and do not reuse it.

Fig. 3.37: Hand gloves

Gloves: They are used to provide protection to the hand at the time of performing the splicing. Figure 3.37 shows the hand gloves holding the OFC.

Fig.3.38: Trash bin

Trash Bin: It is like a dustbin as shown in Figure 3.38, used to dispose of the scraps of OFC and used wipes.

Optical Fibre Epoxy Adhesive Tools

It comprises adhesive tools that are deployed in the termination of the optical cable with an optical fibre connector.

Fig. 3.39: Epoxy for connectorisation

Epoxy for Connectorisation: Epoxy is used in the curing process. The curing is a process in which the optical fibre is glued onto the ferrule of the optical fibre connector. Thus, there will be no movement of the optical fibre, once it is terminated onto the optical fibre connector. Each package can be used to prepare about 25 to 35 optical fibre connectors.

Epoxy Application Syringe: It comes with both a syringe body and needle dispenser. It is designed to inject the epoxy for connectorisation into the optical fibre connectors. A needle dispenser is available together with the syringe body. A typical epoxy application syringe is shown in Figure 3.40.

Fig. 3.40: Epoxy application syringe

Fibre Splicing Equipment

Fusion Splice Machine: It is used for joining two optical fibres end-to-end, using heat to fuse the two fibres in such a way that light passing through the fibres is not scattered or reflected by the splice. Fusion splicers are used to connect optical fibres with high precision to ensure data is transmitted reliably anywhere. It supports multimode and single-mode optical fibres. An LCD touch screen, which provides a highly clear graphical interface, is incorporated in the fusion splicer machine. A fusion splicer machine is shown in Figure 3.41.

Fig.3.41: Fusion splicer machine

Practical Exercises

Activity 8

Demonstrate the fusion splicing using electric arc.

Material Required

OFC, splice machine, optical fibre cleaver, tissue paper, alcohol, protection sleeves, round tube cutter, fibre stripper.

Procedure

1. Consider a damaged OFC as shown in Figure 3.42 to splice.

Fig. 3.42: Damaged OFC

> **Note:** Read the specification printed on the outer coating of OFC, if it is single-mode or multimode. Customise the splice machine setting as per the mode.

2. Cut and remove damaged part of fibre using a cable cutter. Now, you will have two pieces of cable.
3. Now, prepare end of each piece. These two pieces can be spliced perfectly without any loss. Figure 3.43 shows two pieces of cable, which needs to be prepared for splicing.

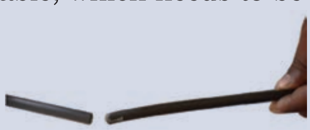


Fig. 3.43: Two ends of fibre cable which is to be splice

Notes

4. Place one piece of fibre cable in round tube cutter, as shown in Figure 3.44 and adjust the blade using knob to remove its jacket and buffer tube.

Fig. 3.44: Removing the jacket of the optical fibre cable using round tube cutter

5. Take a tissue paper with some alcohol poured on it to clean the jelly coming out of the fibre. The process is shown in Figure 3.45.

Fig. 3.45: Cleaning the jelly using tissue paper

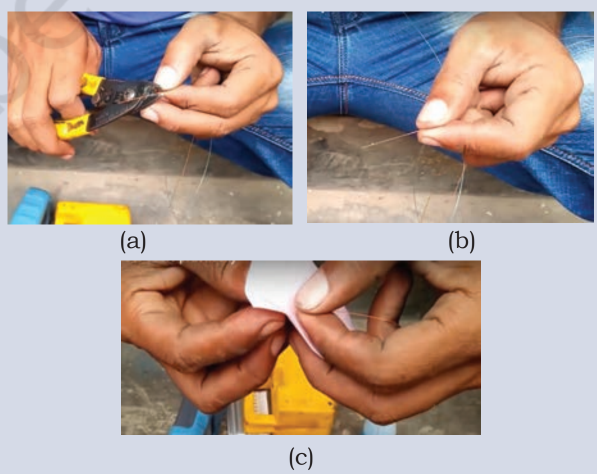
6. Select any one fibre to perform the splicing.

> As you know the procedure of fusion splicing, consider only single fibre. Otherwise, in actual practice all the fibres need to be spliced.

7. Take a protection sleeve and place a fibre inside it. Slide it around 5 inches backward from the end of the fibre as shown in Figure 3.46.

Fig. 3.46: Placing protection sleeve inside the fibre

8. Take the stripping tool and place fibre in its large slot. This will remove the buffer and now, left with cladding. The process is shown in Figure 3.47.



(a) (b)

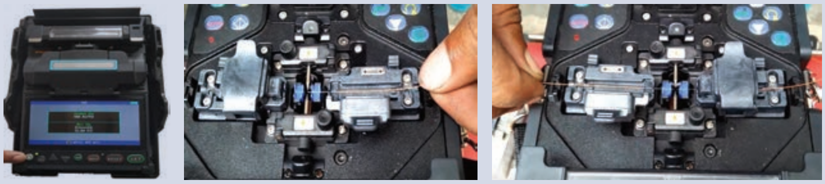
(c)

Fig. 3.47: (a) Stripping the buffer of OFC using optical fibre stripper, (b) Stripped fibre, (c) Cleaning the cladding using tissue paper

9. Now, cut the edge of cladding using precision cleaver.

Do not place your finger inside the cleaver. **CAUTION!**

10. Repeat the above procedure to prepare one more piece of fibre.
11. Now, bring the fusion splice machine, open its cap to place both the fibres in the dedicated slots as shown in Figure 3.48.



(a) (b) (c)

Fig. 3.48: (a) Fusion splicing machine, (b) Placing the first fibre in fusion splice machine, (c) Placing the second fibre in fusion splice machine

12. The machine has two steps of operation. Firstly, it aligns the cores of the two fibres and then the two electrodes of fusion splice machine. Secondly, it performs splicing of the fibres. The splicing process is shown on the display unit as shown in Figure 3.49.

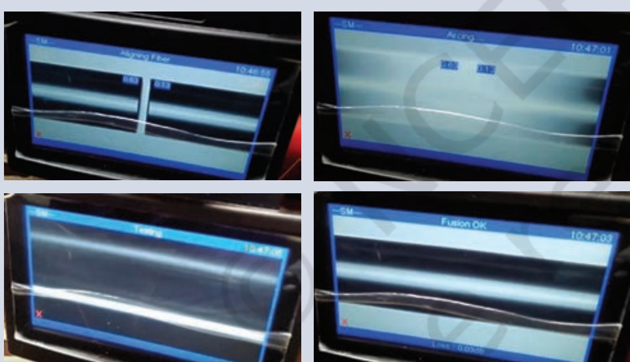


Fig. 3.49: Display unit shows the splicing operation going inside the fusion splice machine

13. Now, open the wind protector and place the spliced fibre with protection sleeve in it. Close the cap of the wind protector and press the heat button. Display will show the operation inside the machine. In this way, protection sleeve is fixed on the spliced fibre joint.

Mechanical Splices: It is used to provide the mechanical splicing. Mechanical splicing creates temporary joints and can be disconnected. This type of splicing is less accurate than fusion splicing. A typical mechanical splice is shown in Figure 3.50.

Fig 3.50: Mechanical splices

Practical Exercises

Activity 9

Demonstrate the mechanical splicing in OFC.

Material Required

OFC, optical fibre mechanical splicer connector, optical fibre cleaver, tissue paper, alcohol, protection sleeves, round tube cutter, fibre cutter/stripper.

Procedure

1. Repeat the procedure of practical activity 8 from steps 1 to 5.

   > In mechanical splicing, protection sleeve and electric arc heating are not used.

2. Take a stripped optical fibre and place it in a ferrule. Ferrule is a capillary glass tube under compression with the help of compressing springs.
3. Insert the two fibres inside the glass ferrules. Place these glass ferrules in the alignment sleeve.

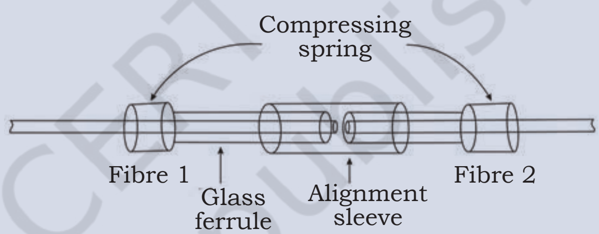


Fig. 3.51: Mechanical splicing housing

4. Index matching gel is present inside the mechanical splice. This gel helps to couple the light from one fibre end to the other.

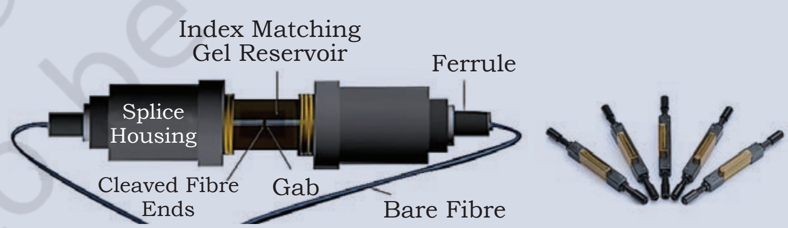


Fig. 3.52: Mechanical connector

Fig 3.53: Fusion splice protector

Fusion Splice Protector: It is used to protect the optical fibre joint from atmospheric impacts, such as air, moisture, and water. The typical fusion splice protector is shown in Figure 3.53.

Optical Fibre Connector

Optical fibre cables can be terminated in two ways, either by joining the optical fibres with the optical fibre connectors or splicing the optical fibres together. The optical fibre connectors are used to connect and align the optical fibres so that the optical light signals can be transmitted without any interference. They are widely used in telecommunication and data communication networks. Some of the commonly used connectors are given in the following table:

FC Connector: It is designed to work with screw type mating mechanism.	 *Fig. 3.54: FC connector*
LC Connector: It is designed to work with the snap-in coupling mechanism.	 *Fig. 3.55: LC connector*
SC Connector: It is designed with a push-pull coupling mechanism.	 *Fig. 3.56: SC connector*
ST Connector: It is designed to work with the thread coupling mechanism.	 *Fig. 3.57: ST connector*

Optical Fibre Adapter

They are utilised in the optical fibre network connection by connecting with the optical fibre connectors. They are designed for both single-mode and multimode OFCs. Optical fibre adapters are usually used to connect with optical fibre connectors of similar kinds. The common adapters are shown in Figure 3.58.

Fig. 3.58: Optical fibre adapters

Optical Fibre Pigtail

It is used to terminate the optical fibre cable. At one end of the optical fibre pigtail a connector is pre-installed and at the other end, it is open. This open end can be connected to the other OFC, which is to be terminated. This connection of optical fibre pigtail and OFC can be

Fig. 3.59: Optical fibre pigtail

done via fusion or mechanical splicing. The optical fibre pigtails are available with various kinds of optical fibre connectors and the most common types are FC, LC, SC and ST.

Fig. 3.60: Optical fibre patch cord

Optical Patch Cord

Optical fibre patch cable, often called *optical fibre patch cord* or *fibre jumper cable,* shown in Figure 3.60, is an OFC terminated with optical fibre connectors on both ends. They are used in optical fibre networking.

Fig. 3.61: Optical fibre attenuator

Optical Fibre Attenuator

Sometimes, the optical signals may be too strong for an optical fibre receiver to accept in optical fibre network transmission and this will cause damage to the receiving device. The optical fibre attenuator shown in Figure 3.61 can be utilised in this situation by reducing the transmission signal power level to a certain level.

Fig. 3.62: Direct termination kit

Direct Termination Kit

It is used to house bare optical fibres. The direct termination kits also provide protection to the optical fibres for termination with the optical fibre connectors. A breakout kit is used to directly terminate the bare optical fibre. Figure 3.62 shows the direct termination kit.

Fig. 3.63: Splice enclosure

Splice Enclosure

It is used to protect stripped optical fibre cables and optical fibre splices from the environment. Outdoor optical fibre enclosures are usually weatherproof with watertight seals. A typical splice enclosure is shown in Figure 3.63.

Fig. 3.64: Optical power meter

Optical Test Equipment

Optical Power Meter: It is used to measure the power in an optical signal, optical loss, and quality of the optical fibre networks. It is designed to work with the optical LASER source to measure the optical loss on OFC to provide highly accurate measurements of the quality of the optical fibre networks. It is also capable of measuring the quality and continuity of the optical fibre network.

A typical optical power meter consists of a calibrated sensor, measuring amplifier, and display. The sensor primarily consists of a photodiode selected for the appropriate range of wavelengths and power levels. On the display unit, the measured optical power and set wavelength is displayed as shown in Figure 3.64.

Practical Exercises

Activity 10

Demonstrate the light source and optical power metre.

Material Required

Optical power meter, OFC with connector, light source.

Procedure

1. Consider an OFC and connect the optical fibre cable to an optical power meter port as shown in Figure 3.65.
2. Consider a light source and connect the other end of the OFC to the light source as shown in Figure 3.66.
3. Turn ON the light source, and a ray of light enters the OFC.
4. Note down the reading from optical power meter.
5. Now, vary the wavelength of a light beam using light source.
6. Observe and tabulate the reading from optical power meter in decibel (dB) and its corresponding wavelength.

Fig. 3.65: OFC connected in optical power meter

Fig. 3.66: Optical power metre with light source

Optical Light Source: It is used to test the optical fibre connection. The optic LASER source is used in conjunction with the optical power meter to measure and provide the attenuation loss of the optical fibre network. A typical optical light source is shown in Figure 3.67.

Fig. 3.67: Optical light source

Practical Exercises

Activity 11

Demonstrate to measure insertion loss in optical fibre.

Material Required

Optical power meter device, test cable, optical light source, reference cord with connector at both the ends, optical connector adapter, tissue paper

Notes

Procedure

1. Take the reference cord and clean both the ends of connector using tissue paper as shown in Figure 3.68.

Fig. 3.68: Clean the ends of reference cord

2. Then connect one end of reference cord to the optical power metre and another end of the reference cord to the optical light source as shown in Figure 3.69.

Fig. 3.69: Connecting the reference cord to the optical power metre and optical light source

3. Choose the wavelength of 1310 nm in light source as shown in Figure 3.70. Press the "RED" button in optical power meter to set the reference dB level. At the same time, note down the reading on power meter display.

   Note: '0' dB in power meter display indicating no loss.

Fig. 3.70: Setting up the optical power meter and light source

4. Now, remove the reference cord end, which was connected to the light source. Take a test cable with connectors. Connect one of the test cable to the light source and connect other end of the test cable via connector adapter to the reference cord end as shown in Figure 3.71.

Fig. 3.71: Connect the test cable to the light source

5. Now, repeat step 2, and note down the reading of optical power meter as shown in Figure 3.72.

   Note: There will be–0.18 dB in power meter display indicating insertion loss.

6. Note down the reading to observe the insertion loss in the optical fibre test cable.

Fig. 3.72: Reading in the optical power meter

Visual Fault Locator (VFL): It uses visible light to check OFC continuity. It can also find faults in the fibre. The LASER-powered VFL is a cable continuity tester that locates fibres, and verifies cable continuity and polarity. This cable continuity tester finds breaks in cables, connectors, and splices. Continuous and flashing modes make for easier identification. It has a long battery life to use for long hours. A typical VFL is shown in Figure 3.73.

Fig. 3.73 : Visual fault locator (VFL)

Practical Exercises

Activity 12

Demonstrate the use of visual fault locator.

Material Required

Visual fault locator, batteries, fibre cable to be tested.

Procedure

1. Consider a visual fault locator as shown in the Figure 3.74. It requires two batteries for operation.

Fig. 3.74: A pen like device of visual fault locator

2. Open the upper cap of the pen as shown in the Figure 3.75.

Fig. 3.75: Opening of the upper cap of the VFL

Notes

3. Then place the batteries and then close the cap shown in the Figure 3.76.

Fig. 3.76: Inserting batteries in VFL

4. After closing the cap, check the working of device by pressing its button, which is on the cap as shown in Figure 3.77. When you press the button, it indicates ON and on pressing again, it will indicate OFF.

Fig. 3.77: Pressing of the button of VFL

5. Now, open the cap at the other end of the device as shown in Figure 3.78.

Fig. 3.78: Opening of the other end of the cap of VFL

6. The passage of high intensity light is now ready to come out of the device by pressing ON button above the cap as shown in Figure 3.79.

Fig. 3.79: Checking of the passage of light emission by VFL

7. Take the fibre end, open its plastics connector cap to perform its testing as shown in Figure 3.80.

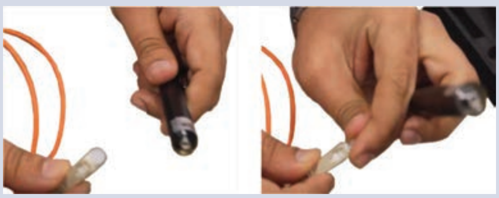


Fig. 3.80: Connection of the connector to VFL

8. Now, place the fibre, after that turn ON the visual fault locator as shown in Figure 3.81. This allows the light beam to pass through the fibre.

Fig. 3.81: Mating of the light passage inside the connector of VFL

9. Observe the other end of the fibre, whether light is coming out. If it is coming out that defines OFC working properly as shown in Figure 3.82.

Fig. 3.82: Checking of the light passage through the fibre

Inspection Microscope: It is used to visualise the end face of a connector to identify any fault/ crack/scratch (Figure 3.83).

Fig.3.83: Inspection microscope

Practical Exercises

Activity 13

Demonstrate the optical fibre inspection microscope.

Material Required

Inspection microscope, OFC

Procedure

1. Connect the OFC to the adapter of microscope as shown in Figure 3.84.

Fig. 3.84: Input the fibre into the fibre insert entrance

2. Press the switch of microscope to pass the light in the OFC. Then observe the microscope through eye piece as shown in Figure 3.85.

Fig. 3.85: Viewing microscope from eye piece

3. To get clean view adjust the focus of microscope as shown in Figure 3.86.

Fig. 3.86: Adjusting the focus control of the microscope

4. Observe and inspect the connector of the OFC.

Fig. 3.87: Optical Time Domain Reflectometer (OTDR)

Optical Time Domain Reflectometer (OTDR): It is used to calculate the various losses in the OFC. It can identify faults, and their location also. This advanced diagnostic tool for optical fibres allows to take a snapshot of a fibre link. The OTDR sends short pulses of light down one end of a fibre at a specified repetition rate. Light reflected from fibre discontinuities and light continuously backscattered from the fibre itself travels back to OTDR, where the instrument records the optical power and arrival time. The arrival time of the pulse from a given point in the fibre is related to its distance from the OTDR. With this information, the OTDR graphically displays returned power versus distance. OTDRs are well equipped for troubleshooting problems because they allow you to visually locate reflective events like connections and fibre breaks and non-reflective events like splices and tight bends by studying the graphical trace. The power difference between the two points on the trace is an estimate of optical loss. A typical OTDR is shown in Figure 3.87.

Practical Exercises

Activity 14

Demonstrate to use different functional keys and ports in optical time domain reflectometer (OTDR).

Material Required

OTDR, notepad, pen

Procedure

1. Consider an OTDR.
2. Observe the ports in OTDR (Figure 3.88) namely charging port, measuring range knob, visible LASER source, USB port, connector for inspection microscope.

Fig. 3.88: Ports of OTDR

3. Observe the functional keys namely shortcut keys, numeric keypad, rotary dial, arrow key, power switch, LCD display as shown in Figure 3.89.

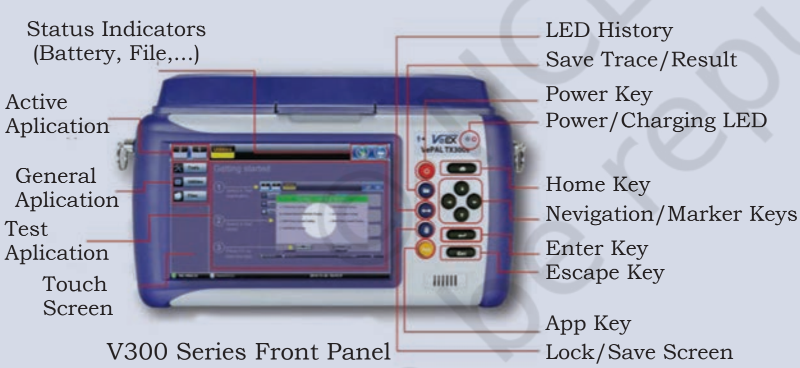


Fig. 3.89: Functional keys interfacing of OTDR

4. Observe the instructional options on LCD screen of OTDR as shown in Figure 3.90.

Fig. 3.90: Interfacing icon on the display of OTDR

5. Observe and note down the functions of all keys and ports.

Notes

Notes

CHECK YOUR PROGRESS

A. Multiple Choice Questions

1. Which of the following tools is used to cut the end of core smoothly?
   (a) Optical fibre stripper (b) Nose plier
   (c) Precision cleaver (d) Scissors
2. Electric splicing is also known as
   (a) Mechanical splicing (b) Fusion splicing
   (c) Arc splicing (d) Soldering
3. Which of the following part of fusion splicing machine is use to monitor the core alignment?
   (a) V-groove (b) LCD display
   (c) Cap (d) L-groove
4. Which of the following is the most commonly used alignment mechanism for mechanical fibre splices?
   (a) Cleaning swab (b) V-groove
   (c) Matching gel (d) Clamp spring
5. Which of the following is not a type of connector?
   (a) LC connector (b) SC connector
   (c) ST connector (d) HT connector
6. Which of the following is not the function of microscopy?
   (a) Identify any fault (b) Identify any crack
   (c) Identify any scratch (d) Identify any break
7. Visual fault locator has ______ modes.
   (a) Continuous mode (b) Flashing mode
   (c) Delay mode (d) Both (a) and (b)
8. Which of the following is not a cutting tool?
   (a) Rotary slitter cutter (b) Armoured cable cutter
   (c) Epoxy syringe (d) Optical fibre stripper
9. Which of the following is not an equipment?
   (a) Optical power meter
   (b) Kevlar scissors
   (c) LASER power source
   (d) Optical time domain reflectometer (OTDR)
10. Which of the following is not a tool?
    (a) Precision cleaver (b) Nose plier
    (c) Rotary slitter cutter (d) Crimper

B. Fill in the Blanks

1. For making the permanent joint of optical fibres ____________ is used.
2. Kevlar scissors are made up of hard ____________ or ceramic material.

3. For grabbing and pulling pull-cords, or ripcords of optical fibre cable _____________ are used.
4. Hard crystal that is used to scratch or mark the point on the fibre for _____________.
5. In order to strip the jacket and buffer coating of the optical fibre cable _____________ is used.
6. To monitor the splicing in fusion splice machine _____________ is used.
7. To visualise the end face of a connector to adjust the focus of _____________.
8. In order to find the insertion loss _____________ and optical power meter is used.
9. One click ferrule is used to remove _____________ from ferrule.
10. Breakout kit is used to directly terminate the _____________ optical fibre.

C. State whether the True or False

1. Precision cleaver cuts the fibre at an angle less than 90 degree.
2. Mechanical splicing machine has a LCD display for monitoring.
3. Fibre stripper cannot be used for the thick cables.
4. Inspection microscopy is used for the monitoring of the fibres.
5. OTDR stands for Optical Time Domain Reflectometer.
6. Optical fibre pigtail has pre-installed connector on its both the ends.
7. Isopropyl solution is used to clean the fibre.
8. Visual fault locator is used to connect the two optical fibres.
9. Optical power meter measures the wavelength of the optical signal.
10. Crimping is performmed at the terminal point of optical fibre.

D. Short Answer Questions

1. Define the terms
   (a) Fibre stripper
   (b) Cleaning swab
   (c) Rotary slitter

Notes

2. Define the connectors
   (a) LC connector
   (b) FC connector
   (c) SC connector
   (d) ST connector
3. Name the tools and equipment used for fibre splicing.
4. How the jacket of the metallic-armoured cables can be removed?
5. What is the role of optical time domain refractometer in optical fibre network?
6. Differentiate between the optical fibre pigtail and optical fibre patch cord.
7. How is fusion splicing different from mechanical splicing?
8. Write the steps to measure the insertion loss in the optical fibre.
9. List the accessories required to clean the optical fibre at the time of installation.
10. List the tools present in the optical fibre installation kit.

Unit 2

Installation of Optical Fibre Cable

This unit describes the general information for the optical fibre cable (OFC) installation. It involves several steps, such as planning, site visit and route inspection, optical fibre cable handling and cable laying, etc. There are different methods for cable laying and installation depending on the site condition and route. The two basic methods of installation are duct cable, i.e., the pulling method and the blowing method. It should be selected based on route length, site condition, accessibility of required machinery, etc. Planning the actual installation should take place only after a thorough route survey.

The essential knowledge and skills required for installation of optical fibre cable are described in this unit through practical activities.

Chapter 4

Site Visit and Route Inspection

171076CH04

One day, I visited a banquet hall in the city with my father. We were looking for a good venue with primary amenities such as interior and space in the hall, location of the venue, parking area, and rooms for the guests. This example shows that to organise any event proper planning and site visits are very important. In the same way, for the installation of optical fibre cable (OFC), first you need to do the proper planning and site visit to the proposed field. In this chapter, you will understand all about the site visit and route inspection for installation of OFC.

Site Visit

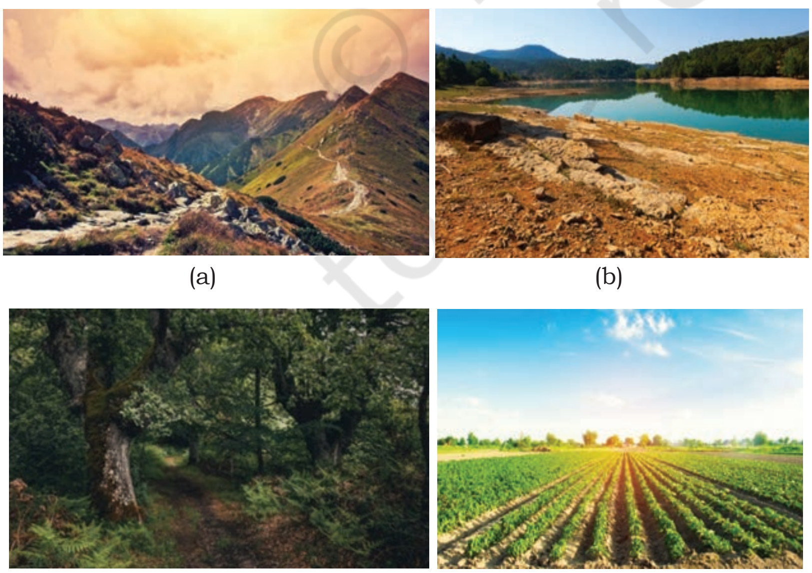
Site visit is the primary step in the installation of OFC. It is necessary to see the ground reality before preparing any plan of action. It gives the necessary information about the changes to be done in the proposed work. Site visit also helps in preparing a list of actions to be taken. This designed action plan is useful at the site while installing the cable. An effective site visit will help the correct installation of cable and avoid ambiguities. Obstructions at the site, which may become a hurdle in transportation, should also be observed. It is necessary to note down all the points observed while performing site visit. Data collected at the site must be managed correctly and it will be used to estimate the planning. After a site visit, the team members allocate the actual equipment locations, routes for excavation and conduits. It will assist in overcoming the constructional challenges like reaching the vehicle to the installation site and environmental conditions. Complete the details obtained from data collected by site visit. Note the climatic conditions and recommend the change if required. One of the typical situations of site visits by team members is shown in Figure 4.1.

Fig. 4.1: Site visit by technician

Benefits of Site Visit: The following are some of the benefits of site visit:

1. Better mapping
2. Save time
3. Save money
4. Understand climatic conditions

Different Site Conditions: In India, the geographical conditions vary after every few kilometres. Keeping this fact of variation in geographical conditions, installation team should plan accordingly. They should prepare the plan as per the requirements of the site condition. Some site conditions, which are commonly found during the visit of the installation team, are rocks, plateaus, mountains, rivers, highways, railway tracks, farms, and forests. Such an area must be checked for transportation reachability. It helps to easily drive the vehicle to the installation site for shifting the raw material from the warehouse and also machinery for excavation. The different possibilities of site conditions are shown in Figure 4.2 (a), (b), (c) and (d).



(a) (b)

(c) (d)

Fig. 4.2: Different site conditions (a) Mountains (b) River (c) Forest (d) Farm

Notes

Route Inspection

Route inspection is the next step after a site visit. It will help to inspect the actual path to be followed for cable laying. It will help to identify the small hurdles, which may create problem during the trenching, such as electric poles, water pipes, and LPG pipelines. It also covers the inspection of a land surface. This inspection assists in knowing the requirement of the conduit type that can be used. Depending upon the type of soil at the installation site, trenching can be done manually or by using machinery. In rural areas, trenching is preferred, whereas in urban areas manual trenching is performed. Route inspection also helps to know the nearby resource for raw material and transportation, required during the cable installation. An effective route planning is depicted in Figure 4.3.

Fig. 4.3: Effective route planning

The following steps need to be performed for route inspection:

1. Obtain the OFC Route Plan
2. Verify the Plan through a Route Walk
3. Corrective Action

1. **Obtain the OFC Route Plan:** In the route plan, the planning team suggests the proposed route for cable laying. This route plan contains information on physical locations, such as premises, building, complexes, and multiplex along the way of cable laying buried cables, such as telephone cable, and electrical cable.

Fig. 4.4: Physical location on the way of OFC

Note: The areas, which are free from the other utility cables, are preferred to avoid damage to existing infrastructure. The site having with underground cables and telephone line junction box in the road side as shown in Figure 4.5 should be avoided.

(a) (b)

Fig. 4.5: (a) Underground cables (b) Telephone line junction box along the road

It also includes the various departments, such as the state electricity board, water and sanitation department, and municipal corporation, from which the installation team has to obtain permissions to carry out the installation of OFC. The special protection equipment is suggested for the installation team to work at unhygienic sites. Figure 4.6 shows an example of an unhygienic situation at the installation site. Such situations should be avoided.

Fig. 4.6: Unhygienic site

2. **Verify the Plan through a Route Walk:** A preliminary survey shall be carried out for finalising the drawing for the route of OFC as a part of project planning and execution for the installation of OFC. The following points may be verified through route walk:
   - Plan the installation of OFC.
   - Create a detailed, written plan of installation as shown in Figure 4.7. Major problems can be eliminated by creating proper site planning.

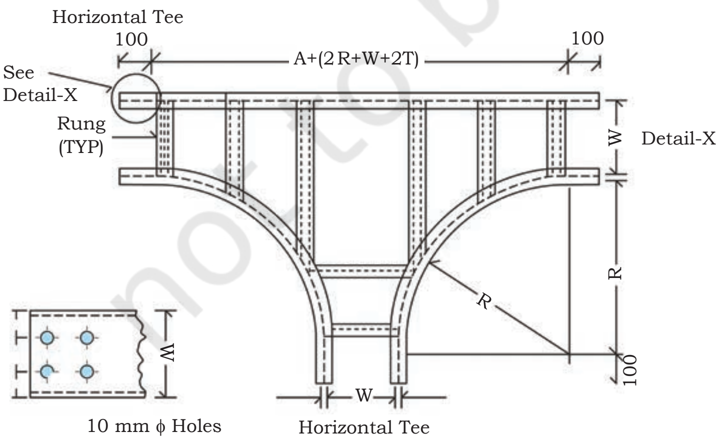


Fig. 4.7: Route plan of cable installation

Notes

- Written documentation may be prepared that include list of equipment, a technical data sheet of the OFC, installation guidelines, problems associated with the total area to be covered, safety measures to be incorporated, total budget or cost involved.

Table 4.1: Requirement list made after route inspection

Name	Required Quantity
OFC length	
Type of cable	
Type of excavation machine	
Warehouse for cable storage	
Technical data-sheet of cable reels	
Number of slicing points	
Safety measures	
Raw material for installation	
Total budget	

- Check the working space for heavy vehicles, which are going to be used in the installation. Also, check for the ground surface on which they are going to be operated. Figure 4.8 shows the excavation in the open area and in the narrow area using a mini excavator.

(a) (b)

Fig. 4.8: (a) Excavation in the open area (b) Excavation in a narrow area using a mini excavator

- Avoid laying of cable close to the track of gas pipes or water pipes. Figure 4.9 shows the OFC close to water pipe and a damaged water pipe.

(a) (b)

Fig. 4.9: (a) OFC close to water pipe (b) Water pipe damage in the excavation

- Avoid laying the cable adjacent to the cultivated fields as shown in Figure 4.10.

Fig. 4.10: Avoid laying of cable adjacent to cultivating field

- Avoid areas that are prone to water logging as shown in Figure 4.11.

Fig. 4.11: Avoid water logging area

- Avoid laying the cable inside the ground, where the soil is composed of cinders, coal and ashes as shown in Figure 4.12.

Fig. 4.12: Ash on the installation ground surface

- Avoid the areas near industries because such industries can discharge poisonous chemicals, which can damage the cable (Figure 4.13).

Fig. 4.13: Area near to the chemical industry

- Avoid the areas that require large rock cutting, and dense jungles as shown in Figure 4.14. Because it will be difficult to approach such areas.

(a) (b)

Fig. 4.14: (a) Excavation in rock (b) Excavation in forest

- Avoid the area, where mega projects as shown in Figure 4.15, are likely to be constructed in the near future, such as highway projects may damage the buried OFC.

Fig. 4.15: Mega structure highway project

- In order to protect the cable from corrosion or moisture damage, it is better to determine the composition of the soil. Performing the soil testing is shown in Figure 4.16.

Fig. 4.16: Performing the soil testing

- The requirement of transport vehicles like loading trucks, dumpers, excavators, and trenchers for the execution of the work must be considered. The requirement is depicted in Figure 4.17.

Fig. 4.17: Transport vehicles involved in the OFC installation

Fig. 4.18: Warehouse storage and ventilation

Fig. 4.19: Electrical sub-station and transmission tower

Fig. 4.20: Precautionary measures must be performed near the electric panel

- Verify the plan for accessibility and availability of material as per design.
- Verify construction methods, tools and equipment and splice locations.
- Check for material storage areas and ventilation. An ideal warehouse storage is shown in Figure 4.18.
- Avoid proximity to AC power station areas to avoid electric shock (Figure 4.19).
- In case, an installer has to work near the electrical panel or electrical wire then installer must wear safety gear as shown in Figure 4.20.
- After performing the above points, make a sketch as per the route walk. The route walk sketch is shown in Figure 4.21.

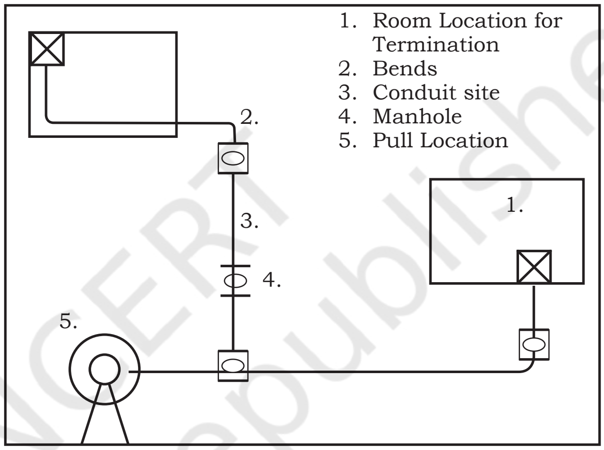


Fig. 4.21 : OFC route walk sketch

3. **Corrective Action:** The next task is to prepare the site for installation by taking corrective action. If required,
   - Take permission from other departments.
   - Revise the route of the cable, splice location, storage location, if needed.
   - Arrange for the availability of any special tool, such as stone drilling machines.
   - Remove any obstruction along the route. Prepare the site for better productivity.
   - If the route contains sections where the optical cable is subject to high temperatures, provide necessary protection.
   - Take measures to prevent optical cables from direct stress.
   - Determine the location where cable reels can be positioned during the installation.
   - Locate and check the accessibility of the storage house.

Benefits of Route Inspection: Route inspection provides the following benefits:

- The issues, such as any obstruction, cannot be known without conducting an 'inspection'.
- It helps to identify the gaps in the plan and actual physical location.
- It helps to maintain the correct bend radius of cable.
- It helps to identify the hazards and safety to be followed during installation.
- Any rework due to lack of a proper plan is avoided.
- Accidents are avoided due to proper planning.

Route Inspection Report

The team will submit the survey report to the authority. It contains all the information on inspection and the most suitable routes for all the optical fibre links along with details. The authority will give the preliminary approval for the route, subject to obtaining the required clearances. On approval, a team shall carry out a detailed survey of the selected routes and submit the final survey report for approval before implementation.

The final survey report shall include the following:

- A drawing of the proposed route indicates all details of the route including relevant details of soil type, bridge, rail over/under bridges, defence area, underground pipeline of gas, oil, water, power and communication cable routes with other important landmarks.
- The distance of the OFC route from the centre of the road/rail/river/bridge shall be indicated in the route maps as well as documented in tables.
- Sections of the links where trenchless digging may be required.
- Sections where galvanised iron (GI) or reinforced cement concrete (RCC) pipe may be required.
- Location and number of permanent and temporary manholes.
- Location of all turns, bends and major landmarks.
- Type, quantity and location of all the splice joints. Care must be taken to minimise the number of splice joints.

NOTES

Notes

- Section lengths of the underground OFC, total length of each link and drum supply scheduling for all the links.
- It shall be the responsibility of the team to propose the alternate route, if the proposed route is not suitable for installation due to the condition of soil or non-availability of clearances.
- The final survey report has to be approved by the authority and requisite clearances need to be obtained before the team commences the cable installation work.

Route Inspection Report	
Project Name: ______	
Team member: ______	
Route: ______ To ______	
Route length in km: ______	
Soil type	
Different areas to be covered	Defence area: Railway track: Road: River: Forest: Mountain: Building:
OFC type to be used	
Landmarks	
Number of bends or turn	
Number of bridges	
Warehouse location	
Type of digging to use	
Number of splice joints required	
Length of OFC required	
Type of ducting required	
Number of manpower required	
Name: ______	
Designation: ______	
Authorised signature: ______	

Safety Precautions

- Do not eat, drink, or smoke in an area near bare cable of fibre, to avoid the cause of fire or any other accidents. Bare glass fibres can result in splinters, which are very difficult to identify and remove them. These splinters can mix with the food and cause severe damage to the internal body parts.
- Before pulling the cable, all ducts, and cable vaults should be reviewed carefully, and observe that it is not damaged from anywhere.
- Ducts should be used for placing the OFC. It should not be mixed along with the copper cables.
- Cut the OFC correctly.
- Ensure that vehicles do not pass over the cables, to avoid harm to the glass core of fibre cables.

Notes

CHECK YOUR PROGRESS

A. Multiple Choice Questions

1. Which of the following is not necessary requirement for OFC installation?
   (a) Skilled labours (b) Equipment
   (c) Technicians (d) Splicing machine
2. Optical cables are comprised of
   (a) Copper (b) Fibres
   (c) Twisted wires (d) Shielded wires
3. Which of the following is not required for installation of OFC true in respect of optical fibre cables?
   (a) Site survey (b) OFC
   (c) Splicing machine (d) Route inspection
4. What is first requirement to install the OFC underground?
   (a) Route plan
   (b) Permission from various governing bodies
   (c) Site visit
   (d) OFC
5. Which of the following is not a step in the route inspection?
   (a) Obtain an OFC route plan
   (b) Verify the plan through a route walk
   (c) Take corrective actions
   (d) Site visit

NOTES

6. Which of the following cannot be a benefit of performing site visit?
   (a) Approximate idea of the area where cable has to be laid
   (b) How much overall area to be covered?
   (c) What obstacles have to be faced like encountering of building or trees?
   (d) Verify the plan through a route walk
7. Which of the following cautions need to be perform in underground cable installation?
   (a) Bury the cable below the frost line to prevent the damage by ground frost heaves
   (b) Do not keep the trench as straight as possible
   (c) Do not bury fibre cable warning labels
   (d) Properly ground of cables is avoided
8. Moisture in the environment can result in
   (a) fibre breakage
   (b) increased fibre strength
   (c) decreased attenuation rate
   (d) increased fibre strength
9. Cable placement defines
   (a) installing the cable without pulling it
   (b) installing the cable by pulling it
   (c) uninstalling the cable without pulling it
   (d) uninstalling the cable by pulling it
10. Which of the following report is final?
   (a) Site visit report
   (b) Route walk report
   (c) Data specification report
   (d) Route inspection report

B. Fill in the Blanks

1. Underground cable layings are basically two most common types of installation named as __________ and __________.
2. Fibre is stronger than __________ when you pull it straight, but it breaks easily when bent __________.
3. Direct burial installation is most common for __________.
4. Most commonly used direct burial installation cable is __________.

C. State whether True or False

1. Cable installation cannot be done with the coaxial cables.
2. Before installation of the cable, it is required to have proper planning where installation can take place.

3. Optical fibre cable can be installed in the water logging area.
4. When working in extremely hot conditions, you need to follow safe work practices to combat working in extreme temperatures.
5. All workers need not to wear safety helmets at all times in all designated areas.
6. Gas pipelines can also be used for deploying optical fibre networks without causing major disruption and requiring extensive road works to the community, which is the norm in the case of conventional cut and fill techniques.
7. Footwear steel capped boots or equivalent cannot be worn at all times on site, except where the site foreman or safety supervisor has given approval to certain trades to use other footwear.
8. Ducts dedicated to placing the optical fibre should be used. It should not be mixed along with the copper cables.
9. Trenching uses machinery to create either a large cut all the way through the pave or a slender cut within the high of the pave to put the fibre cable.
10. Drinking water pipes cannot be used for the deployment of optical fibre cables.

D. Short Answer Questions

1. What is the requirement of a site visit?
2. Why route inspection is necessary? Write the steps to follow route inspection.
3. Write the safety precautions to be followed to perform route inspection.
4. What is route inspection?
5. What are the benefits of route inspection?
6. Briefly explain the 3 steps of route inspection.
7. How to install the cables near existing pipelines?
8. Write at least 6 steps to execute the job at the site safely.
9. List out precautions to be taken to install fibre.
10. How to do a site visit to install the cables.
11. What are the benefits of a route plan?

NOTES

Chapter 5

Optical Fibre Cable Drum Handling

171076CH05

At the time of installation of optical fibre cable (OFC), a large amount of raw material is required to be carried to the site by trucks or lorries. OFC can be damaged during the loading and unloading of the cable drum or while handling the drum at the installation site. Such damage can degrade the cable performance to the extent that replacement is necessary. Considering these facts, one must handle the cable drum in a correct manner. In this chapter, you will understand the different techniques for handling OFC and drums at various installation sites.

Cable Drum Loading

In an ongoing project of optical fibre installation, bulk purchasing of raw materials, such as OFC is the primary requirement. Cable drums are bulky and heavy to move. Hence, a crane is used for placing the cable drum at the respective place in the installation site. Follow the points below to handle OFC:

1. Use the crane or forklift to place the cable drum on a truck or at the installation site. Make sure that at the time of lifting the cable drum, it should not touch the ground as shown in Figure 5.1.
2. During transportation, the cable drums should not be kept in a flat position. It may crush down the layer of the cable, and damage the fibre.
3. Cable drums have to be tied-up properly with slings and chains on the truck. The wooden blocks should be kept in between the flanges of each drum to avoid

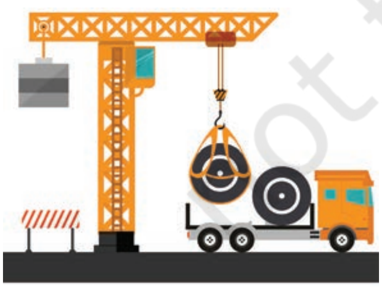


Fig. 5.1: Placing the cable drum using a crane

any jerk during transportation. Figure 5.2 shows how drums are tied during transportation.

Fig.5.2: Cable drums are tied using slings and chains

4. Wedges should be fastened with nails to the platform as shown in Figure 5.3.

(a) (b)

Fig. 5.3: (a) Wooden wedge (b) Wedge is placed to block cable drum

5. When drums are in line, flanges have to be straight against each other as shown in Figure 5.4. This way flanges of one drum will not harm the cable of another.

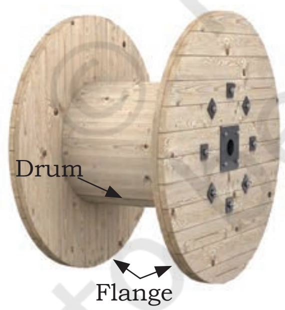


Fig.5.4: Drums are correctly placed on the truck

Know More.....

Cable drums are available in different size and weight. They are made up of materials like plywood, timber, and metal. Depending on the weight and type of cable, they are expected to be reusable or returnable. In addition, choice of material for the drums may depend on whether the drums and cables are being stored indoors or outdoors.

Notes

Fig. 5.5: Directly dropping the cable drum

Cable Drum Unloading

The following precautions need to be taken during the cable unloading:

1. The cable drum should not drop on the floor as shown in Figure 5.5. The weight of the drum and cable may cause flattening deformation or damage to the cable.
2. Roll the drum from a truck onto the receiving platform, which should be at the same height as the tailgate of the truck as shown in Figure 5.6. A forklift can also be used for unloading of cable drum as shown in Figure 5.7.

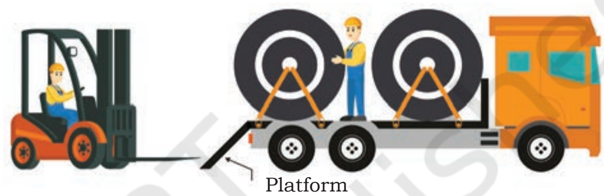
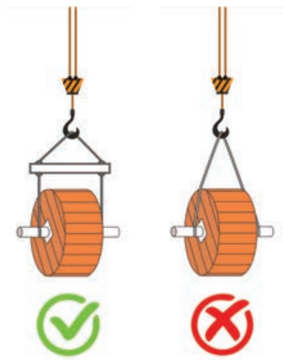


Fig. 5.6: Drum roll on the receiving platform

Fig. 5.7: Forklift lifting cable drum



(a)

(b)

(c)

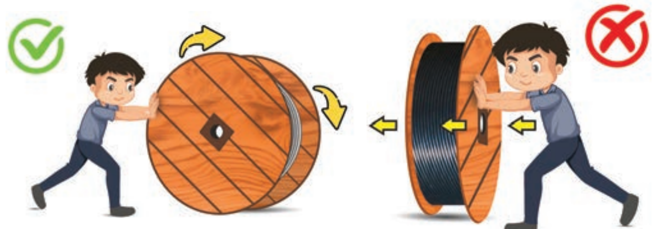
Fig.5.8: Correct way of lifting and shifting the cable drum using a crane (a), (b) and (c)

3. While shifting the cable drum from one place to another, crane should be used. Figure 5.8 (a) and (b) show the incorrect way and Figure 5.8 (c) shows the correct way to lift the cable drum.
4. On an inclined surface or ramp, carefully roll a drum, so that it does not go out of control.
5. Roll one cable drum at a time and place it in the safe storage area.

Cable Drum Handling

1. While loading or unloading cable drums, care must be taken to prevent collision with other drums.
2. Try not to roll the drum for a long distance. If in some special cases, it is necessary to roll the cable

drum for long distance, then it should rolled in the correct way as shown in Figure 5.9.



(a) (b)

Fig. 5.9: (a) Correct way of rolling the cable drum (b) Incorrect way of rolling the cable

(a) (b)

Fig. 5.10: (a) Correct way of placing the cable drum (b) incorrect way of placing the cable drum

3. The cable drum should never be stored or placed on its one flange as shown in Figure 5.10. It should be placed in such a way that both the flanges are the same level.
4. Cable drums should always be stored on a flat surface with blocks placed under the flanges to prevent rolling in either direction.

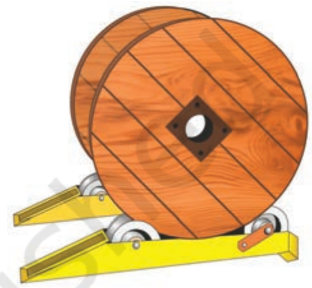


Fig.5.11: Block used to hold the drum

Cable Drum Unwrapping

The following points need to be remembered at the time of cable unwrapping:

1. Wrap on a cable drum plays an important role in protecting the cable from damage during transportation. All drums are wrapped by wooden laggings to protect the cable from minor impacts caused due to rolling the drum over the rough surface.
2. Do not remove the wrap from the cable drum until the cable is ready to install.

Fig. 5.12: Cable drum with wrapping

Cable Storage

At the beginning of the installation of OFC, a number of cable drums are purchased. However, on day-to-day basis few of them are required at the installation site. The rest of them have to be stored in warehouses or shaded secured places. While storing the cable drum, some of the points that need to be remembered are as follows:

1. The drums should always be stored in the correct position. Failing to do so may damage the cable.
2. If storage space is limited, it becomes necessary to arrange the cable drum in order to utilise the space (Figure 5.13).

Fig. 5.13: Cable drum in the warehouse

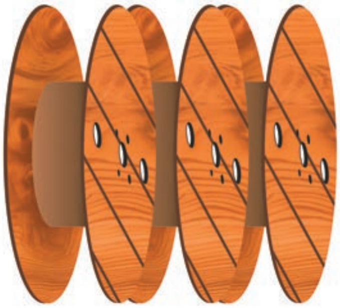


Fig. 5.14: Unaligned flanges on the floor

Fig. 5.15: Cable drums are placed in shaded area

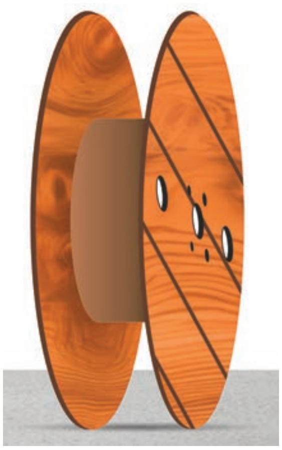


Fig. 5.16: Cable drum placed on hard and flat surface

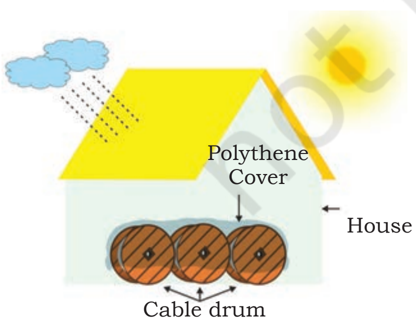


Fig. 5.17: Protection of cable drum from the sun and heavy rainfall

3. If the wrapper is removed from the drum, then their flanges should be lined up in such a way that flanges do not damage the cable of adjacent drums. The unaligned cable drum is shown in Figure 5.14.

Environmental Storage Issues: OFC is wound on wooden drums. Due to the environmental effects, wooden drums are degraded with time. Effective ways to resolve this problem are:

1. To avoid such degradations in wood during its storage period, in-house storage as shown in Figure 5.15 is recommended.
2. If there is a requirement to store the cable drums in the open area, then they should be placed on flat and hard surfaces, and should be moisture-free. This will lesses the harm to the wood of the cable drums. In addition, it will avoid the growth of harmful insects in the wood (Figure 5.16).
3. At the time of heavy rainfall, cover the cable drums with polythene. The drum moisture content should not be more than 25 per cent. To protect the drums from these situations in-house storage is preferred. The protection of cable drums from the sun and heavy rainfall is shown in Figure 5.17.

Pre-Installation Drum Inspection

When the cable drum is unloaded, supervise the cable drum for any damage. This will provide an assurance of correct product delivery. These genuine products will provide long-life work assurance. Check the cable drum for the following:

1. Before taking the cable drum to the site, test the cable for optical continuity. In addition, inspect for any damage due to improper handling and check the attenuation level of the signal in the cable.
2. Make sure that specifications and information about the cable size and its type must be clearly mentioned on the flange of the cable drum.
3. Specifications on the flange include the information, such as cable manufacturer's name, cable length,

cable type, and bend radius. Figure 5.18 shows the information about the cable printed on the cable drum.

4. Check drums for the above points as per plan before dispatching them to the installation site.
5. If any fault or mismatching is observed in the information printed on the flanges of cable drums, then immediately propose a request for the replacement of a particular cable drum.

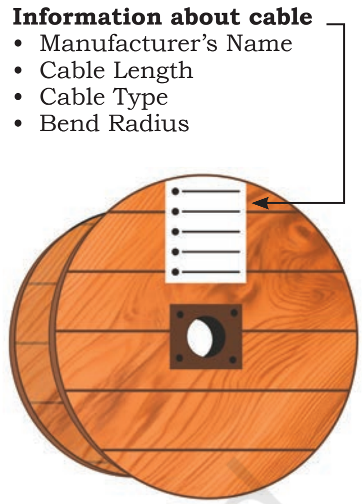


Fig. 5.18: Information about cable printed on the cable drum

Unwrapping of Drum

Open the drum carefully keeping the following points in mind:

1. All cable drums are closed by nailing wooden battens on their respective flanges with the help of aluminium or iron strips to avoid any damage to the cable during transportation.
2. To take out the cable for installation or testing, the batten should be removed carefully without damaging any portion of the cable.
3. Cut the iron strip carefully, using a cutter.
4. Put the screwdriver in the gap of the batten, and press it down to remove the batten from the flange.
5. Remove the batten carefully without damaging the OFC.
6. Remove the thermal wrapper applied over the cable.

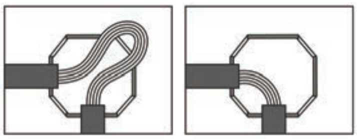
Cable Inspection

After inspecting the cable drum and the relevant information imprinted on the cable drum flange, you need to inspect the cable wound on the drum. Check for the following points while inspecting the OFC:

1. Test OFC for optical signal continuity, OFC length and attenuation.
2. If there is any shipping damage found, then inform the supplier.
3. Locate the inner and outer end of the OFC.
4. Check that there be cable cap at both the terminals of OFC.

Preparation of Drum

1. After inspecting the cable drum for any damage, prepare the drum for installation. This will include the alignment of the drum correctly. At the time of cable installation, correct alignment of the cable drum should be required.
2. Make a setup for drum payoff. To avoid cable rubbing against the cable flanges, orient the cable drum in such a way that the natural payoff direction is towards the pulling direction.
3. When there is a sharp turn at the time of cable laying, it is tough to pull the cable. In such a case, make a chamber at the turning point. First, pull the cable from one side, and then feed the cable to another side as shown in Figure 5.19.



Proper Improper

Fig. 5.19: Proper and improper bending of optical fibre cable

Assignment 1

Observe the picture of handling cable drum and mark whether it is correct or incorrect.

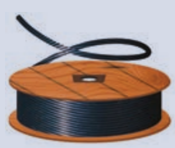
	Correct or incorrect		Correct or incorrect
 *Fig. 5.20*		 *Fig. 5.28*	
 *Fig. 5.21*		 *Fig. 5.29*	
 *Fig. 5.22*		 *Fig. 5.30*	
 *Fig. 5.23*		 *Fig. 5.31*	

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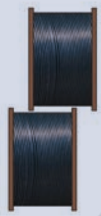
 *Fig. 5.24*		 *Fig. 5.32*	
 *Fig. 5.25*		 *Fig. 5.33*	
 *Fig. 5.26*		 *Fig. 5.34*	
 *Fig. 5.27*		 *Fig. 5.35*	

CHECK YOUR PROGRESS

A. Multiple Choice Questions

1. Which of the following machinery is used to lift the cable drum?
   (a) Crane (b) Truck
   (c) Lorry (d) Tractor
2. For the easy rolling of cable drums, the pulling direction and the payoff orientation should be in _____ direction.
   (a) Same (b) Different
   (c) Straight (d) Vertical
3. The position of the drum in the Figure below

   (a) Incorrect, upright position using wedges in the heels of the flanges
   (b) Correct, upright position using wedges in the heels of the flanges
   (c) Incorrect, using wedges in the heels of the flanges
   (d) Correct, using wedges in the heels of the flanges

4. Which of the following is used to bind the drums onto the trucks?
   (a) Ropes crossing through the central hole
   (b) Wires crossing through the central hole
   (c) Ropes crossing through the edges
   (d) Ropes crossing through the base of the drum
5. Which of the following is used to seal the cable drum?
   (a) Iron sheet (b) Wooden batten
   (c) Plastic frame (d) Thermal wrap
6. Wooden drums are not suitable for long-term storage outdoors unless protected from
   (a) Moisture (b) Water
   (c) Heat (d) Voltage
7. Which of the following is used to fasten the cable drum?
   (a) Wrench (b) Wire
   (c) Chain (d) Wedge
8. Which of the following is used to tie up the cable drum on the truck?
   (a) Nails (b) Screw
   (c) Slings and chain (d) None of these
9. Which of the following terms is not associated with cable drum?
   (a) Flange of drum diameter
   (b) Drum barrel or drum core
   (c) Width of the drum
   (d) Drum clad
10. Which of the following materials is used to manufacture the cable drum?
   (a) Plywood (b) Timber
   (c) Metal (d) All of these

B. Fill in the Blanks

1. Wooden batten should be taken out safely using a tool called _________.
2. Optical fibre cables are protected by enclosing it with wooden batten nailing on the _________.
3. To load and unload the cable drum on truck _________ the machine is used.
4. Optical fibre cable is prone to damage due to improper _________ and such damages can degrade the cable performance.
5. Cable drum should be placed on the _________ and _________ surface.

C. Short Answer Questions

1. State the factors that can damage the cable at the time of transportation of cable drum.
2. Write the steps to inspect the cable drum.
3. What are the environmental issues that need to be considered in storage area of cables?
4. What points need to be consider while handling the cable drum?
5. List the specification and information printed on the flange of the cable.

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Chapter 6

Installation of Optical Fibre Cable

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Installation of optical fibre cable (OFC) is the most critical task. Splicer and team members execute the plan of commissioning. They complete the task of laying the OFC network. In the previous chapters, you have learned about optical fibre communication, tools, equipment, site visits, route inspection, drum handling techniques, and splicing. In this chapter, you will understand the installation and splicing of an OFC. It includes sequential steps for the installation of OFC.

Optical Fibre Cable Installation Specifications

The specification of OFC plays a major role in installation. Cable is specifically designed and manufactured as per the field in which it is going to be used. If these cables are used in a field other than the one specified by the manufacturer, then in that case, the cable will not work officially. Following are some of the guidelines for specification and installation of OFC.

In this digital era, fast, efficient, and quality communication is the foremost priority for users. Communication medium is the backbone of communication. It is the path through which data and information are going to be transferred from one place to another. Specifications ensure that you purchase and install the right product for every job. Considering an example, OFC is the medium, that provides the fastest means of transferring data or information at the speed of light. Before performing the installation of OFC, you should know about the specifications of OFC. These specifications are classified into subgroups:

1. Cable specification
2. Environmental specification

1. Cable Specification

Cable specification contains the physical and technical information. It defines the information of a cable. This will help the user to know in which application the cable is to be used. Some of the cable specifications are discussed below:

(a) Bend Radius
(b) Tensile Strength
(c) Diameter of Cable
(d) Impact Resistance
(e) Crush Resistance

(a) Bend Radius: It defines the bend in the cable. It is the minimum radius of a cable or wire at which it can be safely bent. The higher the radius, the greater will be the flexibility of the material. The cable does not perform the transmission of light as we bend the cable beyond the specified bend radius of the cable. In this case, light will be absorbed by the core and cladding. Figure 6.1 shows the cable with a bend radius.

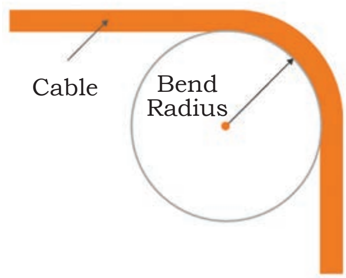

Fig 6.1: Bend radius

Example: Find the minimum bend radius of a 5 mm diameter cable. If a cable 5mm in diameter is running outside of a building under a tensile load, what is the minimum bend radius?

Ans: The minimum bend radius for cables running outside a building is 20 times the cable's outside diameter if the cable is under a tensile load.

$5\,mm \times 20 = 100\,mm$

Result: The minimum bend radius unless specified by the manufacturer is 100 mm.

(b) Tensile Strength: At the time of installing the cable, there is a need to pull the cable for proper underground laying. At that time, OFC bears high tensile force on its surface. This may damage the outer layer of the cable. For this the reason, the

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manufacturer specifies the maximum tensile strength of the cable. Thus, tensile strength can be defined as "the maximum tension which a cable can bear, without getting damaged".

Know More...

Strength, toughness, and elasticity all are mechanical properties. What does it really means?

Take a thick solid piece of plastic in your hand. Hold it by two ends, and try to pull it. If nothing happens, it is strong. But term that describes the kind of strength is *tensile strength*. Tensile strength is important for a material that is going to be stretched or under tension, like rope. Here are some kinds of strength, starting with tensile strength. Each one depends on what one is trying to do with the sample.

Different kinds of strength	Technique
Tensile strength	Try to pull
Compressional strength	Try to compress
Flexural strength	Try to bend
Torsional strength	Try to twist
Impact strength	Try to hit sharply and suddenly like with the use of a hammer

(c) **Diameter of Cable:** It defines the thickness of the cable. In other words, it is the cross-section of a cable. The diameter of OFC is so small that it cannot be measured without using appropriate measuring instruments.

(d) **Impact Resistance:** The action of one object coming forcibly into contact with cables is defined as impact on cable. The cable should be manufactured enough to bear this impact safely.

(e) **Crush Resistance:** It defines the compression strength of the cable. It includes deformation, fracture, and collapse of optical fibre cables.

2. Environmental Specification

Environmental specifications must be met to ensure the successful operation of the cable in its environment. Environmental factors include soil, water, climate, natural vegetation and land forms. General environmental specifications are as follows:

(a) Temperature range of operation
(b) Flame resistance
(c) UV resistance
(d) Resistance to damage from species
(e) Resistance to damage from water
(f) Crush loads
(g) High flexibility
(h) Resistance to solvents, petrochemicals, and other chemicals
(i) Airtight sealed fibre
(j) Radiation resistance

(a) Temperature Range of Operation: In the different area where fibre cable is going to be installed, have different temperatures and climatic conditions. To ensure the proper internal working of OFC in these climatic conditions, the manufacturer provides a range of operating temperatures of fibre cable. Exceeding these limits of operating temperature may disturb the internal performance of the cable. Installers should go through the information sheet, which is prepared by the cable manufacturer. The typical working temperature range of various applications is shown in Table 6.1.

Table 6.1

Temperature Range	Application (°C)
Indoor	–10 to +60, –10 to +50
Outdoor	–20 to +60,
	–40 to +50,
Military	–40 to +70
Aircraft	–55 to +85
	–62 to +125

(b) Flame-Resistance: It specifies that the cables be constructed of flame-resistant materials. Many commonly used materials are either flame-resistant in their most commonly used formulations, or can be made flame-resistant through the use of additives.

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(c) **UV Stability or UV Resistance:** Mostly cables are to be placed or installed in the open environment. Then, the cable must be ultraviolet radiation protected. Otherwise, the cable jacket will get cracked and lose flexibility under exposure to sunlight. Black polyethylene jacketing materials are used for UV protection. This material has built-in UV absorbing features.

(d) **Resistance to Damage from Species:** There are varieties of species in our environment. These species may damage the outer jacket of the OFC. Animals may bite the OFC. So, it may be protected by modifying the construction. Now-a-days, advanced OFCs have amour in their outermost layer, protecting the cable from these damages.

(e) **Resistance to Damage from Water:** In a pathway of cable installation water reservoir or river may come. In such a case, the cable will be getting immersed in water, either permanently or for extended periods. This will damage the OFC. Every cable must be protected from water or moisture. Moisture-resistant jacket, usually polyethylene, and a filling of water-blocking gel is used to protect it from water and moisture.

(f) **Crush Loads:** It is the compressive force that acts on the cable. This force is applied perpendicular to the cable. Crush loads can be divided on the basis of time duration for which it is applied, i.e., short-term and long-term loads. Short-term crush load is for the duration of installation. The long-term crush load is for the entire life of the cable.

(g) **High Flexibility:** As flexibility is the quality of bending easily without breaking, similarly high flexibility shows a high quality of bending. In some places, there is a need for repetitive bending of OFC. For example, in military field, elevators, the flexibility requirements must be met by both cable materials and fibres.

(h) **Resistance to Solvents, Petrochemicals, and Other Chemicals:** In some situations, you need the OFC to be resistant to worse from of exposure to certain chemicals. Examples of the chemicals to which cables are occasionally exposed are gasoline, aircraft fuel, fuel oil, grease, and crude oil.

(i) **Airtight Sealed Fibre:** In applications requiring exposure of the cable to very high water pressure or high temperature, the fibre must be airtightly sealed to retain its mechanical strength and/or its low attenuation. Airtight sealing is required because contact with moisture (or other chemicals) results in a significant reduction in the strength of the fibre, and absorption of hydrogen from water results in a significant increase in attenuation.

(j) **Radiation Resistance:** When OFC is used in an environment subjected to ionising radiation, such as in the core of a nuclear power plant, outer space, or an X-ray chamber, specify that both the cable materials and the fibre be radiation resistant. The cable material must be radiation resistant to retain acceptable mechanical properties. Since, these properties tend to be degraded by exposure to ionising radiation.

Installation Method

Installation methods of OFC can be categorised into two ways: (a) Underground Installation, and (b) Aerial Installation.

Underground Installation

It is also known as *trenching method*. It is a planned process, as a number of factors have to be considered, while performing the installation. The following are the stages involved in underground installation method:

1. **Trenching:** It is a process for making narrow excavation. Trenching is performed for short distances as well as long distances. It is a process to make an underground way for cable placement. Figure 6.2 shows a trench offer performing the trenching.

   Trenches can be formed using two methods namely manually using hand tools as shown in Figure 6.3 (a) or by using excavation machinery as

Fig. 6.2: Trench

shown in Figure 6.3 (b). The excavation for longer distances using machinery known as *ploughing*.

(a) (b)

Fig.6.3: (a) Trenching using hand tools (b) Trenching using machinery

After digging, it should be inspected and verified. There should not be any rock, or sharp objects in the trench, which will damage the OFC. This process needs more manpower and time. But, it is the most effective installation method for short distances. Trenches are done where the excavation will be hard because more obstacles are present and normally at urban and sub-urban areas for laying OFC as shown in Figure 6.4.

Fig.6.4: Men making the trench in urban area

Points to Remember

- Hazardous climatic conditions can also harm the worker. A deficiency of oxygen taking place at some critical workplaces may create a breathing issue.
- Gases as such methane, carbon monoxide, and carbon-dioxide can cause poisoning, suffocation or death.
- Material and objects can fall into the excavated portion, which can cause serious injuries, it may strike a worker working in the trench.
- Materials, such as dirt, rock, and stones, including objects, such as tools, pipes, and other equipment must be kept 2 ft from the place of excavation to avoid any accident.
- Water accumulates in the excavation during the rainy season or leakage in the water pipe. This will weaken the excavation wall making it them unstable. This will cause hazards to the worker.
- Water must be kept away or pumped out of the trench.
- Workers must not stand in the water-logged trench.

- Damaged underground utilities can expose work to the hazard and can cause an electric shock if an underground electric cable is struck, or may cause an explosion, if a gas pipeline is struck, or water logging if a water pipeline is struck.
- Prior to digging it is required to make contact with the local utility owner. Mark the area of gas pipeline, water pipeline, and underground electric cable. This will make it on easy to make the trench.
- The trench route should be selected by considering the future development planning in the area of installation. For example, road widening should not disturb the installed fibre cable.
- At the time of completing the trenching at maximum speed, trenching width and depth will not go over the requirement.

Practical Exercises

Activity 1

Demonstrate the way of making the trench.

Material Required

Trenching machine, labour, shield, and excavation equipment.

Procedure

1. In initial stage of making the trench, team members must inspect the soil of trench. Figure 6.5 shows that a technician is testing the type of soil.

Fig.6.5: Testing the type of soil

2. Test will determine the soil type, refer the Table 6.2.

Table 6.2: Type of soil and their stabilisation level

Type of soil	Level of stabilisation
Type A	The most stable type of soil for making trench
Type B	Next stable type of soil for making trench
Type C	The least stable type of soil for making trench

3. After determining the soil type, safe depth level of the trench will get decided.

4. Generally, trench will form up to the depth of 4ft.
5. Start making a trench using slope, bench, and shield to avoid the collapsing of the sidewall as shown in Figures 6.6, 6.7, 6.8.

Fig. 6.6: Slope in the trench

Fig.6.7: Bench in the trench

Fig. 6.8: Shielding of trench

6. These practices will avoid the collapsing of the sidewall.

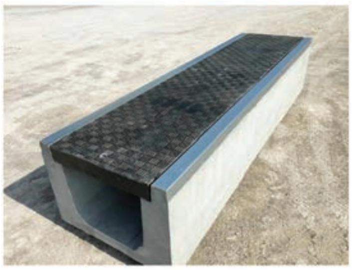

Fig. 6.9: A duct made up of concrete is placed to pull the optical fibre cable

2. **Duct Placement:** It is the placement of hollow tubes in the trench. Duct helps in pulling off OFC and at the same time, they protect the OFC from environmental effects. After completion of trenching, ducts are placed in the trenches. There are various types of ducts available in the market and duct selection depends on the characteristic of soil where installation is being done. They are made up of different materials, such as concrete, plastic, and metals. A duct made up of concrete is shown in Figure 6.9.

Fig. 6.10: Placing the cable in the trench

3. **Cable Placement:** At the time of installation of OFC, cable tension is a considerable part while pulling it through the duct. If the cable tension exceeds the limit, then it may damage the cable. To maintain the pulling tension in OFC, the extra cable is pulled out first from the cable drum, and then that cable is kept on the floor in the pattern of eight. This prevents the twisting of the cable. Figure 6.10 shows placing the cable in the trench.

   Figure 6.11 shows the wrong way to place the cable. Figure 6.12 shows the correct way to place the cable in the pattern of eight.

Fig. 6.11: Wrong way to put the optical fibre cable on the floor

Fig.6.12: Right way to put the optical fibre cable on the floor

Following steps may be performed to place the OFC in the Figure 8 pattern:

- To create Figure 8 of OFC, draw two adjacent circular patterns of diameter 1.5–2 metres.
- Pull the OFC from the drum or payoff trailer. Place it over the circumference of the circle.
- Place the cable in the shape of the numeric digit 8.
- To create Figure 8 pattern loop for heavy OFC, three persons are required, one to stand at the joining point of the circles and one each will stand beside both circles.

Practical Exercises

Activity 2

Demonstrate the cable placement in the pattern of Figure 8.

Material Required

OFC of length 100 feet, hand gloves

Procedure

1. Arrange for an open and flat surface area.
2. Wear hand gloves for protection from OFC.
3. Now, place a cable drum on the cable stand as shown in Figure 6.13.

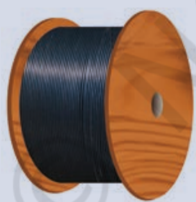

Fig. 6.13: Placing a cable drum on the cable stand

4. Start pulling the optical fibre cable as shown in Figure 6.14.

Fig. 6.14: Pulling the optical fibre cable

5. First keep the cable to be pulled from the drum on the ground surface in a circular pattern.
6. If you pull the cable in this circular pattern, it will be entangled.
7. Repeat the step 4. Place the optical fibre cable in the pattern of eight as shown in Figure 6.15. If you pull the cable it will not be entangled.

Fig. 6.15: Placing the optical fibre cable in the pattern of eight

8. This specifies that importance of placing the cable in the pattern of eight.

4. Cable Pulling and Blowing: In the installation of optical fibre cable, safely placing fibre in the duct is a critical process. To execute this task precise techniques are used as per the requirement. Commonly, used techniques for cable placement in the duct are cable pulling and cable blowing.

Fig. 6.16: Cable puller machine and pulling rope

(a) Cable Pulling: In some situations, hand-pulling the method can be used to place the optical fibre cable for a short straight path in short straight path. To do so, the cable strengthen member is tied to the pulling rope. Then, slowly optical fibre cable will be pulled through the duct. The cable puller machine and pulling rope are shown in Figure 6.16.

Fig. 6.17: Pulling machine pulling the optical fibre cable

In this operation, a pulling machine can also be used. This pulling method is generally preferred where underground ducts are not continuous for more than 200 to 300 metres. Figure 6.17 shows the pulling machine and pulling of the OFC.

Under this condition, there will be manholes to pull the cables. At each manhole, an extra bunch of optical fibre cables is left. Figure 6.18 shows a bunch of optical fibre cables in the manhole.

Fig. 6.18: Optical fibre cable kept in a manhole in the form of coil

Hence, optical fibre cables installation into a duct using a pulling method is suitable to apply for short distances. Pulling OFC using a rope is shown in Figure 6.19.

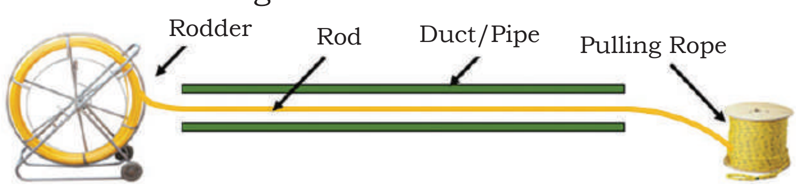

Fig. 6.19: Pulling the optical fibre cable using a rope

(b) Cable Blowing: In this type of installation method, an OFC is fed into the duct along with high speed compressed air. High speed compressed air reduces the friction inside the duct, which will help in feeding the OFC into a duct. Standard OFC can be installed by using this method. This method applicable and applies to continuous lengths of more than 1000 metres. Figure 6.20 shows the concept of air blowing method.

Fig. 6.20: Air blowing method

5. Cable Termination and Splicing: This is the last stage of the underground cable laying process. Termination refers to an end. Therefore, cable termination is the point, where the optical fibre network ends. At the terminating point of the cable, cap is placed to protect the core and cladding from damage. Route markers and warning tape are used to protect the underground cables from future excavation. The underground cable will be buried under a standard depth to avoid accidental damages.

Fig. 6.21: Route marker and warning tape on the ground surface

If there is a requirement to expand the optical network, technicians perform the splicing to spread the optical network. Let us understand, in more details using practical activity 3.

NOTES

Practical Exercises

Activity 3

Demonstrate to prepare optical fibre cable for splicing.

Material Required

Optical fibre cable, scissors, cable stripper, isopropyl wipes.

Procedure

1. Take an optical fibre cable, remove the optical fibre cable's protective jackets and buffers to allow access to the optical fibre. Make sure the cutting members are not damaging the buffer tubes.
2. The Kevlar can be trimmed using scissors or Kevlar cutters.
3. Clean the jelly on buffer tubes with isopropyl wipes.
4. The cable should be fixed in the enclosure according to the recommendations of the manufacturer of the splice enclosure.
5. The buffer tubes, like the outer jackets, can be removed by stripping tools. Care must be taken to avoid damage to internal coated fibres.

At last, the optical fibre splicer performs the testing of the installed OFC. Check for continuity of optical signal. If there is any fault or problem occurred, it will be resolved. Put some identification marks on the optical cables that will help with future maintenance and troubleshooting.

Aerial Installation

The word aerial defines operating in the air, or we can say that operating above the ground. This optical fibre installation method is common now-a-days. An aerial method is also known as *pole-to-pole installation*. To adjust to the harsh outdoor environment and prevent fibre theft, the aerial OFC is made up of different materials. This material is different from that used for a typical underground OFC.

Aerial cable is a type of OFC used to install the cable on poles. Because of its installation environment, the design of aerial OFC may be considered to protect it from the destruction of nature and man-made damage or theft. The aerial cable laying method is not hard to implement as it can utilise the existing overhead pole line to install. This will save the constructional cost and installation time.

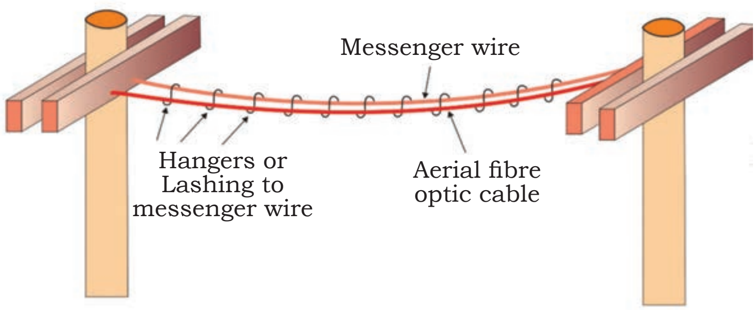

Fig. 6.22: Aerial cabling method

Aerial cabling is easily affected by natural disasters, such as storms, snowfall, floods and many more. In addition to this sunlight weakens the cable. Therefore, the failure rate of aerial optical fibre cables is higher than that of underground optical fibre cables (Figure 6.22).

There are two common methods for aerial installation of OFC:

(i) Moving Reel Method

(ii) Stationary Reel Method

(i) Moving Reel Method: It is the simplest way to install aerial OFC. Whenever there is installation of new lines, it is the primarily used cable placement method. At the time of installation of the cable, how to move the installation vehicle must be clear. Figure 6.23 shows a typical moving reel method.

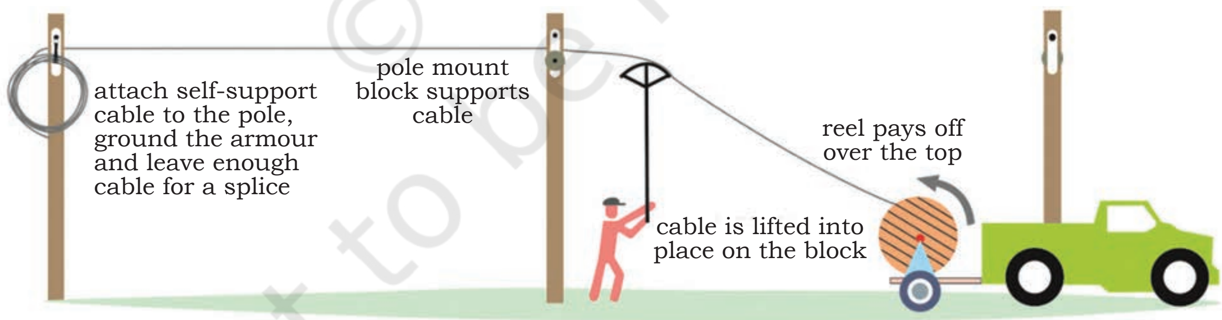

Fig. 6.23: Moving reel method of aerial cabling

(ii) Stationary Reel Method: This method contains three steps namely cable roll set-up, pulling set-up, and cable block placement.

(a) Cable Rolls Set-Up: The cable roll should be positioned in-line with the pole. A cable roll

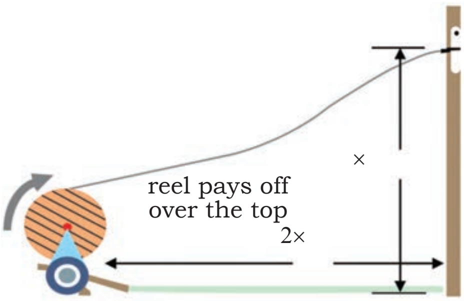

Fig. 6.24: Cable rolls set-up

Fig. 6.25: Swivel for cable pulling

must be kept at some distance from the pole. This distance will be twice the height of the pole as shown in Figure 6.24. Place protective barriers and cones as needed to protect pedestrians.

(b) Pulling Set-Up: Attach the correct-sized cable grip. Then attach a swivel and pull the OFC. Give attention to the tension that occurred in OFC.

(c) Cable Block Placement: Cable blocks are fixed on the poles by the manufacturer. First, pull the cable and then, lift it upward to place it in the cable blocks. This can be done using a cable lifter or by hand from a bucket truck as shown in Figure 6.26. Typical, cable blocks are shown in Figure 6.27.

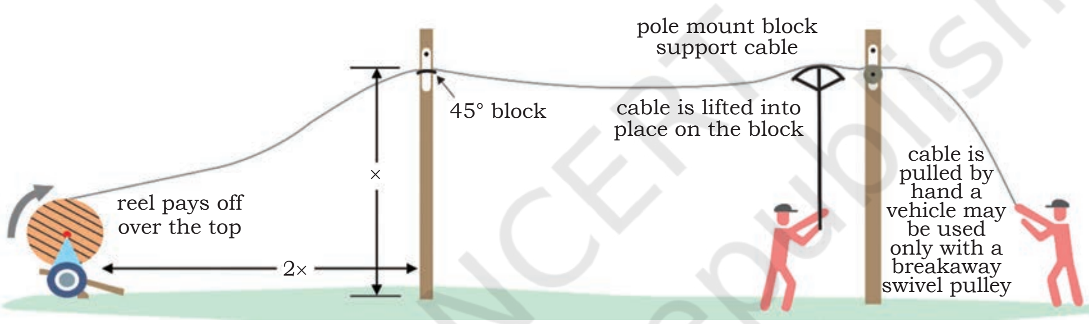

Fig. 6.26: Cable block placement

Fig. 6.27: Cable blocks

Cable Termination and Splicing

Refer the termination and splicing of underground installation of cable laying.

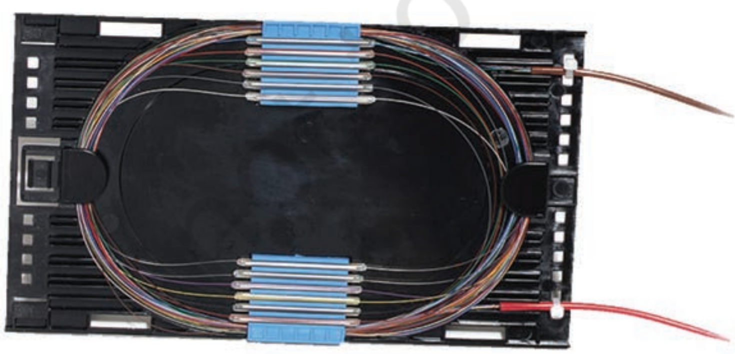

Fig. 6.28: Splice tray

Splice Trays

They are used to hold and protect individual fusion or mechanical spliced optical fibre cables. The splice tray should be matched to the type of splice used. For example, a splice tray designed to house mechanical splice fibres will not hold fusion splice fibres. Splice trays normally hold up to 12 splices fibres, and several trays are used together to splice a large number of fibre cable. A typical tray is shown in Figure 6.28.

> **Note:** Care should be taken for the individual fibre-bending radius should be kept as large as possible, greater than the minimum fibre bending radius.

Practical Exercises

Activity 4

Demonstrate the installation of the optical fibre cable in a splice tray.

Material Required

Spice tray, optical fibre cables, tools of fusion splicing.

Procedure

1. Take a splice tray as shown in the Figure 6.28.
2. Consider loose buffers inside a cable of different colours, say orange and blue. Place them in a tray as shown in Figure 6.29 and 6.30.

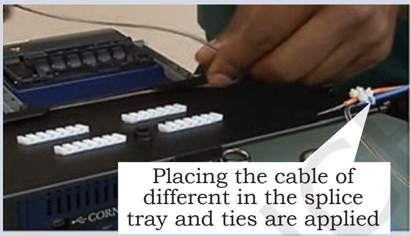

Fig. 6.29: Placing the cables of different colours in splice tray

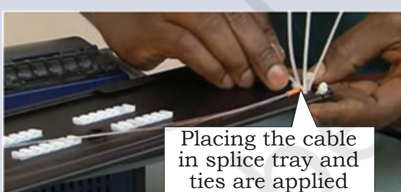

Fig. 6.30: Placing the cable in splice tray and ties are applied

3. Route fibres into splice tray as shown in Figure 6.31.

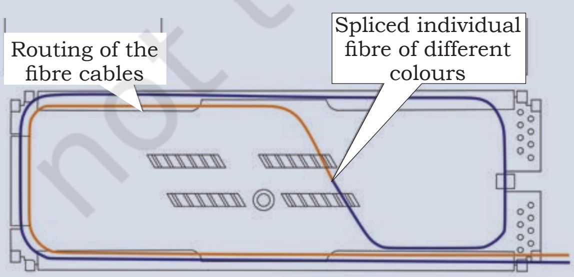

Fig. 6.31: Routing of fibre in splice tray

4. Spliced the fibres and put the protection sleeve over it, as shown in Figure 6.32.

Fig. 6.32: Spliced fibre

5. Place spliced fibre into the sleeve holders arranged by colour code as shown in Figure 6.33.

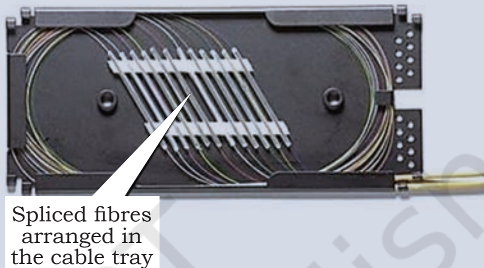

Fig. 6.33: Spliced fibre arranged in the cable tray

6. In this way, following the steps from 1 to 6 arrange the spliced cables in the tray and tied together shown in the Figure 6.34.

Fig. 6.34: Multiple spliced tray arranged and tied together in enclosure

Splice Enclosures

Splice trays require placement inside a splice closure or a patch panel box for premises applications. These enclosures are used to protect stripped optical fibre cable and optical fibre splices from the environment, and they are available for indoor as well as outdoor mounting. The outdoor type should be weatherproof, with a watertight seal. A typical splice enclosure is shown in Figure 6.35.

Fig. 6.35: Optical fibre splice inside an enclosure

Optical Fibre Splice Enclosure: Splice enclosures are of two types: Horizontal Splice Enclosure and Vertical Splice Enclosure.

Fig. 6.36: Horizontal type splice enclosure

1. **Horizontal Splice Enclosure:** Horizontal type enclosure looks like a flat or cylindrical case as shown in Figure 6.36. They provide space and protection for OFC splicing and joint. They can be used for aerially, buried, or for underground applications.
2. **Vertical Splice Enclosure:** Vertical type enclosures look like a dome, hence, they are also called *dome type enclosures*. They are similar to the horizontal type enclosure. A typical vertical type splice enclosure is shown in Figure 6.37.

Fig. 6.37: Vertical splice enclosure

   Once, the fibre tray is placed in the enclosure with the necessary sealing. It will be considered to be ready for placing in the pit.

Fibre Distribution Frame (FDF)

It is a frame used to provide cable interconnections between communication facilities, which can integrate fibre splicing, fibre termination, optical fibre adapters and connectors, and cable connections in a single unit. It can also work as a protective device to protect optical fibre connections from damage. A typical FDF is shown in Figure 6.38.

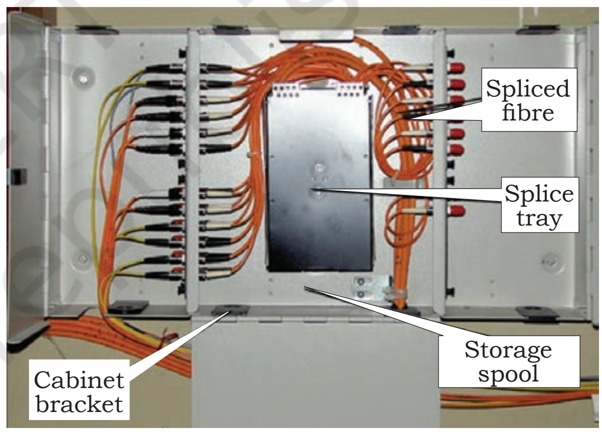

Fig. 6.38: Optical Fibre Distribution Frame (FDF)

Types of Fibre Distribution Frame

According to the structure, FDFs can mainly be divided into three types, namely wall mount FDF, floor mount FDF, and rack mount FDF.

1. *Wall mount FDF* usually uses a design like a small box, which can be installed on the wall and is suitable for fibre distribution with small counts. A typical wall mount optical distribution frame is shown in Figure 6.39.

Fig. 6.39: Wall mount optical distribution frame

Fig. 6.40: Floor mount optical distribution frame

Fig. 6.41: Rack mount distribution frame

2. *Floor mount FDF* consists of the box and distribution board. It is designed with a firm structure to mount on the floor. Side holders make it possible to mount the FDF on the floor. A typical floor mount optical distribution frame is shown in Figure 6.40.
3. *Rack mount FDF* is usually modularity in design with a firm structure. It can be installed on the rack with more flexibility according to the OFC counts and specifications. A typical rack mount distribution frame is shown in Figure 6.41.

Reporting and Documentation

It is necessary for future reference and troubleshooting. Therefore, one must ensure proper reporting and documentation.

The installed optical fibre network of a premise or area has to be mapped on paper for future upgradation and maintenance. It helps in,

- The cable laying process will be faster, including cable pulling and installation.
- Tracing links and finding faults.
- Speed up the pulling process if the routing and terminations are already documented.
- The test data should be documented with the previous information to get the acceptance from the end user.
- After the installation, if there is any repositioning of equipment the documentation will help to re-routing to the exact end points.

Information record about the cable, splice, fibre, paths is necessary and should be noted as follows:

- *Cable*: Manufacturer, type, ID, length and drum number.
- The distance at which the splices and termination point are done.
- Optical fibre type and size, splice and connectors position, losses.
- Route of cable placement.
- OFC route, loss and test results on cable should be noted.
- All these data should be kept with the documents of component, connection, and test results.
- OTDR test results will be stored separately for maintenance purposes in the future. It can be printouts or in digital format. The digital data file

should be stored in a database in an arranged manner to make maintenance easy.

All the cable drums should be marked with type, installation method to be followed, that total number of fibres in the wrapped cable, and the total length of the cable.

Special requirements should be specified as type of application and installation requirements to estimate the total manpower and cost required.

- Record test data on each fibre run.
- It will reduce the complexity of troubleshooting.

Documentation will let one know about things that are required for a cable installation, like where the cable goes, the distance between access points, the areas in which installation takes more time and many more. Testing information gives a way to find out the degradation overtime.

Merely, recording is not enough, its storage is also essential. The following points may be considered to maintain the data record:

- Documentation of data in plant location is very essential.
- The database has to be stored in different data formats, paper printouts or digital files, should have multiple copies stored in several locations and make sure that the data is accessible for every team to review.
- Ensure it is available to all the authorities for review.

The following reports should be filled regularly:

- Report on the status update
- Pending issues
- Challenges
- Faults and serviceability
- NOC for cable installation
- Final closure of the job

CHECK YOUR PROGRESS

A. Multiple Choice Questions

1. Splice enclosure used for
   (a) Whenever a fibre has been spliced
   (b) When a splice must be placed underground
   (c) When a splice must be placed underwater
   (d) When a splice must be placed above ground

NOTES

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2. FDF stands for
   (a) Fibre Distribution Frame
   (b) Fibre Digital Frame
   (c) Frame Display Fibre
   (d) Frame Distribution Fibre
3. Which of the following is not the type of FDF?
   (a) Rack mount FDF (b) Side mount FDF
   (c) Wall mount FDF (d) Floor mount FDF
4. Which of the following is used to hold and protect the spliced fibre cable?
   (a) FDF (b) Ducts
   (c) Plastic cover (d) Splice tray
5. In air blowing installation of optical fibre _____ is used.
   (a) Compressed air
   (b) Uncompressed air
   (c) Mixed air
   (d) Air at atmospheric pressure
6. Which of the following is not the cable specification?
   (a) Tensile strength
   (b) Impact resistance
   (c) Diameter
   (d) Temperature range of operation
7. Bend radius defines
   (a) Attenuation in cable
   (b) Bending in the cable
   (c) Transfer of light
   (d) UV radiation detection
8. The range of temperature for military operations is
   (a) –55 to +85 (b) –30 to +70
   (c) –20 to +60 (d) –10 to +80
9. Polyethylene is used to protect the cable from
   (a) Fire (b) Tensile load
   (c) Water (d) UV radiation
10. Which of the following defines the compression strength of cable?
   (a) Crush resistance (b) Impact resistance
   (c) Tensile strength (d) Bending radius

B. Fill in the Blanks

1. Cable installation into a pre-installed underground duct by manual pulling or by puller machine is referred as _________.
2. Duct is like a _________.

3. Cable blocks are built up by the manufacturer in the _________.
4. Aerial OFC installation procedure includes _________ and _________.
5. Trenching can be performed using _________.
6. The jacket of OFC can be damaged because of _________ ray.
7. Cable installation by using high speed air flow combined with additional mechanical pushing force is called as _________.
8. At the time of maintenance of the OFC network _________ and _________ is necessary.
9. Compressed air in the cable blowing method reduces the _________.
10. Trenching using a machine is called as _________.

C. Short Answer Questions

1. Explain the cable pulling method.
2. Explain the cable blowing method.
3. What is trenching?
4. How the duct is prepared for installation using an air blowing method?
5. Explain the aerial OFC installation procedures.
6. How the conduct is done using figure 8?
7. How the trimming of the buffer tube is done?
8. Write the steps for the OFC preparations.
9. What is the purpose of OFC pull boxes?
10. Define the following terms in respect of OFC

    (a) Crush Load
    (b) Impact Resistance
    (c) Flexibility
    (d) UV Stability
    (e) Bend Radius
    (f) Tensile Strength

NOTES

Unit 3

Testing of Optical Fibre Link

Fibre testing happens at various points to ensure proper performance before and after installation, changing, upgrading, or adding equipment. Fibre testing is the process of verifying the performance of optical fibre cabling. This process includes a range of tests and measurements, such as insertion loss, optical return loss, and fibre length.

Regularly testing fibre optic cable is an integral part of the maintenance. It ensures the network's connectivity and system uptime. A visible light source is used to find a fault along a fibre optic cable quickly. A power metre and light source is the best option when looking for and recording the most accurate attenuation levels over a fibre optic cable segment. OTDR (Optical Time Domain Reflectometer) is an excellent tool for troubleshooting issues because of its ability to provide a graph of events along a fibre optic line. By using a combination of all three methods, you can quickly isolate and diagnose issues with your fibre optic cabling and take the necessary steps to upgrade or replace it.

This unit describes the process of testing optical fibre links by all three methods through practical activities.

Chapter 7

Testing Optical Fibre Link

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Optical fibre cable (OFC) is made up of glass material. During the installation, a connector may get broken and optical fibre may get damaged. External impact on the cable will lead to the failure in an optical fibre transmission system. Optical fibre communication failure not only causes a direct economic loss, but also causes great inconvenience to people. Therefore, it is important to ensure the wellness of OFC. Testing OFC plays a significant role in monitoring and restoring faults in optical fibre communication systems.

Testing Optical Fibre

Testing is done to check the performance of optical fibre elements and systems. Testing is done in different parts, such as fibres, connectors, splices, optical light sources and many more to check the performance of optical fibre parts, cables, and systems. In order to observe the installed system, the installation team frequently takes feedback and tests results. To monitor the installed OFC:

1. Verify the individual splices using OTDR. This will ensure that every splice is working correctly.
2. All fibres must be tested frequently for continuity, correct end-to-end connections, and intermediate losses.
3. Each test is performed depending on the geographical nature of the installation site and the actual layout of the OFC.

NOTES

4. A lot of time and money can be saved if the installation team knows the correct signal strength, which is to be measured in the installed OFC.
5. To verify the correct input and output state of OFC, technicians can measure and compare the transmitted and received power. Some of the commonly used test equipment in optical fibre installation, maintenance, repairing are Visual Fault Locator (VFL), Inspection Microscope, and Optical Time Domain Reflectometer (OTDR).

(a) Visual Fault Locator: This equipment is used to visually inspect the fault and leakage of light in the OFC. Let us understand the working of a visual fault locator using practical activity 1.

Practical Exercises

Activity 1

Identify faults using visual fault locator (VFL).

Material Required

Visual fault locator

Procedure

1. Consider a visual fault locator (VFL). Observe its different parts, such as adapter, battery, and switch as shown in Figure 7.1.

Fig. 7.1: Visual fault locator

2. Starting with adapter, it is used to connect the OFC and various connectors, such as ST-type, SC-type, LC-type. Generally, in VFL 2.5 mm diameter universal adapter is used. The adapter of VFL is shown in Figure 7.2.

Fig. 7.2: Adapter of visual fault locator

NOTES

3. A battery is fixed from the back portion of VFL. Two batteries of voltage 1.5V are used in VFL. The battery slot is shown in Figure 7.3.

Fig. 7.3: Battery slot of visual fault locator

4. Last one is switch, this switch has three mode namely OFF, Continuous Wave (CW) and Glint. These three modes are shown in Figure 7.4.

Fig. 7.4: Three modes of visual fault locator switch

5. In OFF mode, light will not appear.
6. In Continuous Wave (CW) mode, continuous beam of light will come out.
7. Glint mode helps to find out the correct fibre at the other end of optical fibre if more fibres are present in the cable.

Practical Exercises

Activity 2

Demonstrate continuity testing using VFL.

Material Required

Visual fault locator, optical fibre cable with SC connector, optical fibre cable with LC connector, connector cleaner.

Procedure

1. Consider an optical fibre with SC connector. Clean the connector using 2.5mm SC cleaner as shown in Figure 7.5.

Fig. 7.5: SC connector cleaner for 2.5mm diameter

2. After cleaning the SC connector, connect the visual fault locator to SC connector of optical fibre cable as shown in Figure 7.6.

Fig. 7.6: SC connector connected to the VFL

Notes

3. Turn ON the light beam, observe the light coming out from the end of OFC as shown in Figure 7.7. If this happens, it shows the OFC has no damage.

Fig. 7.7: Light travel from one end to other in SC connected OFC

4. Consider an optical fibre with LC connector. Clean the connector using 1.25mm LC cleaner.
5. As you know that the diameter of VFL adapter is 2.5 mm. To connect the VFL adapter to LC-connector of 1.25 mm diameter, the interfacing adapter is used.

Fig. 7.8: 2.5mm to 1.25mm adapter connected to VFL

6. This adapter will convert the VFL 2.5mm diameter to 1.25mm diameter as shown in Figure 7.9.

Fig. 7.9: 2.5mm to 1.25mm adapter

7. After cleaning the LC connector, connect the VFL to LC connector of OFC as shown in Figure 7.10.

Fig. 7.10: LC connector cleaner for 1.25mm diameter

8. Turn ON the VFL, observe the light coming out of the end of OFC as shown in Figure 7.11. If this happens, it shows that the OFC has no damage.

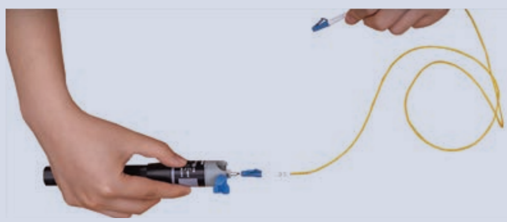

Fig. 7.11: VFL connected to the LC connected OFC

(b) Inspection Microscope: It is equipment used to inspect the OFC and connector for any fault or breakage. Let us understand, the working of inspection microscope using the practical activity 3.

Practical Exercises

Activity 3

Demonstrate the parts and functions of the inspection microscope.

Material Required

Inspection microscope

Procedure

1. Consider an inspection microscope. Observe its various parts, such as connector adapters, eyepiece, and switch.
2. Start with the connector adapter. The SC and LC adapter are shown in Figure 7.12. They are detachable as per the requirement of an optical fibre connector.
3. The eyepiece has a lens as shown in Figure 7.13 and is used to focus inside the OFC. The focus of lens can be adjusted using the knob on the microscope.
4. Pressing the switch of inspection microscope will turn it 'ON'. This will provide an image of optical fibre ends and connector ends.

(a) (b)

Fig. 7.12: Adapter in the microscope (a) SC adapter (b) LC adapter

Fig. 7.13: Adjustable knob of the lens

Activity 4

Demonstrate the inspection of fibre and connector ends using inspection microscope.

Material Required

Inspection microscope, optical fibre cable

Procedure

1. Consider an inspection microscope and OFC. Connect them as shown in Figure 7.14.

Fig. 7.14: Inserting the optical fibre cable into inspection microscope

Notes

2. If required adjust the screw of the connector adapter of microscope to align the optical fibre cable as shown in Figure 7.15.

Fig. 7.15: Adjustable screw of the microscope

3. Observe the OFC through the eyepiece of microscope, see the image of fibre and connector ends. Check for any contamination in the ends of fibre and connector.

Fig. 7.16: Optical time domain reflectometer

(c) Optical Time Domain Reflectometer (OTDR): It is a measuring device in an optical fibre system. It measures the various parameters of OFC, such as splice loss, measure the cable length, and locate the faults.

The OTDR is used to collect data. The data produced by the OTDR is typically used to create a picture called as "trace". This information can be stored. Usually, the OTDR analyses the loss at connections and splices. OTDR traces are used for troubleshooting the faults that occured in OFC. Light reflecting back in an optical fibre is the result of reflection or backscatter. Reflections happen when the light travelling through the optical fibre encounters changes in the refractive index. These reflections are called *Fresnel reflections, Backscatter,* or *Rayleigh scattering*. It is due to density variations in the OFC. Figure 7.17 shows the photons that travel back toward the OTDR are considered backscattered.

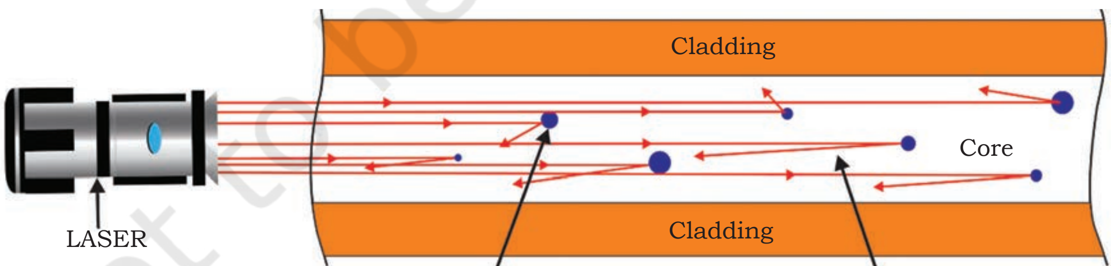

Fig. 7.17: Backscattered photons

OTDR Operation: A typical OTDR includes eight basic components: the directional coupler, LASER generator, time circuit, signal-board computer, Digital Signal

Processor (DSP), the analogy to digital converter, sample-and-hold circuit, and avalanche photodiode. Figure 7.18 is a block diagram of the OTDR showing light launched from LASER through the directional coupler into the optical fibre. The directional coupler directs the light, which is returned by the optical fibre

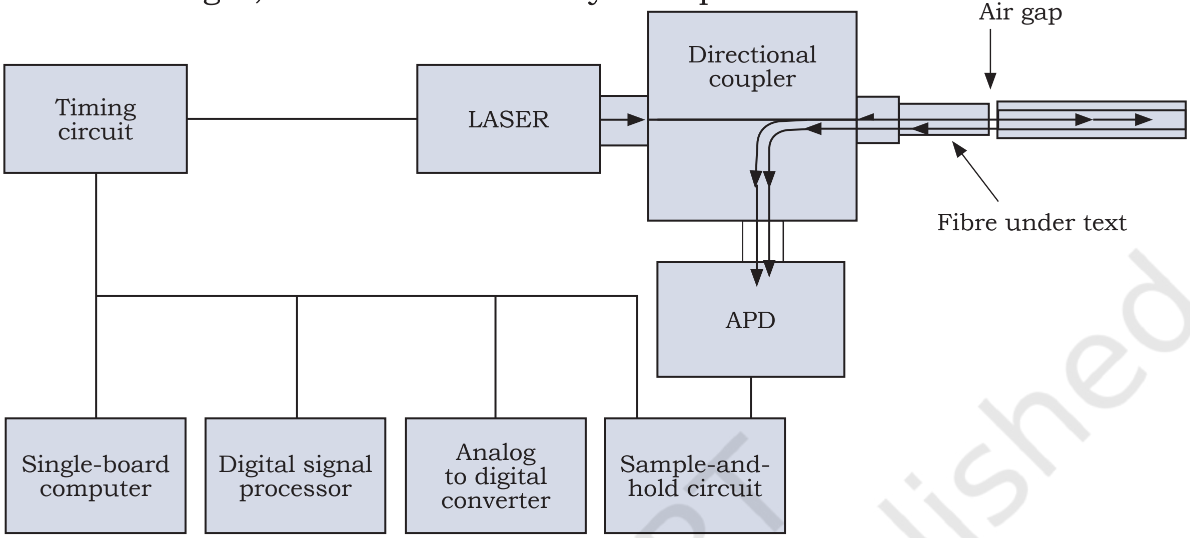

Fig. 7.18: Block representation of OTDR

to the avalanche photodiode. The avalanche photodiode converts light energy into electrical energy. The electrical energy is sampled at a very high rate by the sample-and-hold circuit. The sample-and-hold circuit converts the electrical value to a numerical value. The numerical value is processed by the digital signal processor and then after processing it will be stored in memory and then displayed on the screen.

OTDR Display: The OTDR shows the time or distance on the horizontal axis and amplitude on the vertical axis. On the horizontal axis, measuring unit is metres or kilometres, and dB (decimal) is the vertical axis.

OTDR Setup: Correct setting leads to more accurate results. When setting up the OTDR, select the correct fibre type, wavelength, range, resolution, pulse width, refractive index, and backscatter coefficient.

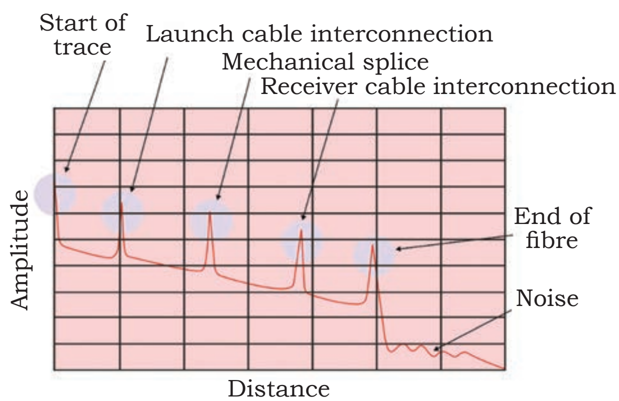

Fig. 7.19: Graphical display of signal in OTDR

Notes

Practical Exercises

Activity 5

Identify the parts of OTDR.

Material Required

Optical time domain reflectometer, pen, notepad

Procedure

1. Consider an OTDR. Identify and name its functional keys as shown in Figure 7.20. These keys are named as USB Ports, Power Key, Charging Indicator, Soft Keys, Enter Key, Rotary Knob, Arrow Keys, Setup Key, Ethernet Port, DC Supply Connectors, Menu Key.

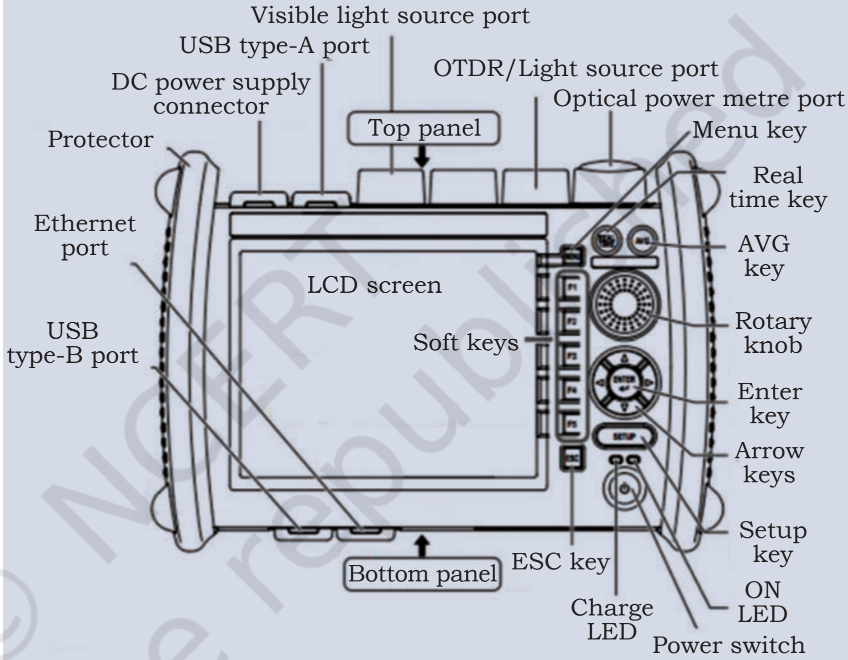

Fig. 7.20: Different parts of OTDR

2. Observe and note the functions of different keys and indicators.

   Power Port: It is the slot through, which the supply is provided, i.e., AC or DC.

   USB type-A Port: Used to connect a memory device or USB printer.

   USB type-B Port: Used to connect the OTDR to the personal computer.

   Indicator: The charging indicator is used to indicate the charging status of OTDR. A power indicator is used to indicate the status of the power supply, i.e., ON or OFF.

   Ethernet Port: Used to connect the network.

   Display: It shows the graphical view of the traces. It also has some options to control with the soft keys.

   Escape Key: It is used to return to the previous menu.

Setup Key: It is used to setup the measurement condition, system setup and file operation menus.

Real Time Key: It is used to start-stop the real time optical pulse measurement.

AVG Key: It is used to start/stop averaged optical pulse measurement.

Rotary Key: It is used to change the features, change settings and move the cursor.

Enter Key: It is used to confirm procedures and settings.

Arrow Keys: It is used to change values, move between digits and move the cursor.

Power Switch: It is used to turn ON or OFF the OTDR.

Notes

Practical Exercises

Activity 6

Demonstrate to measure the splice loss in optical fibre cable.

Material Required

OTDR, optical fibre cable, notepad, pen

Procedure

1. Consider an OTDR. Connect it with OFC.
2. Consider a spice joint in the OFC.
3. Now, launch the light pulse into the OFC and observe the graph in the OTDR.
4. Observe the splice loss in the graph. Trace it using OTDR.
5. Amount of light loss at the splice joint in decibel, is displayed by the OTDR.
6. Note the reading of splice loss at the splice joint and, then trace the graph.

CHECK YOUR PROGRESS

A. Multiple Choice Questions

1. Which of the following is not used as fault detector in optical fibre cable?
   (a) Optical time domain reflectometer (OTDR)
   (b) Visual fault locator
   (c) Inspection microscopy
   (d) Connector
2. Which of the following instrument is used to find the distance of the fault occurrence in optical fibre cable?
   (a) OTDR
   (b) Visual fault locator
   (c) Inspection microscopy
   (d) Connector

NOTES

3. The word baseline trace or trace is a familiar term used in ________ instruments.
   (a) Optical time domain reflectometer (OTDR)
   (b) Visual fault locator
   (c) Inspection microscopy
   (d) Power metre
4. Splice loss can be determined using ________ the instrument.
   (a) OTDR (b) Visual fault locator
   (c) Inspection microscopy (d) Power metre
5. Which of the following instrument have the adjustable knob control?
   (a) OTDR (b) Visual fault locator
   (c) Inspection microscopy (d) Power metre
6. What size of adapter is used in VFL?
   (a) 2.25mm to 1.55mm (b) 2.15mm to 1.50mm
   (c) 2.5mm to 1.25mm (d) 2.20mm to 1.45mm
7. Which of the following instruments has ethernet port connectivity?
   (a) OTDR (b) Visual fault locator
   (c) Inspection microscopy (d) Connector
8. Which of the following functions of the escape key in OTDR?
   (a) Go to the next menu
   (b) Cancel the task
   (c) Start the light pulse
   (d) Back to the previous menu
9. In which of the following instruments term glint is used?
   (a) OTDR (b) Visual fault locator
   (c) Inspection microscopy (d) Power metre
10. In which of the following instrument term CW or Continuity Wave mode is used?
   (a) OTDR (b) Visual fault locator
   (c) Inspection microscopy (d) Power metre

B. Fill in the Blanks

1. Visual fault locator has __________ modes.
2. In the continuous mode of the visual fault locator, light beam is __________.
3. The diameter of the LC connector is __________.
4. The diameter of the SC connector is __________.
5. Visual microscope uses __________ part to focus the optical fibre cable.

6. In a visual microscope, an adjustable __________ is used to align the optical fibre cable.
7. In the optical time domain reflectometer, __________ is used to connect a memory device or USB printer.
8. An optical time domain reflectometer, __________ is used to connect the OTDR to the personal computer.
9. In optical fibre cable, reflection due to a change in reflective index is known as __________.
10. In the OTDR display, the horizontal axis represents __________ and vertical axis represents __________.

C. State whether True or False

1. The amount of light loss in decibels is displayed by the OTDR.
2. Digital signal processing is not performed by the OTDR.
3. Two batteries of 10V is used in visual fault locator.
4. Visual microscope used as a light source in optical fibre communication.
5. Universal connector cleaner is used to clean the SC and LC connector.
6. Continuous light mode will help to identify a fibre among number of optical fibre.
7. Glint mode will generate the blinking light beam.
8. Eyepiece in visual microscope is use to visualise the contamination in the ends of fibre.
9. OTDR is used to measure the loss in OFC, length of OFC and locate the fault.

D. Short Answer Questions

1. List the name of different functional keys of OTDR.
2. Define the terms
   (a) Visual Fault Locator
   (b) Optical Time Domain Reflectometer (OTDR)
   (c) Connector Cleaner
   (d) Inspection Microscope

Notes

Unit 4

Occupational Health and Safety

Fibre optic installation, splicing, testing and maintenance is a process where the technicians have to be careful about their safety and also handling equipment. When we think of the safety precautions during the fibre optic installation, the very first precaution should be taken for eyes from the LASER light source. Because it has images of LASER burning holes in metal or burning of watts. Working with fibre optics requires a high level of expertise and a keen eye for health and safety. The other safety precautions should be taken for bare fibre safety and some general health and safety precautions. This unit describes all such precautions to be taken for the health and safety of the technician while working on the splicing and installation of optical fibre.

Chapter 8

Safety and Hazards

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The splice of optical fibre cable (OFC) work can expose it to several workplace hazards. It includes hazards ranging from LASER light sources to ladders. Optical fibre splicers are responsible for their own safety as well as for the safety of co-workers. In this chapter, you will understand the working environment in a splicing workplace, job holding efficiency, health and safety of workers. To perform the splicing job efficiently, knowledge of safe work practices is necessary. This chapter also describes the types of hazards that will be encountered in the splicing workplace and different methods to work safely.

Personal Protective Equipment

Personal Protective Equipment (PPE) required around a machine will depend on the machine and the task performed by an employee. Gloves, helmets, safety glasses, earplugs and other gears are important to wear wherever necessary. For safety, signs can be post near panels reminding employees to wear PPE. Typical PPE is shown in Figure 8.1.

Fig. 8.1: Personal Protection Equipment (PPE)

Safety Helmets: The splicer technician must wear a safety helmet at the installation site as shown in Figure 8.2. It protects from being hit by any falling material or objects.

Fig. 8.2: Safety helmets

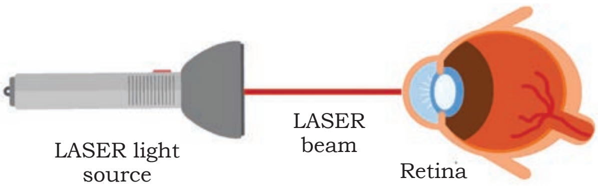


Fig. 8.3: Protection of light against LASER light

Eye and Face Protection: LASER light is used as a source in optical fibre communication. So splicer must be cautious, while installing and testing the OFC. If a person looks directly at the LASER light, it will damage the retina. The impact of LASER light is shown in Figure 8.3.

Whenever, a technician is performing testing of OFC, it is necessary to wear safety glasses as shown in Figure 8.4.

Fig. 8.4: Safety glasses or goggles

Respiratory Protection: Respiratory or dust masks as shown in Figure 8.5 are used to wear, when carrying out tasks that create inhalable dust or fumes, when handling certain chemicals, or when working in a dusty environment.

Fig. 8.5: Respiratory or dust masks

Clothing: Do not wear loose clothes. Loose clothes like T-shirts, belts, unbuttoned jackets or even loose shoelaces, can stick up in the moving part of a machine. Hence, avoid wearing these types of clothes. Safety clothes are shown in Figure 8.6.

Fig. 8.6: Safety clothes for worker

Footwear: It is essential to wear the boots at the installation site. Rubber shoe has a protective strengthening in the toe, which prevents the foot from falling objects and prevents the person at the installation site. Typical footwear is shown in Figure 8.7.

Fig. 8.7: Footwear

Gloves: It is very much required to wear safety gloves of appropriate protective material at the time of installation or maintenance of OFC. It helps in handling OFC. It protects the person from sharp or hot materials, chemicals or dangerous liquids.

Fig. 8.8: Hand gloves

Fibre particles can become lodged in clothing and can later get into food, and drinks, and be ingested by other means. A coat also ensures clothes protection from small particles.

Fig. 8.9: Coat and reflecting jacket for protection

Always use insulated tools as shown in Figure 8.10, while working.

Fig. 8.10: Insulated tools

Chemical Hazards

If chemicals are stored improperly, there can be a possibility of a chemical leak. So, place the chemicals in the correct place to avoid any accidents.

Mishandling of chemicals due to inadequate training or negligence (Figure 8.12).

Diseases and environmental illnesses can be caused by exposure to toxic substances at the workplace as shown in Figure 8.13.

After a person has been exposed to chemical hazards at the workplace, some of the symptoms of exposure to toxins can include:

- Chemical burns
- Itchy burning eyes
- Nausea, vomiting and diarrhoea
- Headaches
- Fever
- High or Low blood pressure

Fig. 8.11: Improper storage of chemical

Fig. 8.12: Mishandling of chemicals

Fig. 8.13: Exposure to toxic substances can cause illness

Fig. 8.14: Read all labels imprint on the box to work safely

Fire Extinguisher

It is a basic protection device used to extinguish and control the fire. It is cylindrical, having a pressurised gas or powder containing an agent, which is discharged to extinguish a fire.

A fire extinguisher with its different parts is shown in the Figure 8.15.

The following steps demonstrate the operation of a fire extinguisher in case of a fire emergency:

1. Identify the safety pin of the fire extinguisher as shown in Figure 8.16. It is generally present in its handle.
2. Remove the seal from the handle as shown in Figure 8.17.

Fig. 8.15: Parts of fire extinguisher

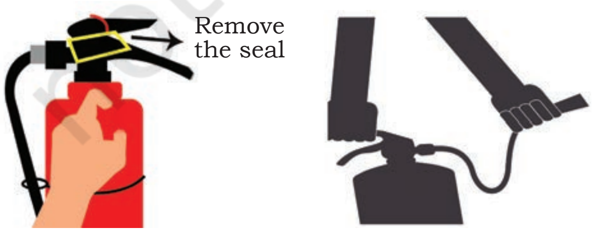


Fig. 8.17: Removing the seal

Fig. 8.16: Removing the pin

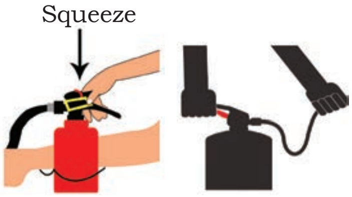


Fig. 8.18: Squeezing the handle

3. Use the fire extinguisher by squeezing the lever and sweeping it over the fire as shown in Figure 8.18.

Depending on the cause of the fire, different fire extinguishers are used. There are various types of fire extinguishers named as Class A, B, C, D, and K.

Class A: This type of fire extinguisher is used, when the causes of fire are paper, wood, cloth, or plastic.	 *Fig. 8.19: Class A*
Class B: This type of fire extinguisher is used, when the causes of fire are gasoline, grease, oil, and many more.	 *Fig. 8.20: Class B*
Class C: This type of fire extinguisher is used, when the causes of fire are electrical cables, wires, equipment, and many more.	 *Fig. 8.21: Class C*
Class D: This type of fire extinguisher is used, when the causes of fire are combustible metal.	 *Fig. 8.22: Class D*
Class K: This type of fire extinguisher is used, when the causes of fire are materials present in the kitchen.	 *Fig. 8.23: Class K*

First Aid

At the workplace site with cables, accidents can cause many injuries. Injury can be minimised to save many lives, if proper rescue techniques and treatment are used. Accidents may occur at any time or place. Timely response and treatment of victims are a major concern. When an accident occurs, due to the effect of muscle cramping, a victim is often incapable of moving or releasing from the contact of live wire or electrical conductor. Caution should be primary consideration during any accident or emergency. The possible items in the First Aid kit are shown in Figure 8.24.

Fig. 8.24: First aid kit

While working around the electrical panel or during the installation of OFC adjacent to the electrical substations transformers or electric poles, accidents may occur resulting in an electric shock. In case of a medical emergency, Cardiopulmonary Resuscitation (CPR) can help to save lives during a cardiac or breathing emergency. Steps to perform CPR are shown in Figures 8.25, 8.26, and 8.27.

Fig. 8.25: Chest compression

- If the victim is breathing and has a heartbeat, give first aid for injuries and treatment for shock.
- Ensure the victim gets medical care as soon as possible.
- Physicians attending the victim must have detailed information to properly diagnose and care for the victim. The physician must determine whether the victim should be sent to a 'Trauma or Burn Centre'.

Fig. 8.26: Open the mouth for airway

Site Safety: Many of the locations optical fibre components may be in areas that require special safety precautions. It may include construction sites, enclosed areas, locations near high-voltage power lines, or areas requiring access by ladder. Always follow the on-site safety requirements and observe all warning signs.

Fig. 8.27: Rescue breathing

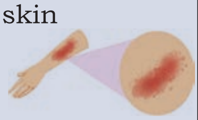
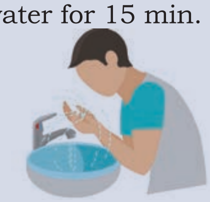
Materials Safety: Optical fibre splicing and termination use various chemical cleaners and adhesives as part of the processes. Normal handling procedures for these substances should be observed. Always work in well-ventilated areas. Avoid skin contact as much as possible, and stop using chemicals that cause allergic reactions. Even simple isopropyl alcohol, used as a cleaner, is flammable and should be handled carefully.

NOTES

Know More.....

Primary treatments for exposure to isopropyl alcohol used to clean fibres or cables are present in Table 8.1.

Table 8.1: Primary treatments for isopropyl exposure

Types of exposure	**Isopropyl**	
	Effects of exposure	**Emergency treatments**
Inhalation  *Fig. 8.28: Inhalation*	Irritation of upper respiratory tacks  *Fig. 8.29: Irritation*	Move the victim to an area having fresh air. Perform artificial respiration, if breathing is irregular.  *Fig. 8.30: Artificial respiration*
Contact with skin  *Fig. 8.31: Reaction due to chemical on skin*	Skin Irritation  *Fig. 8.32: Skin irritation*	Wipe off the affected area of skin and wash with soap and water.  *Fig. 8.33: Washing hands*
Contact with eyes  *8.34: Contact with eyes*	Eyes Irritation  *Fig. 8.35: Eyes irritation*	Wipe eyes with plenty of water for 15 min.  *Fig. 8.36: Washing eyes*

Seek emergency treatment for inhalation, ingestion, severe contact with skin, and contact with eyes.

CHECK YOUR PROGRESS

A. Multiple Choice Questions

1. Do not look directly at the ends of the optical fibre cable as it will damage the
   (a) Retina (b) Ears
   (c) Skin (d) Nose

2. Which of the following is used as a source for optical fibre communication?
   (a) LED light
   (b) Sunlight
   (c) LASER light
   (d) Bulb
3. Which of the following is not concerned with using the fire extinguisher?
   (a) Identify the safety pin of the fire extinguisher
   (b) Break the seal and pull the safety pin from the handle
   (c) Use the fire extinguisher by squeezing the lever
   (d) Hang the fire extinguisher on the wall
4. When do we use the fire extinguisher?
   (a) In case of flood
   (b) In case of electric shock
   (c) In case of fire
   (d) In case of burn injury
5. Which of the following are the safety items technicians must not have while working?
   (a) Safety boots (b) Gloves
   (c) Helmet (d) Belt

B. Fill in the Blanks

1. While working on electricity, the technician must wear _______ gloves and shoes.
2. Keep stretching your arms, legs, neck and back while working to ensure that they are not ______.
3. To recover the unconscious person due to electric shock ______ can be given.
4. When fire is due to combustible metal then ______ type of fire extinguisher is used.
5. Defective or inadequate insulation may result ______.

C. State whether True or False

1. Optical fibre splicing and termination use various chemical cleaners and adhesives as part of the processes.
2. The broken ends of fibres and scraps of fibre created during termination and splicing are extremely dangerous.
3. Fire extinguishers for use on electrical fires will have a C, BC or ABC on the label.
4. All the parts of the body of the affected person be kept in a straight position and should be laid down on an even spot.

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5. Fire extinguisher consists of a hand-held cylindrical pressure vessel containing an agent, which can be discharged to extinguish a fire.
6. Check the rating and physical condition of the components and cables.
7. Fire extinguisher is used in case of an earthquake.

D. Short Answer Questions

1. What are the factors that result in hazard?
2. List out the various remedies to be taken in the workplace.
3. What are the precautions to be taken for preventing electric shock on the job?
4. List out the various items that must be in the first aid box.
5. Write down the steps for the correct way of operating a fire extinguisher in case of a fire emergency.

ANSWER KEY

Chapter 1. Optical Fibre Communication

A. Multiple Choice Questions

1. (b)	2. (c)	3. (d)	4. (b)
5. (c)	6. (d)	7. (a)	8. (a)
9. (b)	10. (b)		

B. Fill in the Blanks

1. bending
2. Total Internal Reflection
3. seven
4. optical fibre
5. slightly less than the speed of light in vacuum (around 2,00,000 km/s)

C. State whether True or False

1.True	2.False	3.False	4.False
5.True	6.False	7.True	

Chapter 2. Splicing of Optical Fibre Cable

A. Multiple Choice Questions

1. (a)	2. (a)	3. (a)	4. (c)
5. (a)	6. (a)	7. (a)	8. (a)
9. (c)	10. (c)	11. (b)	

B. Fill in the Blanks

1. 0.3, 1.0 dB/km
2. 0.1 dB/km
3. splicing
4. the buffer coating
5. the splice

Chapter 3. Optical Fibre Tools and Equipment

A. Multiple Choice Questions

1. (c)	2. (b)	3. (b)	4. (b)
5. (d)	6. (d)	7. (d)	8. (c)
9. (b)	10. (d)		

B. Fill in the Blanks

1. fusion splicing
2. steel
3. nose plier
4. cleaving
5. optical fibre stripper

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6. LCD display
7. inspection microscope
8. light source
9. dust
10. loose tube

C. State whether True or False

1.False	2.True	3.True	4.True
5.True	6.False	7.True	8.False
9.False	10.True		

Chapter 4. Site Visit and Route Inspection

A. Multiple Choice Questions

1. (d)	2. (b)	3. (c)	4. (b)
5. (d)	6. (d)	7. (a)	8. (a)
9. (b)	10. (d)		

B. Fill in the Blanks

1. Direct burial and Duct installation
2. steel, sharply
3. long-distance communication cables
4. armoured fibre cable

C. State whether True or False

1.False	2.True	3.True	4.True
5.False	6.True	7.False	8.True
9.True	10.False		

Chapter 5. Optical Fibre Cable Drum Handling

A. Multiple Choice Questions

1. (a)	2. (a)	3. (b)	4. (a)
5. (b)	6. (a)	7. (d)	8. (c)
9. (d)	10. (d)		

B. Fill in the Blanks

1. Crowbar
2. edges of the drum
3. crane
4. handling
5. flat and stable

Chapter 6. Installation of Optical Fibre Cable

A. Multiple Choice Questions

1. (a)	2. (a)	3. (b)	4. (d)

5. (a) 6. (c) 7. (b) 8. (a)
9. (d) 10. (a)

B. Fill in the Blanks

1. duct installation
2. protective tube
3. factory
4. Pole mounting and cable lasher usage
5. excavators
6. UV
7. air-blown fibre installation
8. cleaning, testing
9. friction
10. mechanised trenching

Chapter 7. Testing Optical Fibre Link

A. Multiple Choice Questions

1. (d) 2. (a) 3. (a) 4. (a)
5. (d) 6. (c) 7. (a) 8. (d)
9. (a) 10. (b)

B. Fill in the Blanks

1. two
2. steady
3. 1.25 mm
4. 2.5 mm
5. lens
6. knob
7. USB port
8. ethernet port
9. Fresnel reflection
10. distance, signal strength (or attenuation in dB).

C. State whether True or False

1.True 2.False 3.False 4.False
5.True 6.True 7.True 8.True
9.True

Chapter 8. Occupational Health and Safety

A. Multiple Choice Questions

1. (a) 2. (c) 3. (d) 4. (c)
5. (d)

B. Fill in the Blanks

1. insulated
2. strained

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3. CPR (Cardiopulmonary Resuscitation)
4. Class D
5. electric shock

C. State whether True or False

1.True	2.True	3.True	4.True
5.True	6.True	7.False	

Glossary

Absorption: *A physical mechanism in fibres that attenuates light by converting it into heat. In practice, the temperature increase is very small. Absorption is mainly from impurities and defects in the glass crystalline structure.*

Acceptance angle: *Half the vertex angle of the cone within which light may be successfully coupled into a multimode fibre. For graded index multimode fibres, the acceptance angle varies depending on the position on the end face of the fibre's core.*

Attenuation: *The reduction in optical power as it passes through a fibre optic cabling system. In optical fibres, the power loss results from absorption and scattering and is generally expressed in decibels (dB) for a given length of fibre or per unit length (dB/km) at a specific wavelength.*

Backscattering: *The scattering of light in a direction opposite the original light source direction.*

Bandwidth: *It is the total range of frequency needed to send specific information at a given rate. For one channel telephone speech takes only a few KHz of bandwidth. Whereas one channel of television needs at least several MHz.The greater the amount of information and/or the greater its necessary transfer rate the larger the bandwidth required.*

Bending loss: *Loss caused because light does not maintain total internal reflection due to the curvature in the fibre bend. See macro bending loss and micro bending loss.*

Breaking strength: *The amount of force needed to break a fibre.*

Brittle: *Easily broken without much bending.*

Buffer fibre: *A protective acrylate/plastic coating is applied over the fibre cladding.*

Bundle: *A group of fibres within a cable sharing a common binder group. For example, a group of fibres wrapped with a colour coded tape in a cable or within a colour coded plastic tube in a loose tube cable.*

Centre wavelength: *The wavelength of an optical source that might be considered to be most powerful and dominant within the spectrum of wavelengths emitted and is typically in the middle or centre of all parts of the emitted spectrum.*

Chromatic dispersion: *This is mainly a problem with LASER system. Although, LASER's emit a single mode they still emit more than one wavelength within that mode. Thus the chroma or different wavelength will travel at different speeds causing a spreading of the pulse at the distant receiver. With very high speed switching at high data rates this spread becomes critical to error free operation.*

Cladding: *The glass layer that surrounds a fibre's core. It can be made up of plastic or silica. It has a lower refractive index than that of the core.*

Cladding diameter: *The diameter of the circle that circumscribes the cladding layer.*

Cleaving: *The controlled breaking of a fibre. Rough cleaving is used when making some connectors then the fibre is polished to create a smooth end surface. Precision cleaving breaks the fibre very precisely leaving a smooth end finish that is used in mechanical splices or fusion splices.*

Coating: *A protective material (usually plastic) applied to the fibre immediately after drawing to preserve its mechanical strength and cushion it from external forces that can induce micro bending losses.*

Coherent/focussed light: *The light emission has the same amplitude and is in phase. LASERS emit coherent light over a certain distance after which it becomes incoherent.*

Conduit: *A tube or pipe that may be buried or installed within buildings to provide passageways into which cables can be pulled.*

Connector: *It is used to join two fibres temporarily. Fibre can be disconnected or reconnected as per the requirement. Different types of connectors are used to join the fibres.*

Core of the fibre: *The core of the fibre is made up of glass through which light propagates. It has a higher refractive index than that of the cladding.*

Core diameter: *The diameter of the circle that circumscribes the core.*

Critical angle: *The smallest angle at which a ray of light will be reflected within a fibre.*

Crosstalk: *The pickup of unwanted light from another fibre.*

Decibel (dB): *A unit used to express the ratio of two powers and given by 10 log(P_{OUT} / P_{IN}). It is used to measure the attenuation of fibres, splices and connectors and the return loss from these and other components.*

Dispersion: *It is a term defined as the spreading of light in fibre optics. In the case of multimode fibre different rays of light travel inside the fibre. Hence, it arrives at different times at the output. This results in dispersion of light.*

dBm: *dBm is an abbreviation for the power ratio in decibel (dB) of the measured power referenced to one milliwatt (mW). Both dBm (decibel-milliwatts) and mW (milliwatts) are units of optical power. Power (dBm) = 10 log (power/ 1 mW).*

Detector: *A device that produces an electrical output signal when excited by an optical input signal.*

Ferrule: *A tube that holds a fibre for alignment. It is usually part of a connector. Typically a solid ceramic cylinder with a tiny hole through the middle of the cylindrical section where the fibre is fed through and fixed permanently with epoxy or adhesives.*

Fibre: *Hair thin silica glass structures, cylindrical in shape for transmitting photonic signals. They consist of a high index core* *surrounded by a lower index cladding and covered with a protective coating. Synonym for light guide. Spelling fibre or fibre is acceptable.*

Fibre optics: *Light transmission through flexible optical fibres for communication or signalling.*

Frequency: *The number of cycles per unit of time, denoted by Hertz (Hz). One Hz equals one cycle per second.*

Fuse: *To join two fibres together through heat melting.*

Fusion splice: *Joining two fibres by applying localised heat sufficient to fuse or melt the ends of the two fibres together to form a continuous fibre.*

Glass: *It is a transparent material. It is generally made of silica obtained from sand in abundance. It is breakable in nature.*

Graded index fibre: *A type of fibre (multimode) where the refractive index starts at a high value in the centre of the core and decreases smoothly with the radius toward the cladding.*

Hardware: *For terminating the fibre and splicing the fibre hardware is required for protection and management of patch panels, splice closures, etc.*

Hybrid cable: *A cable containing both optical fibre and electrical conductors. Synonym for composite cable.*

Incident angle: *The angle between an incident ray and a line perpendicular to the end face of a fibre.*

Incoherent light: *A random form of light whereby the phase of the light is unpredictable. LEDs emit incoherent light.*

Index matching gel: *A material, often a liquid, gel, or epoxy whose refractive index is nearly equal to that of the fibre's core. Used to reduce the Fresnel reflections, and refractive effects from a fibre end face. Also called elastomeric gel.*

Index profile: *The refractive index of a fibre as a function of radius measurements from the central core to the outer cladding.*

Index of refraction: *The ratio of light velocity in a vacuum to its velocity in a material medium. It is a function of wavelength and of the composition, temperature and pressure of the medium. Synonym for refractive index.*

Infrared (IR): *The band of the electromagnetic spectrum having wavelengths between 1 and 100 microns.*

Insertion loss: *The optical power loss caused by inserting an optical component such as a fibre, connector, or splice into an optical transmission path. Synonym for loss and optical loss.*

Interconnect cable: *Short distance cables intended for use within buildings primarily as patch cords, and jumpers between the equipment and generally less than 3 metres long.*

Ionising radiation: *The form of electromagnetic radiation that can turn an atom into an ion by knocking one or more of its electrons loose. Examples are X-rays, gamma rays, and cosmic rays.*

Jacket: *A plastic extrusion over a fibre or cable. A jacket also called a buffer is used to protect the fibre from physical damage, shocks, and vibrations.*

Joint: *The general term used to include both connectors and splices.*

Laminate: *A sheet of two dissimilar materials joined together.*

LASER: *Light Amplification by Stimulated Emission of Radiation. An optical source that emits coherent light with a narrow beam and narrow spectral width.*

Lateral offset: *Transverse misalignment of a source to fibre, fibre to fibre, or fibre to a detector. Lateral offset causes an extrinsic loss that depends on the joining hardware and method.*

Launch angle: *The angle between an incoming light ray into a fibre and the fibre's axis.*

Launching fibre: *A fibre whose light output excites another fibre in a particular way.*

LED (Light Emitting Diode): *A semiconductor optical source that emits incoherent light. LEDs emit light over wider angles and wider spectral widths than LASERS.*

Light: *Traditionally, the region of the electromagnetic spectrum is perceived by the human eye. However, the term is used more generally in fibre optics to include wavelengths from about 0.3 to 30 µm.*

Local detection: *A method for testing splices in which light is detected from the fibre immediately after the splice.*

Local injection: *A method for testing splices in which light is injected into the fibre immediately before the splice.*

Long wavelength: *Light whose wavelength is greater than about 1 µm.*

Loose construction: *A type of cable construction in which the fibres are permitted to float freely to relieve stresses and minimise bending induced losses.*

Loose tube: *A loose cable construction in which a loose plastic tube is extruded around one to 12 fibres. Several tubes may then be stranded together to make a cable.*

Macro bend: *A large fibre bend that can be seen with the unaided eye.*

Macro bending loss: *The loss attributed to large bends in a fibre.*

Manhole: *An underground vault made from concrete or fibreglass, that is large enough for a person to enter and splice cables.*

Material dispersion: *One of the two components that causes chromatic dispersion. Material dispersion arises because the index of refraction of glass depends on the wavelength of light.*

Mechanical Protection (MP): *An outer cable covering consisting of a corrugated steel tape plus an outer polyethylene jacket.*

Mechanical splice: *Any splicing method except fusion.*

Mechanical stripping: *Removing the coating from a fibre using a tool similar to those used for removing insulation from wires.*

Micro bend: *A small fibre bend that cannot be seen with the unaided eye. The bends are only a few micrometres high and have periods of a few millimetres. They can occur due to coating, cabling, installation, temperature, etc.*

Micro bending loss: *The loss attributed to microscopic bends in a fibre.*

Micro cracks: *Submicroscopic flaws in the surface of glass fibres.*

Modal bandwidth: *A bandwidth limiting mechanism in multimode fibres (and also in "Single Mode" fibres when operated at wavelengths below cutoff). Modal bandwidth arises because of the different arrival times of the various modes. Synonym for intermodal distortion.*

Modal noise: *Fluctuation in optical power because of the interaction of power travelling in more than one mode.*

Mode: *A single "electromagnetic field pattern or the radiation " (think of a ray of light) that travels in fibre. A discrete electromagnetic field pattern within a fibre. Only one mode propagates in a single mode fibre whereas several hundred modes propagate in a multimode fibre.*

Monochromatic: *Consisting of one colour or wavelength. Although light in practice is never perfectly monochromatic, it can display a narrow range of wavelengths.*

Monomode fibre: *See single mode fibre.*

Multifibre splice: *Simultaneously splicing more than two fibres.*

Multimode fibre: *A fibre whose core diameter is large compared with the wavelength of light and therefore propagates more than one mode.*

Multiplexing: *Multiplexing means sending multiple signal streams of information on a carrier at the same time as a single signal.*

Network: *A network is a collection of computers, servers, mainframes, network devices, peripherals, or other devices connected to one another to allow the sharing of data. An excellent example of a network is the internet, which connects millions of people all over the world.*

Noise: *Any unwanted signal.*

Non-ionising radiation: *Electromagnetic radiation that does not turn an atom into an ion. Examples are visible light and radio waves.*

Non-metallic cable: *See dielectric sheath or cable.*

Numerical Aperture (NA): *An angle just outside the end face of a fibre that describes the largest angle that a light ray can have to the fibre axis and still be captured and propagated within the fibre.*

Open: *A broken fibre.*

Optical power: *It is measured in "dBm", or decibels referenced to one milliwatt of power. While the loss is a relative reading, optical power is an absolute measurement, referenced to standards. You measure absolute power to test transmitters or receivers and relative power to test loss.*

Optical loss: *It is defined as the amount of optical power lost as light is transmitted through fibre, splices, couplers, etc. This optical signal is expressed in "dB" which is dimensionless.*

Optical cable assembly: *A cable that is terminated with connectors. Usually, the cable has been terminated by a manufacturer and is ready for installation.*

Optical loss: *See insertion loss.*

Optical Time Domain Reflectometer (OTDR): *An instrument for characterising a fibre. An optical pulse is sent down a fibre and the resulting backscattered light and reflected light to the input is displayed as a function of distance on a screen. The instrument is useful for measuring fibre loss, and splice loss and determining the location of faults or breaks.*

Optoelectronic: *A device that converts optical signals to electrical signals or vice versa.*

Organiser, splice tray: *A mechanical assembly consisting of a frame, one or more splice trays and mounting hardware.*

Outside plant: *The portion of a cable network that resides outside of buildings. Outside plants can consist of cable, conduit, utility poles, and enclosures.*

Passive splicing: *Aligning the two ends of a fibre without monitoring its splice loss.*

Photon: *A discrete quantity of light energy.*

Pigtail: *A short length of fibre permanently attached to a component and used to couple light between it and another fibre.*

Plug connector: *The cylindrical or conical ferrule portion of a connector with the fibre fastened inside.*

Polarisation: *The property of light relating to the direction of the vibrations. Light from the sun, incandescent lamps and many other sources vibrate in many directions perpendicular to the direction the light ray is travelling and is said to be randomly polarised. For lasers, the vibrations (all in a plane perpendicular to the light ray) are in a definite form that may be a straight line, circle, or ellipse.*

Polarisation maintaining fibre: *A single mode fibre that transmits light without changing its state of polarisation. Synonym for polarisation retaining fibre.*

Pole, utility: *A tall slender column of wood, fibreglass, concrete, or steel used to support cables.*

Polishing: *Preparing a fibre end by moving the end over an abrasive material (lapping film).*

Perform: *A glass structure that's a magnified version of the fibre to be drawn from it.*

Primary coating: *The first protective coating applied to the surface of a fibre in a dual coat structure.*

Pulse spreading: *An increase in the width of an optical pulse as it travels along a fibre.*

Quality assurance test: *A test to verify that a product meets advertised performance specifications.*

Radiation: *Energy and its propagation through matter or space. Radiation may either be 'electromagnetic', which is usually considered to travel in the form of waves, or 'particles' which is subatomic particles moving at high speeds.*

Ray: *A geometrical representation of a light path through an optical medium that indicates the direction of energy flow.*

Rayleigh scattering: *Scattering of light caused by index of refraction variations in the submicroscopic structure of the glass.*

Receiver: *An optical and electronic package that takes optical input signals and converts them to electrical output signals.*

Reel cable: *A large wooden or steel spool on which cable is wound for shipping and storage.*

Reflectance: *The ratio of reflected power to incident power. Synonym for "return loss."*

Reflection: *The abrupt change in the direction of light as it travels from one material to a dissimilar material. Some of the reflected power in a fibre gets transmitted back to the source.*

Refraction: *The bending of light as it passes through two dissimilar materials or in a medium whose refractive index varies.*

Refractive index: *See index of refraction.*

Regenerator: *A receiver and transmitter combination used to reconstruct signals for digital transmission. The receiver converts incoming optical pulses to electrical pulses, decides whether the pulses are '1's' or '0's' generates 'new' electrical pulses, and then converts them to 'new' optical pulses for transmission on the fibre.*

Repeater: *An optoelectronic device that amplifies or boosts a signal. This is an analog technique, no regeneration takes place.*

Restoration cable: *Locating, repairing and returning service to a damaged cable during an emergency.*

Return loss: *The reflectance is measured at a point of reflection and then calculating the loss of that reflectance back to the source. This is important as too much reflectance may cause distortions in the transmitting device.*

Ribbon: *An assemblage of up to 12 fibres laid parallel to one another side by side and fastened together. Several ribbons can then be stacked on top of one another to make a cable.*

Scattering: *Scattering is the phenomenon by which a beam of light is redirected in many different directions when it interacts with a particle of matter. The intensity of the scattered light depends on the size of the particles and the wavelength of the light.*

Secondary coating: *The protective coating applied over the fibre's primary coating in a dual coat structure.*

Sheath: *The protective outer covering of a cable core. It may consist of plastics, metals and non-metallic strength members.*

Shield cable: *The metallic components in a cable sheath that drain off the current induced by lightning discharges.*

Short patch: *An emergency cable restoration method in which a short length of cable is used to patch around the damaged region.*

Short wavelength: *Used to refer to light having wavelengths generally less than 1 μm.*

Signal: *It is an electromagnetic representation of data.*

Signalling: *It is the act of propagating a signal over a suitable medium.*

Silica: *The short name for the chemical compound silicon dioxide (SiO_2). Silica exists in nature both in free form as in quartz and in combined form as in silicates.*

Silicate: *A chemical compound of silicon, oxygen and metals.*

Single end pull: *A method for pulling cable into conduit or duct liner from one direction. The cable reel is positioned at a splicing manhole and a truck with a capstan winch is located at the pull manhole.*

Single mode fibre: *A fibre having a small core diameter and in which only one mode (the fundamental mode which may consist of two polarisations) will propagate at the wavelengths of interest.*

Slotted core: *A loose cable construction in which fibres are loosely placed into slots (grooves) molded around the outside surface of a plastic rod. Synonym for open channel and fluted.*

Source: *A device (usually LASER or LED) that emits light energy.*

Spectrum: *The range of electromagnetic radio frequencies used in the transmission of voice, data, etc.*

Spectral width: *A measure of the wavelength content of optical power.*

Splice: *A permanent joint between two fibres is called splicing. A connection of one or several fibres that in most instances is considered permanent. Splicing can be classified as fusion or mechanical splicing.*

Splice case: *A metal or plastic housing used to enclose and protect fibre splices. Synonym for splice closure.*

Splicing cut ends: *An emergency cable restoration method in which the cut ends are put back together.*

Static fatigue: *The decrease in fibre strength with time when under stress and exposed to humidity, high temperature, alkalinity or ammonia.*

Step index fibre: *A fibre having a uniform refractive index in its core and a sharp decrease in refractive index at the core cladding interface.*

Strain: *The length by which a wire or fibre deforms divided by its original length.*

Stranding: *The manufacturing process by which fibres are which fibres are wrapped about some other cable member. Stranding imparts extra length to the fibres.*

Strength member: *Steel aramid yarns, fibreglass epoxy, rods or other material used to increase the tensile strength of a cable.*

Stress: *The force per unit of cross sectional area.*

Stripping: *Removing the coating from a fibre.*

Support strand: *A stranded metallic cable attached to utility poles and used to support aerial cables. The cables are lashed or clipped to the support strand.*

Switch: *A mechanical or electronic device that opens or closes circuits. It also completes or breaks an electrical path or selects paths or circuits.*

Talk set optical: *An instrument for talking over fibres usually when installing and testing the cable.*

Target rod: *A solid cylinder usually made from alumina onto which submicroscopic glass particles are deposited in the OVD process.*

Tensile strength: *The pulling force necessary to break a material.*

Tight construction: *A type of cable construction in which the fibres are tightly coupled to other cable components and move with them.*

Total bandwidth: *The combined modal and chromatic bandwidth.*

Total internal reflection: *Confinement of light within a structure by having the light strike the interface between two optically different materials at an angle of incidence greater than the critical angle.*

Transmitter: *An optical and electronic package that takes electrical input signals and converts them to optical output signals.*

Tray splicing: *Flat rectangular compartments used to secure splices and store excess fibre.*

Telephony: *Word used to describe the science of transmitting voice over a telecommunications network.*

Ultraviolet: *The region of the electromagnetic spectrum containing wavelengths between 10 and 400 nanometres.*

Under fill: *A condition for launching light into a fibre in which not all the modes that the fibre can support are excited.*

Underground Cable: *Cable installed in buried conduit. Does not include cables buried directly in the ground.*

Universal closure: *A splice closure suitable for use in aerial, underground or buried plants.*

Waterproof cable: *Cable containing a filling compound in all available spaces in the core to resist the entrance of water.*

Waveguide: *A conducting or dielectric structure able to support and propagate one or more modes.*

Wavelength: *It is a term used to measure light in terms of nm or microns (m). Fibre specifications like attenuation, and dispersion are expressed in terms of wavelength. Wavelength is inversely proportional to the frequency of light. It means if frequency increases, wavelength decreases and vice-versa.*

Wavelength Division Multiplexing (WDM): *A method to simultaneously transmit two or more optical signals on a fibre by using different wavelengths.*

Notes

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