Draft Study Material

विद्यया ऽमृतमश्नुते

एन सी ई आर टी
NCERT

OPTICAL FIBRE SPLICER

(Job Role)

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

(Grade X)

PSS CENTRAL INSTITUTE OF VOCATIONAL EDUCATION
(a constituent unit of NCERT, under Ministry of Education, Government of India)
Shyamla Hills, Bhopal - 462 002, M.P., India

Preface

Vocational Education is a dynamic and evolving field, and ensuring that every student has access to quality learning materials is of paramount importance. The journey of the PSS Central Institute of Vocational Education (PSSCIVE) toward producing comprehensive and inclusive study material is rigorous and time-consuming, requiring thorough research, expert consultation, and publication by the National Council of Educational Research and Training (NCERT). However, the absence of finalized study material should not impede the educational progress of our students. In response to this necessity, we present the draft study material, a provisional yet comprehensive guide, designed to bridge the gap between teaching and learning, until the official version of the study material is made available by the NCERT. The draft study material provides a structured and accessible set of materials for teachers and students to utilize in the interim period. The content is aligned with the prescribed curriculum to ensure that students remain on track with their learning objectives.

The contents of the modules are curated to provide continuity in education and maintain the momentum of teaching-learning in vocational education. It encompasses essential concepts and skills aligned with the curriculum and educational standards. We extend our gratitude to the academicians, vocational educators, subject matter experts, industry experts, academic consultants, and all other people who contributed their expertise and insights to the creation of the draft study material.

Teachers are encouraged to use the draft modules of the study material as a guide and supplement their teaching with additional resources and activities that cater to their students' unique learning styles and needs. Collaboration and feedback are vital; therefore, we welcome suggestions for improvement, especially by the teachers, in improving upon the content of the study material.

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Date: 19 September, 2024

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Table of Contents

Module 1 Fiber Optic Communication and Splicing

Module Overview

Fiber optic communication uses thin glass or plastic fibers to send information as light signals. This technology allows data to travel very quickly and over long distances with minimal loss, making it perfect for things like internet and TV services. The core of a fiber optic cable carries the light, while the cladding around it helps keep the light inside the core, so the signal stays strong.

Splicing is the method used to join two fiber optic cables together. There are two main types: fusion splicing, where the ends of the fibers are melted and fused together, and mechanical splicing, where the fibers are aligned and held together with a special connector. Good splicing is essential for maintaining the quality of the signal, as even small errors can affect the performance of the communication system.

Learning Outcomes

After completing this module, you will be able to:

- Demonstrate fundamental principles of optical fiber communication systems and their applications.
- Execute precise splicing techniques to connect optical fibers with minimal loss and optimal performance.

Module Structure

Session 1: Optical Fibre Communication

Session 2: Splicing

Session 1: Optical Fibre Communication

One-day Nitya, got a chance to visit the **I**ndian **S**pace **R**esearch **O**rganisation (ISRO). (Figure 1.1) 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 the spacecraft and satellites. She studied and observed the utilization of optical fibre communication in different sectors. She came to know about the present age of 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.

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

Communication technology travelled a long journey 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 a speed of light. In this chapter, you will understand the technology behind optical fibre communication and its applications.

COMMUNICATION

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

Mobile Communication – It is used for the transmission of signal and provide services in the mobile phones as shown in Figure 1.2.

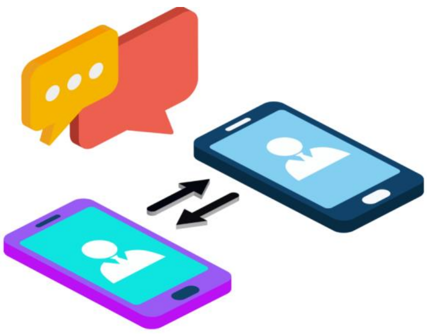


Fig.1.2 Signal transmission between the mobiles

Data Communication – It is used in computer networking for transmission of data between computers as shown in Figure 1.3.

Fig.1.3 Transfer 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 as shown in Figure 1.4.

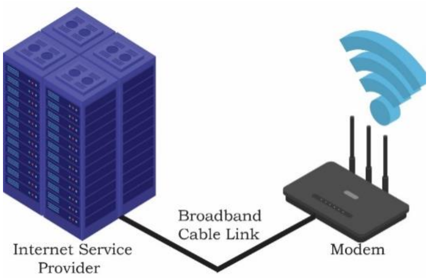


Fig.1.4 Optical fibre cable used in broadband cable link

Voice Communication: It is used in landline phone and Public Switched Telephone Network (PSTN) as shown in Figure 1.5.

Fig.1.5 Voice communication over landline phones via telephone exchange

Satellite Communication – It is used in space technology, defence, media, weather forecasting and meteorology as shown in Figure 1.6.

Fig.1.6 Satellite communication

BASICS OF OPTICAL FIBRE COMMUNICATION

In general, optical fibre communication network has three sections namely transmitter, optical fibre cable, and receiver as shown in the Figure 1.7. For example, when a person 1 place a call to person 2, signals first forwarded to the nearby cellular tower (transmitter). Then signals will transfer to the central exchange using optical fibre cables. From central exchange it will be forwarded to the nearby concerned cellular tower (receiver) using optical fibre cables. In this way, call is attended by person 2.

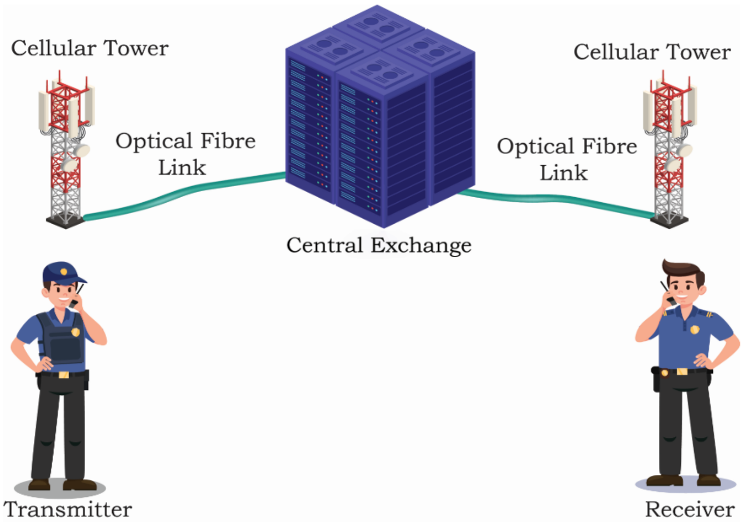


Fig.1.7 Sections of optical fibre communication

Data from the sender to the receiver is transferred as shown in Figure 1.8. To connect sender and receiver a medium is required. This medium can be wired or wireless. The wired medium has a physical link, whereas wireless medium has a non-physical link.

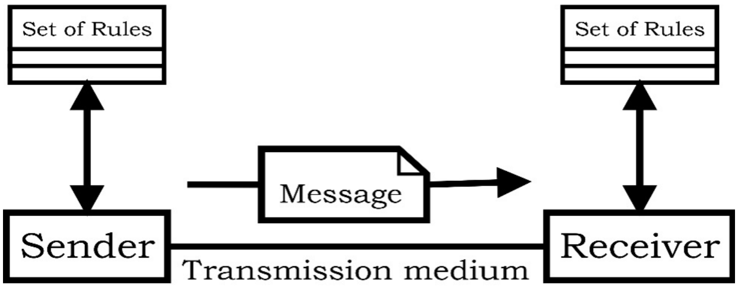


Fig.1.8 Data transfer process

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).

(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 the antennas such as cell site antenna, microwave antenna mounted on the towers.

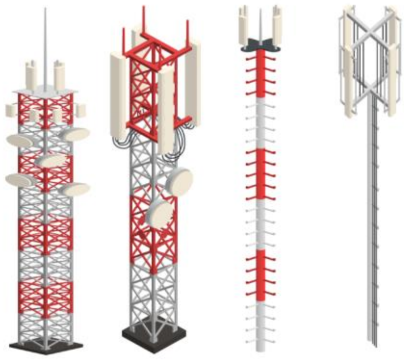


Fig.1.10 Antenna mounted on the tower

Therefore, optical fibre cable is a replacement of copper wire in a wired communication.

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.

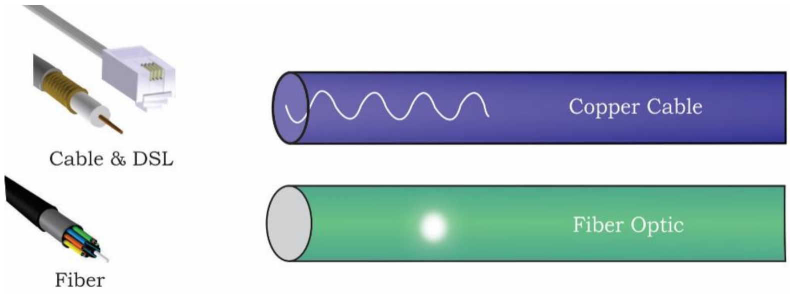


Fig.1.11 Copper cables carrying electrical current, and optical fibre carrying the light signal

Structure of an Optical Fibre Cable

Optical fibre cable (OFC) is made up of glass or plastic fibre, cotted with serveral layers. The various layers in optical fibre cable is shown in Figure 1.12. The structure of an optical fibre include following parts:

a) Core

b) Cladding

c) Buffer

d) Strength Member

e) Jacket

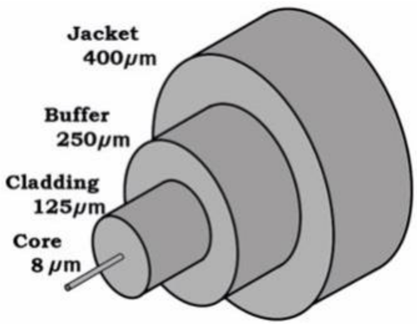


Fig.1.12 Diameter of various layers in optical fibre cable

(a) Core – It is thin and innermost part of an optical fibre cable. Figure 1.13 (b) shows the side view of 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 OFC, which surround the core. It reflects the light back into the core. It helps to trap the light in core using Total Internal Reflection. This concept will be discussed later. Figure 1.13 (a) and 1.13 (b) shows the front and side view of cladding in OFC.

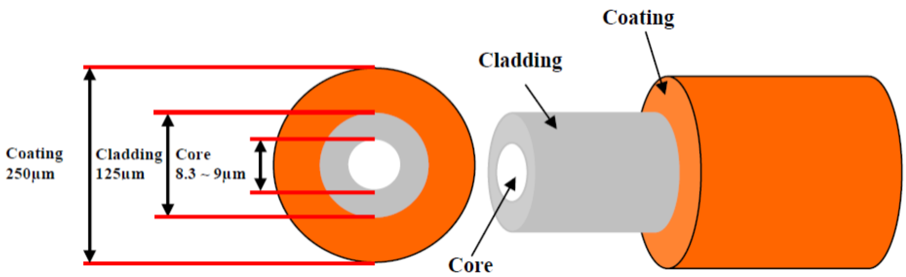


Fig.1.13 (a) Cross sectional view of single mode optical fibre cable (b) Side view of single mode optical fibre cable

Core and cladding of optical fibre are available in variety of size. 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

c) Buffer – As you know, core is the portion of OFC through which light travels and 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 protecting layer. It is made-up of hard-plastic coating. Buffer can be of loose tube buffer or tight buffer.

Loose Tube Buffer – It consist 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 environment such as dense forest, an area prone to heavy rainfall. Typical, loose tube buffer is shown in Figure 1.14.

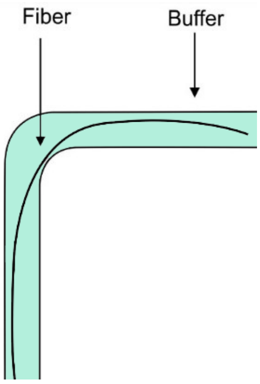


Fig.1.14 Loose tube buffer

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

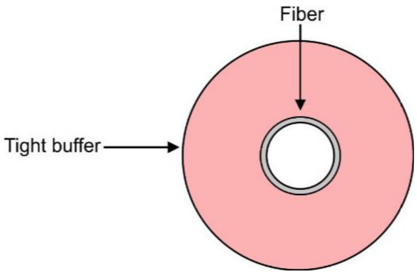


Fig.1.15 Tight buffer

d) Strength Member – In extreme environmental condition, 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 strength member placed between the buffer and jacket. It also protects the fibre against stretching and excessive bending. Materials like aramid yarn, fibreglass are used as a strength material.

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

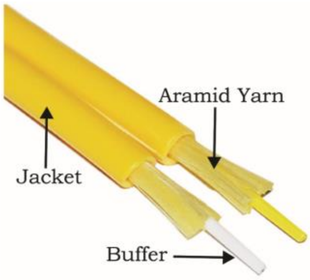


Fig.1.16 Aramid yarns in optical fibre cable

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

Fig.1.17 Fine fibre of glass

e) Jacket – It is a protective layer over strength material of an optical fibre cable. This part protects the fibre from the worst 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 number of fibres, on each fibres separate jackets are used this is known as inner jackets and the common outer jacket is known as a sheath as shown in Figure 1.18.

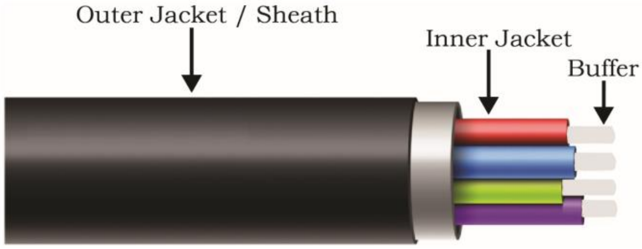


Fig.1.18 Sheath as an outer layer of a cable with multiple jacket on the fibre

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

Table 1.2 Material used to manufacture layers of optical fibre cable

Layer	**Material**
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

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 the core.
2.	Strength member	The outermost jacket that 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 jacket for outdoor
9.	Sheath jacket	It helps to increase a cable's tensile strength.

Applications of Optical Fibre Cable

Optical fibre cables have revolutionized 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 Provider (ISP), telephone exchange, computer network, health, defence and aerospace.

1. Internet Service Provider (ISP) – OFC offers high bandwidth, hence, it is suitable to transmit large amount of data at very high speed. This optical fibre technology is therefore widely used by Internet Service Provider (ISP).

2. Telephone Exchange – OFC are used in telephone exchanges. Presence of OFC 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 are easier, secured and faster because of the presence of OFC in the network.

4. Health – OFC are widely used in the medical equipment, pharmaceutical industries and medical research institute. For example, OFC are used to provide illumination in endoscopy.

5. Defence and Space – To fulfil high level of data security in the field of defence and aerospace, OFC are right choice to be used for high-speed transmission of data and 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 to our eyes and enable us to see things. Figure 1.19 illustrates the way, that how a person can see the objects.

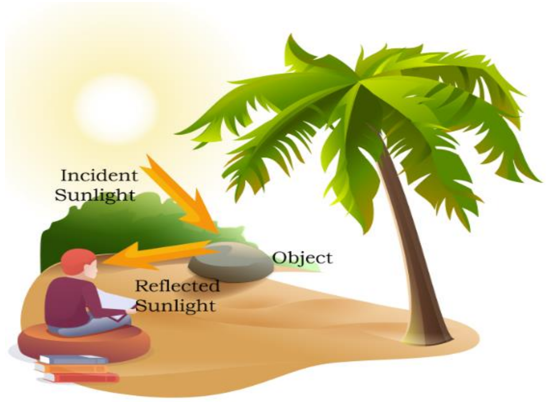
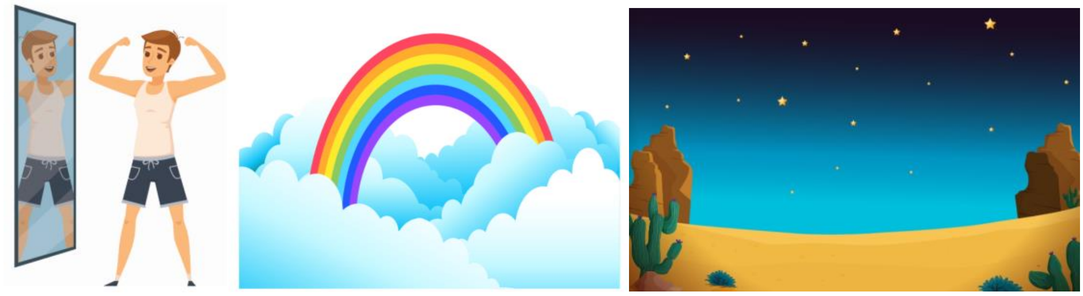


Fig.1.19 Reflection of light ray into the eyes

In our daily life, you have so many examples of reflection and refraction of light such as image formation by a mirror is because of reflection of light, colours of the rainbow, twinkling of stars are because of refraction of light as shown in Figures 1.20.



(a) (b) (c)

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

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

a) Wave Nature of Light – In wave nature, light acts like an electromagnetic wave, which travels at a speed of light 'c' in a vacuum. For example, if one mix 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, 'B' is the magnetic field.

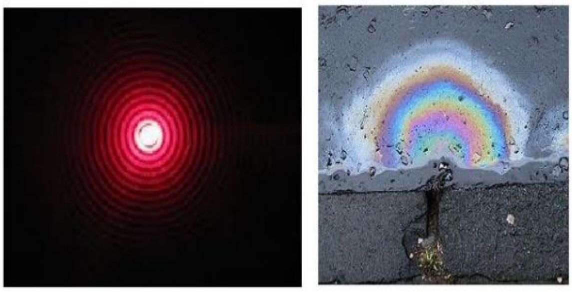


Fig.1.21 Wave nature of light

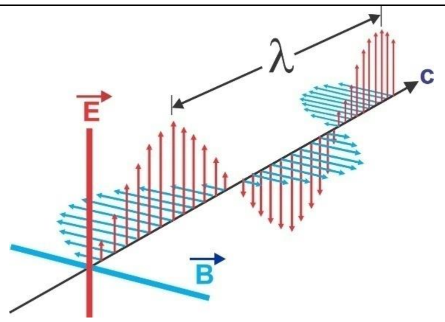


Fig.1.22 Light as an electromagnetic wave

Based on the light propagation pattern, waves can be further classified as transverse and longitudinal waves. When wave oscillates perpendicular to the direction in which it is traveling such waves are called as transverse wave. Wave pattern of transverse wave is shown in Figure 1.23.

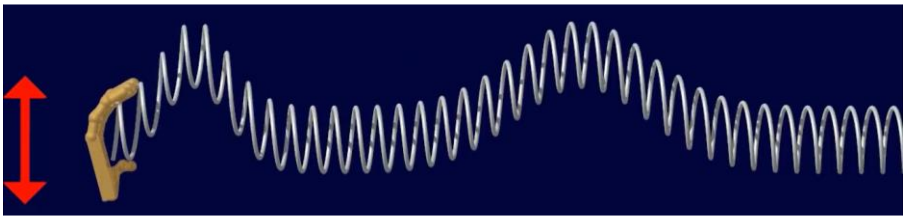


Fig.1.23 Propagation pattern of transverse wave

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 the way in which transverse wave travels in a medium.

Fig.1.24 Transverse wave propagation pattern in the water

When the wave oscillates in the same direction in which it is travelling, it is called as longitudinal wave. Longitudinal wave is shown in Figure 1.25.

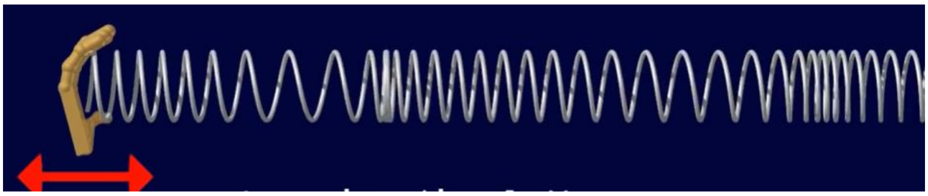


Fig.1.25 Propagation pattern of longitudinal wave

Sound waves are the example of longitudinal wave. When sound travel from 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.

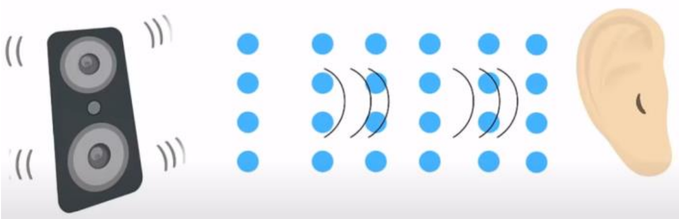


Fig.1.26 Sound travelling in the air

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 meter.

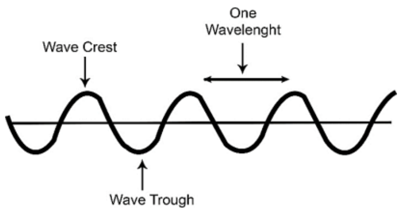


Fig.1.27 Wavelength

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. 0^0 to 360^0. The relationship of frequency (f) and time period (T) is given by the equation. (Figure 1.28)

$f = 1 / T$

$T = 1 / f$

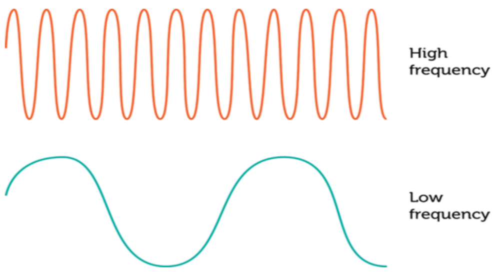


Fig. 1.28 High and low frequency

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 surface from the Sun. (Figure 1.29)

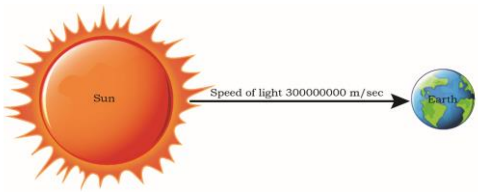


Fig.1.29 Speed of light

Electromagnetic Spectrum – It is the range of all electromagnetic waves such as visible light waves, microwaves, radio waves, X-rays, gamma rays, infrared rays. The visible light is the portion of the electromagnetic spectrum that is visible to the human eyes as shown in Figure 1.30. Visible region include seven colours. Sunlight is an example of visible light.

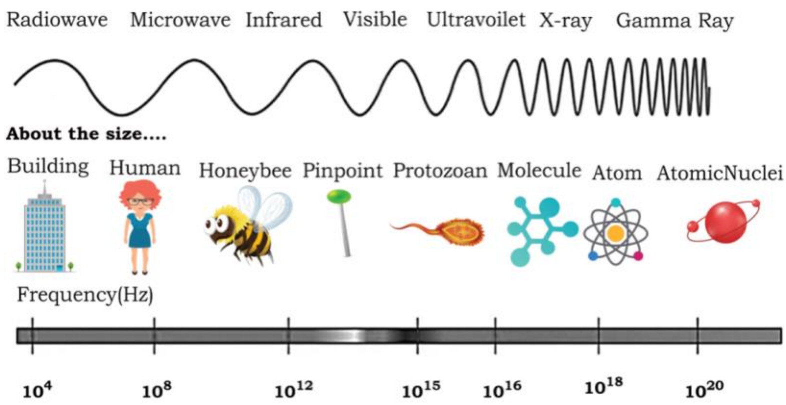


Fig. 1.30 Electromagnetic Spectrum

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

Table 1.3 Applications in various frequency bands

Frequency Bands	**Application**
Radio Waves	They are used in radio and television signals broadcasting.
Microwaves	They are used in satellite communication, military equipment, microwave oven.
Infrared radiation	They are used in remote controls, heat-sensitive thermal imaging cameras, night vision cameras.
Visible Light	They are used in traffic signals, vehicles headlamp, indicators and many more.
Ultraviolet	They are used in a hospital for cleaning the bacteria, microbes, living microorganism present on the surgical equipment.
X-rays	They are used in X-ray machines to check the fractures or broken bone.
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 as photons. Figure 1.31 shows sunlight consist of photons.

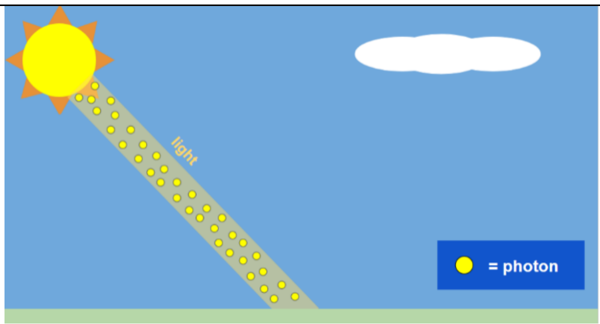


Fig.1.31 Particle nature of light

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.

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 back and reaches to your eyes. Reflection occurs when the rays of light bounces back in the same medium after reflection.

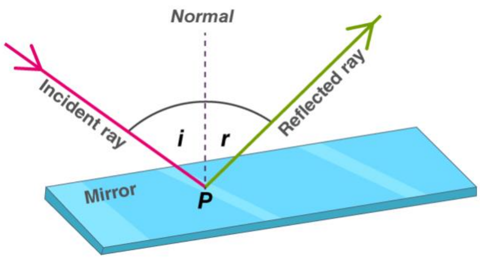


Fig.1.32 Reflection of light through mirror

The incoming light ray is called the incident ray. The light ray bouncing back into the same medium is called a 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.

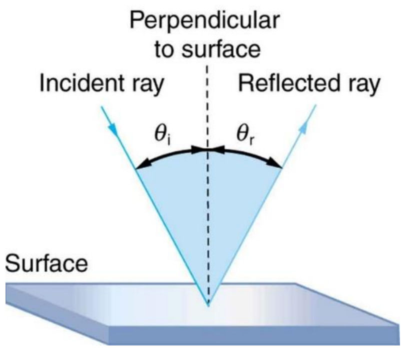


Fig. 1.33 Reflection of light

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 Activity 1 – 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

Step 1. Place the paper on the board and fix it.

Step 2. Place the mirror vertically on the white sheet of paper and trace its edge.

Step 3. Draw a line at right angle to the edge of mirror that will act as normal "ON".

Step 4. Starting with an angle i of 30^0, draw an incident ray and place two pins, P and Q along it.

Step 5. Observe the reflected ray using a mirror and mark the position of as R and S. Fix the pins at the respective points.

Step 6. Remove pins R and S and join the dots by drawing a straight line.

Step 7. Measure and record angle 'R'.

Step 8. Repeat the procedure 4, 5, 6 and 7 for angles incidence angle i = 35^0, 40^0, 45^0, 50^0 and 55^0.

Step 9. Note down, the values in the table. Carefully, observe the result as:

1. The angle of incidence equals the angle of reflection.
2. Incident ray, reflected ray and the normal at the point of incidence lie in the same plane.

Hence, the laws of reflection proved.

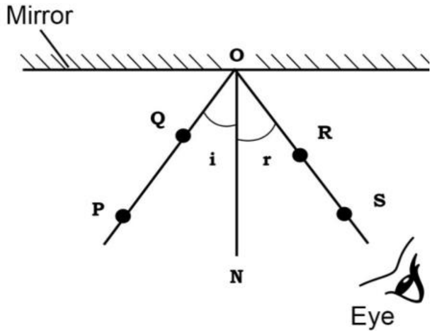


Fig.1 Setup for law of reflection

Refraction

Light travels in 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 change its direction? Recall your day-to-day experiences. Have you seen a pencil, partly immersed in water tumbler? It appears to be displaced at the interface of air and water as shown in Figure 1.34.

Fig.1.34 Bending of pencil in the glass

You may have seen that a lemon kept in water tumbler appears bigger than its actual size as shown in Figure 1.35, when viewed from the side of glass.

Fig. 1.35 Lemon in the glass

These observations indicate that light does not travel in the same direction, when it travels through different mediums. It appears that when traveling obliquely from one medium to another, the direction of propagation of light in the second medium changes. This phenomenon is known as the refraction of light. It is illustrated in Figure 1.36.

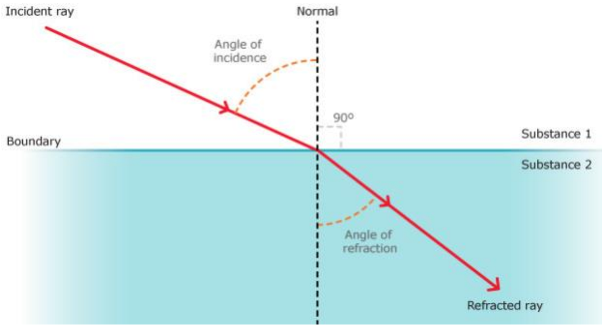


Fig.1.36 Refraction of light

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 one go?
4. Ask your friends to do this. Compare your experience with his experience.

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 "refractive index" in some 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 light beam travels in a medium. Refractive index of a material is dimensionless.

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

As you know that a ray of light that travels from one transparent medium into another will change its direction in the second medium. Bending of light will depend upon the extent of the refractive index of the medium. Speed of propagation of light varies in a various medium. It turns out that light propagates with different speeds in a different medium. 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 speed of light in air and 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 about its exact position as shown in Figure 1.37. This is due to change in the refractive index of air and water.

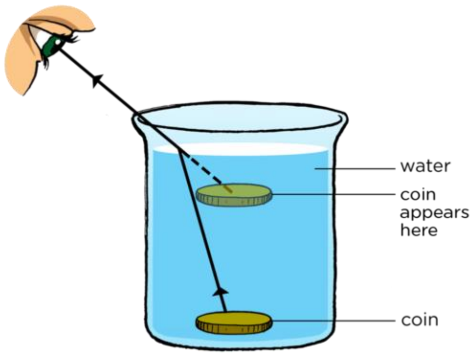


Fig.1.37 Observe the coin in the glass bowl

Table 1.4 Refractive Index of Some Material

Material	**Refractive Index**	**Material Medium**	**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 = 3×10^8 / 2×10^8 = 1.5

Refractive index of the material is 1.5 and it is unit-less.

Assignment 3

1. A ray of light travelling 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 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 medium, 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 1.38. Figure 1.38 shows three rays of light A, B and C. Glass has a higher refractive index than air. When light travels from medium of glass to the second medium air, then it bends away from the normal. Light ray 'A' shows the first case of refraction. Light ray 'B' shows the refracted ray becomes parallel to the surface of the glass at a particular angle called a 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 ..., then incident angle (θ_1) is less than the criticle angle (θ_c) the light is transmittted through the air. But if light travells at the incident angle (θ_1) greater than the critical angle (θ_c), it will not pass through the air. Instead it will be reflected back to the first medium i.e. water. Hence this phenomenon is known as Total Internal Reflection.

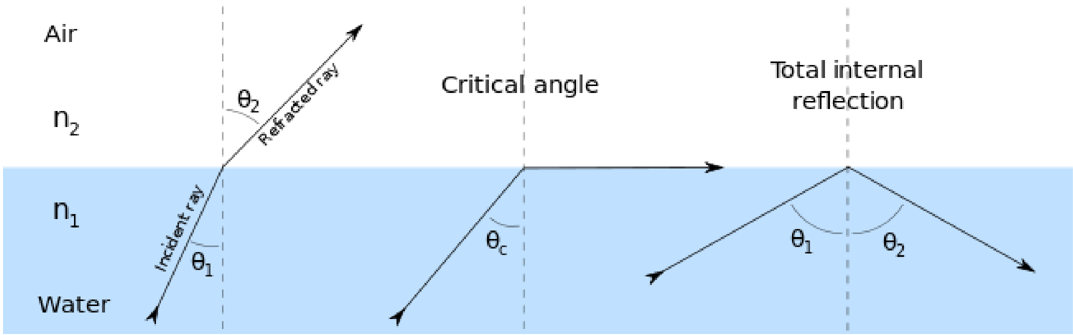


Fig.1.38 Concept of total internal refraction at air and glass interface

Concept of Total Internal Reflection is used in optical fibre communication. The propagation of light in the fibre occurs by the method of the total internal reflection.

Figure 1.39 shows the propagation of light through optical fibre cable. This propagation is due to total internal reflection in the core.

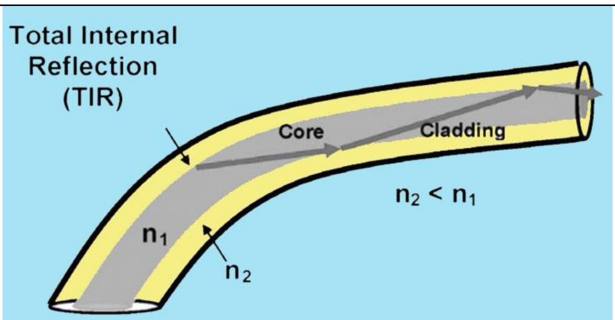


Fig.1.39 Propagation of light in core of fibre cable using total internal reflection

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

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

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

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

Let us, understand the numerical aperture using the following activity.

Practical Activity 2 – Measure the numerical aperture of OFC.

Material Required

Optical Fibre Trainer (OFT) Kit, Optical fibre cable, Screen, Connecting wires, NA measurement unit, Frequency generator.

Procedure

Step 1. Connect power supply to OFT kit, and make all the connections.

Step 2. Connect one end of the OFC to the OFT kit and other end to the numerical aperture jig.

Step 3. Vertically, hold the white screen with four concentric circles (10, 15, 20 & 25mm diameter) such that the optical fibre axis is perpendicular.

Step 4. Maintain the suitable distance to make the red spot emitted from the optical fibre coincide with the 10 cm circle. Note that circumference of a circle must coincide with the circle.

Step 5. Record L, the distance of screen from the fibre end and note the diameter W of the spot.

Step 6. Compute, the numerical aperture using a formula, NA=Sin θ =W/√ (4L²+ W²)

Where, θ is called as the acceptance angle, it is the maximum angle of incidence at the input end of the optical fibre. So that, the optical ray can just propagate within the optical fibre.

Step 7. Tabulate the reading and repeat the experiment for 15 mm, 20 mm, 25 mm 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

Step 8. Numerical aperture of an optical fibre cable is 0.4 mm.

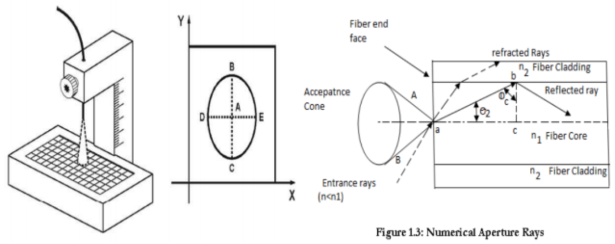


Fig.1 Set up to measure the numerical aperture (Change the diagram)

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 as shown in Figure 1.40.

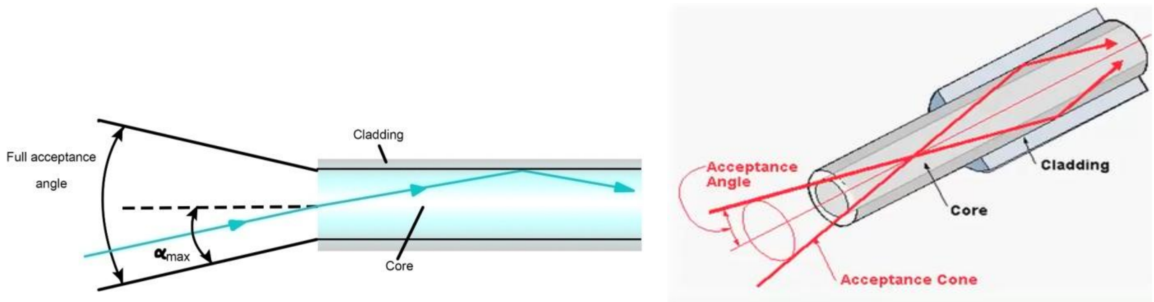


Fig.1.40 Light propagation through the optical fibre cable

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 – Based on the material optical fibres are classified into two types: Glass fibres and Plastic fibres

1. Glass Fibres – Most of the optical fibres is 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 Meta Acrylate (PMMA), Polyethene (PE), Polystyrene (PS). They 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 a ray of light. Modes of the fibre are classified into two types named as single-mode and multimode fibres as shown in Figure 1.41. Multimode fibres are further classified as step-index and graded-index.

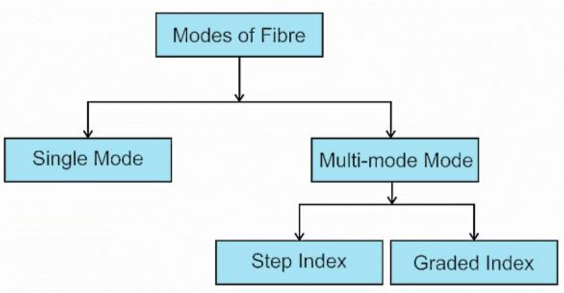


Fig.1.41 Classification of optical fibre based on transmission mode

1. Single Mode – In this only one light ray is used to send the data for transmission as shown in Figure 1.42.

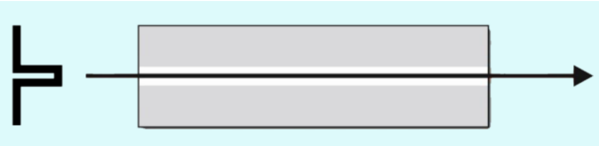


Fig.1.42 Single mode optical fibre cable

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 1.43.

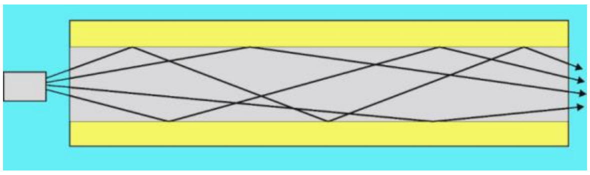


Fig.1.43 Multimode optical fibre cable

Practical Activity 3 – Identify single mode and multimode fibre

Material Required

Optical fibre cable, Laser source, Optical connector, Plain white sheet.

Procedure

Step 1. Connect the laser light using optical connector to one end of OFC.

Step 2. Focus the other end of OFC on white paper.

Step 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. Uuse both single-mode and multi-mode fibre and compare the result? Similarly, use a LASER light and observe the result for the same.

Multimode fibre 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 1.44.

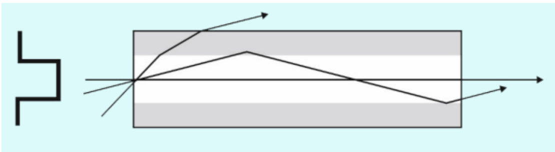


Fig.1.44 Optical signal in step index fibre

b) Graded Index Fibre – In this, the core itself has several layers. The layer, which is close to the axis of optical fibre, has 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, refractive index decreases as shown in Figure 1.45. Finally, at the interfacing point of core cladding, the light will be reflected into the core.

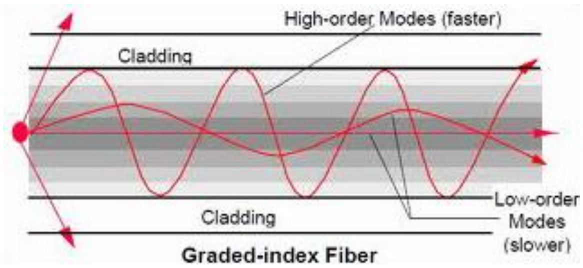
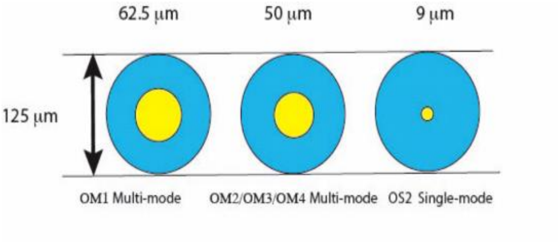
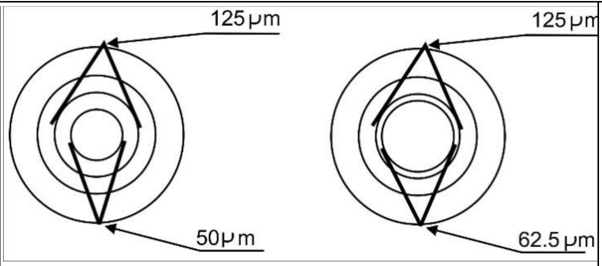


Fig.1.45 Optical signal in graded index fibre

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, cladding diameter is about 125 micrometres (μm) as shown in Figure 1.46.	The core diameter of multimode fibre is about 50 micrometre (μm) and 62.5 micrometre (μm). Whereas, cladding diameter is about 125 micrometre (μm) as shown in Figure 1.47.

	 Fig.1.46 Core diameter of single mode fibre	 Fig.1.47 Core diameter of multimode fibre
3.	Single mode fibres are used for long distance communication 50 to 60 Km.	Multi-mode fibres are used for short distance communication such as building or campus up to 10-15 Km.
4.	Single mode fibre has higher bandwidth and less attenuation.	Multi-mode fibre has lower bandwidth and higher attenuation.
5.	Single mode fibre allows less dispersion.	Multi-mode 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 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.

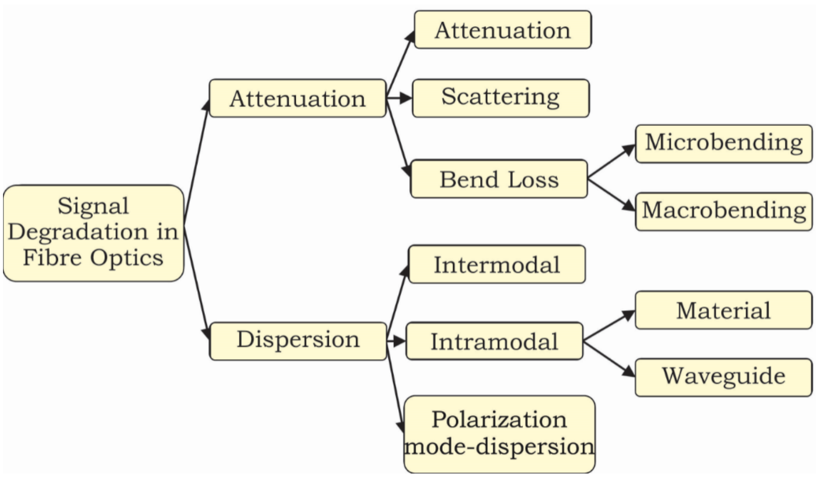


Fig.1.48 Signal degradation and its classification in optical fibre communication

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

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 '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.

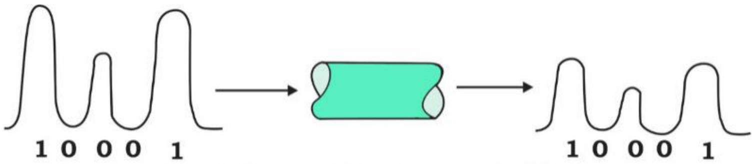


Fig.1.49 Reduction in strength of the optical pulse

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

a) 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 the impurities in the fibre material. This heat radiation will get waste.

b) Scattering – It defines light is dispersed in all directions. This dispersion is caused due to structural imperfection in the optical fibre material as shown in Figure 1.51.

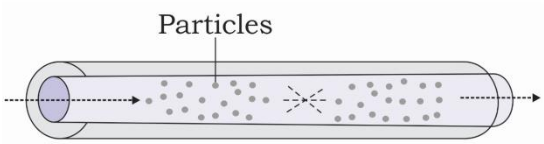


Fig.1.51 Scattering of light in optical fibre cable

c) 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 the 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.

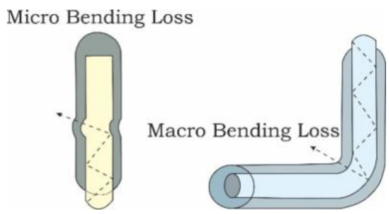


Fig.1.52 Macro and micro bending in optical fibre cable

Practical Activity 4 – Calculate macro bending loss in optical fibre cable.

Material Required

Optical fibre, LASER, Connector, optical power meter

Procedure

Step 1. Connect a laser light at one terminal of OFC using a connector.

Step 2. Make sure that the OFC does not have any bend. Connect an optical power meter at the other end of OFC. Observe and note the reading.

Step 3. Now, bend the OFC and again connect the optical power meter. Observe and note the reading.

Step 4. Compare the two noted readings above. 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 error at the receiver output in the transmission channel. It limits the information carrying capacity of the fibre. Typical, spreading of digital pulse in the OFC is shown in Figure.1.53.

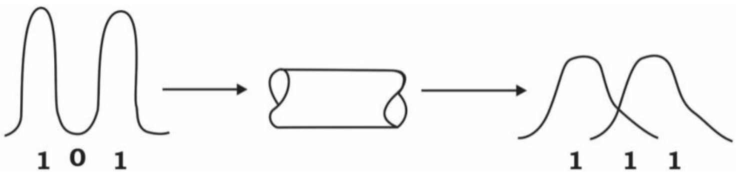


Fig.1.53 Dispersion of pulse in the optical fibre cable

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 does not reaches simultaneously at the end of the fibre. In multimode OFC, each ray of light has different wavelength travel. Therefore, each ray will travel at different speed inside the fibres and reaches 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 transmit the three pulse i.e. first pulse represents 1, second pulse represents 0, third pulse represents 1 at the input of OFC. It is shown in Figure 1.54. After some time, when bits reach the output, then at the end of fibre, it is received as 111.

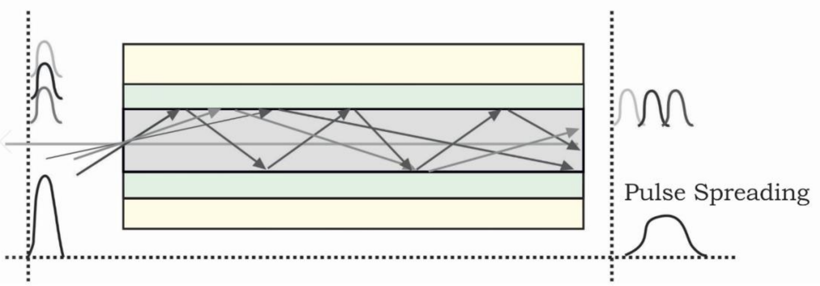


Fig.1.54 Intermodal dispersion in the multimode optical fibre cable

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 travelling at different speeds in the fibre. For example, white light composed of seven colours and when it passes through the fibre the blue, light travels faster and red light travels slower. Typical, intramodal dispersion is shown in Figure 1.55.

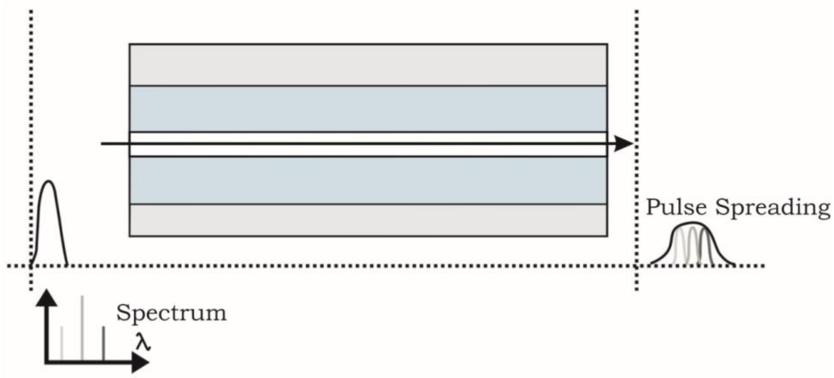


Fig.1.55 Intramodal or Chromatic dispersion in optical fibre cable

Intramodal is divided into two parts namely Material Dispersion, 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 as material dispersion.

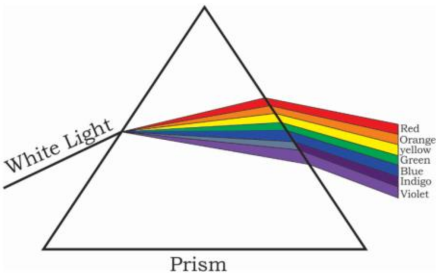


Fig.1.56 Splitting of white Light into seven colours by glass prism

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

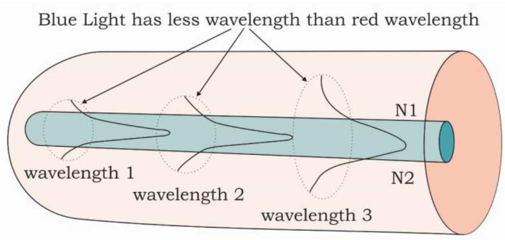


Fig.1.57 Waveguide dispersion in the core of optical fibre cable

Practical Activity 5 – Study the dispersion of white light using a prism.

Material Required

Darkroom, Light source, Plane white paper, prism.

Procedure

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

Fig. 1 Prism on plane surface

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

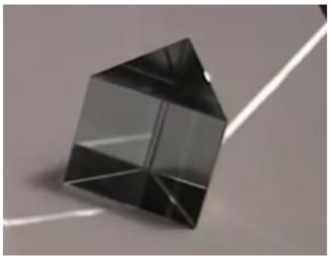


Fig. 2 Incident light ray on the prism

Step 3. In a dark room, observe that white light incident on a face of prism is divided into seven colours.

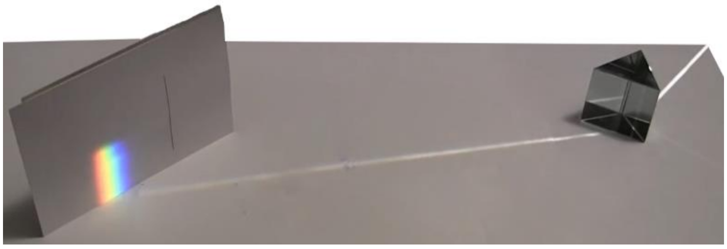


Fig. 3 Split of white light into seven colours

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 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 can 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 medium A and B have same refractive index.
6. The critical angle is that angle of incidence for which the angle of refraction is (a) 1800 (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.
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 takes place in __________ cable.
5. Light through the optical fibre propagates inside core at a speed of __.

C. State whether the following statement are True and False

1. If white light is passed through the prism, the light split 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, diameter of the core is larger than the cladding.
4. The buffer coating is made-up of steel.
5. Buffering layer protects the core and cladding of the optical fibre cable.
6. Speed of light becomes larger when it travels from rarer medium to the denser medium.
7. 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 is taken to restore the weak signal?
5. List various layers used in the manufacturing of optical fibre cable.

Session 2: Splicing

Today, 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 distance, you need a long OFC. So, there is felt need of joining the OFC. In electrical network the wires are joined by soldering. Connecting OFC is analogous to joining electrical wires. Splicing is the process to joining two OFC. In splicing, the broken fibre ends are joined permanently. It is noble name of "soldering". In this chapter, you will learn understand the process of splicing and equipment required for splicing.

SPLICING

OFC cables are widely used in communication network. They act as veins of communication system. OFC is made-up of glass. If these cables are broken or damaged it requires to join. The specialized technique used to join the damaged OFC is called as *splicing*. Splicing phases are shown in Figure 2.1 and 2.2

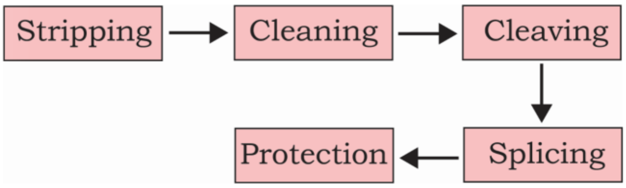


Fig. 2.1 Steps for performing splicing

Fig. 2.2 Damaged optical fibre cables

Factors Affecting the Optical Fibre Cable

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

Water – It is very harmful for OFC. Water slowly reduces strength of coatings on OFC. Water may be entered into the OFC through splice joints. This may damage the quality of OFC as shown in Figure 2.3.

Fig. 2.3 Damage in the splice enclosure due to water

Rodents – They are often responsible for extensive damage to optical fibre cable. Even metal armoured cable can cut by them as shown in Figure 2.4.

Fig. 2.4 Damage in the fibre cable due to rodent

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

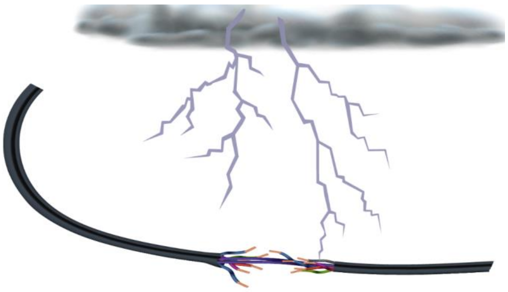


Fig. 2.5 Damage in fibre cable due to Lightening

Infrastructural Construction – It is the biggest cause of damage to buried cable. As you know, OFC are installed beneath the earth's surface. Therefore, at the time of digging, caution has to be taken on site as shown in Figure 2.6.

Fig. 2.6 Damage of the fibre cable due to construction

Ice Crush – In a cold place, water that enters in a splice joint convert into ice. It damage the internal structure of OFC as shown in Figure 2.7.

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

TYPES 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 called as *fusion splicing*. Fusion splicing is mostly used. Fusion splicing is done by heating the ends of the fibre using electric arc. It is useful to join the fibre ends permanently. It has lower attenuation loss of 0.1dB/km. In mechanical splicing, the joint is temporary and has loss between 0.2 to 0.72dB/Km, which is more than fusion splice.

Assignment 1

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

Assignment 2

Label each part of the splicing machine along with its use in fusion splicing.

Assignment 3

After performing the assignment 2, 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.

LOSSES IN SPLICING

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

Poor Concentricity – It is a joined optical fibre causes a splice loss. For example, if the light source wavelength is 1310 nm, misalignment by 1 μm 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 make 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.

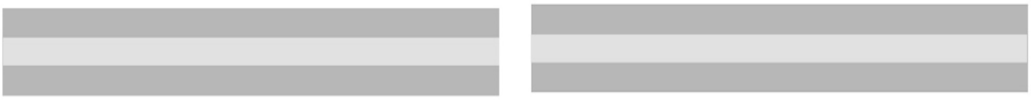
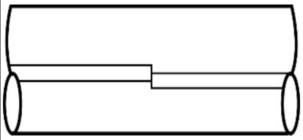
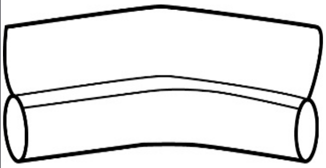
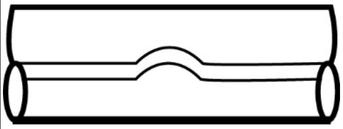
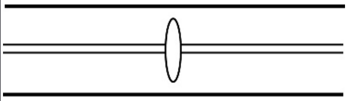
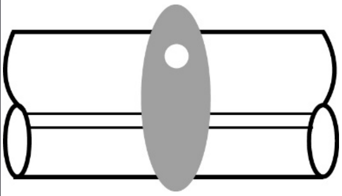
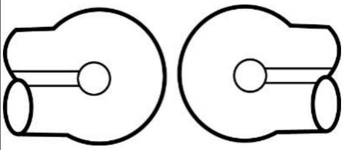
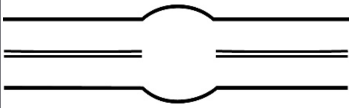
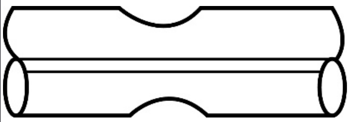
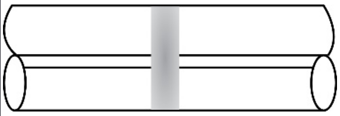


Fig. 2.10 Splice loss due to Gap

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

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

Symptom	Cause	Remedy
Core axial offset  **Fig. 2.11**	Dust on the V-groove of fusion splice machine or fibre clamp	Clean V-groove and fibre clamp
Core angle  **Fig. 2.12**	a. Dust on the V-groove of fusion splice machine or fibre clamp. b. Bad fibre end 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-end face quality b. The 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
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 the 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 too high, Gap too wide	Maintain the current and feed rate
Line  **Fig. 2.20**	Fusion current is very less, 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 joined (d) Partially joined
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 splice 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 occur, 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, which 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 occurs at the time of splicing.
5. List the common loss in the optical fibre cable.

Module 2 — Tools and Equipment and Route Inspection

Module Overview

In this Module tools and equipment are crucial for the successful installation and maintenance of optical fiber cables. Essential tools include precision cleavers for clean fiber cuts, fusion splicers for permanent connections, and optical time domain reflectometers (OTDRs) for fault detection. Equipment such as cable splicers, visual fault locators, and fiber optic testers are also vital for ensuring optimal performance and reliability. Proper handling and calibration of these tools are necessary to prevent damage and ensure accurate results.

Route inspection is a critical pre-installation process that involves evaluating the proposed cable path. This includes identifying obstacles, assessing ground conditions, and ensuring compliance with safety regulations. Effective route inspection helps in planning the installation process, minimizing potential issues, and optimizing the placement of cables. It involves a detailed site survey to ensure that the selected route is feasible and that all environmental and structural considerations are addressed before installation begins.

Learning Outcomes

After completing this module, you will be able to:

- Identify and effectively use essential optical fiber tools and equipment for installation and maintenance.
- Conduct thorough site visits and route inspections to ensure optimal fiber cable installation planning and execution.
- Properly handle and manage optical fiber cable drums to ensure safe and efficient cable deployment.

Module Structure

Session 1. Optical Fibre Tools and Equipment

Session 2. Site Visit and Route Inspection

Session 3. Optical Fibre Cable Drum Handling

Session 1. Optical Fibre Tools and Equipment

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 correct way ensures the correct installation and repairing of OFC. These equipment helps to identify the faults occurred in OFC. It is recommended to keep the complete set of tools required for digging, installation, splicing, connecting, testing and troubleshooting. The tool kit primarily consists of splicing machine, test equipment, cable handling tools, termination/ splicing tools and consumables as shown in Figure 1.1. In this session, you will understand the various tools and equipment used in the installation of OFC.

Fig.1.1 Optical fibre tool kit and testing equipment

TOOL KIT AND EQUIPMENT

Tools and equipment are essential for cable laying, installation, testing and splicing of OFC. (Figure 1.2) Tools are same for different cables, but may vary in size and shape as per their brands. Refer the manual for appropriate size of tool for OFC installation. Keep tool-kit clean. It contains essential tools for carrying out termination, polishing of OFC at the work sites. It is a 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.

Fig.1.2 Optical fibre Termination Tool Box

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 inch to 2.75 inch. Adjust the blade of the slitter according to the thickness of the outer jacket of the cable as shown in Figure 1.3. Then place it on the mark point. Rotate the slitter around the cable, and then, slide it towards the end point of cable.

Fig. 1.3 Rotary Cable Slitter

Practical Activity 1 – Demonstrate cable stripping using rotary cable slitter.

Material Required

Rotary cable slitter, OFC

Procedure

Step 1. Take a piece of OFC and rotary cable slitter.

Step 2. Set the blade of rotary cable slitter in accordance with the thickness of the jacket of OFC.

Step 3. Place the OFC in the slot of rotary cable slitter and then tighten the slitter knob.

Step 4. Rotate the slitter in circular direction in such a way that only jacket of OFC should be cut.

Step 5. Move the slitter in the outward direction.

Step 6. After removing the jacket, inspect the fibre for any damage.

Armored Cable Cutter – It is used with larger diameter metallic-armored cables for cutting outer jacket and armor of the cable. The depth of the cutting blade is generally correct for cutting the outer jacket and armor without harming the inner jack or fibres in a metallic-armored cable as shown in Figure 1.4. Cut the armor just like tubing, making several revolutions around the cable, tightening the cutters with each revolution.

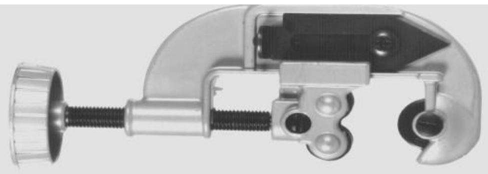


Fig. 1.4 Armored cable cutter

Practical Activity 2 – Demonstrate the cable stripping using armored cable jacket stripper.

Material Required

Armored cable cutter, OFC

Procedure

Step 1. Take a piece of OFC and armored cable cutter.

Step 2. Open the universal cable jacket stripper and adjust its blade, according to the diameter of OFC.

Step 1. Place the OFC in the slot of universal cable jacket stripper and then close the universal cable jacket stripper.

Step 4. Move the stripper in the outward direction in such a way that only jacket of

OFC is strip down.

Step 5. After removing the jacket, inspect the fibre for any damage.

Fibre Stripper – It is a tool used to strip the cladding, 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, cladding layer respectively.

Fig.1.5 Optical Fibre Stripper

Practical Activity 3 – Demonstrate OFC stripping using optical fibre stripper.

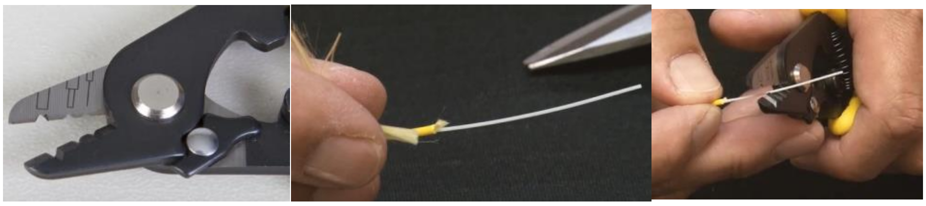
Material Required

Optical fibre stripper, OFC

Procedure

Step 1. Take an optical fibre stripper. Firstly, place the fibre in the large slot of stripper in order to remove the jacket of fibre.

Step 2. Place the optical fibre in the middle slot of stripper as shown in Figure 1. It will strip the buffer layers, left with cladding layer.



- **(a)** **(b)** **(c)**

Fig. 1 (a) Three slots of optical fibre stripper (b) Buffer layers of OFC (c) Stripped fibre is placed in middle slot of optical fibre stripper

Step 1. Clean, the cladding of an optical fibre using tissue paper poured into isopropyl solution as shown in Figure 2.

Fig. 2 Cleaning the optical fibre using tissue paper

Step 4. Again, place the same fibre in the small slot. This will remove the cladding of the optical fibre as shown in Figure 1.

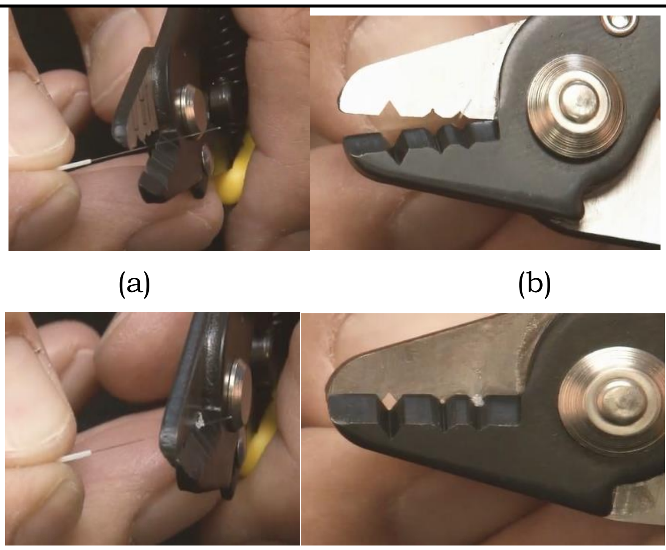


Fig. 3 (a) Placing cladding portion of OFC in little slot (b) Side view of placing the OFC in small slot (c) Squeeze the stripper removes the cladding (d) Side view of cladding removable in stripper

Step 5. Observe the core and cladding layers. Visualize 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 as shown in Figure 1.6.

Fig.1.6 Buffer Tube Stripper

Practical Activity 4 – Demonstrate cable stripping using buffer tube stripper.

Material Required

Buffer tube stripper, OFC

Procedure

Step 1. Take an OFC and buffer tube stripper.

Step 2. Open the buffer tube stripper according to the diameter of OFC as shown in Figure 1.

Fig. 1 Open the buffer tube cutter

Step 1. Place the OFC in the slot of buffer tube stripper and then close the buffer tube stripper as show in Figure 2.

Fig. 2 Placing the cable in the buffer tube stripper

Step 4. Move the stripper in the outward direction in such a way that only buffer of OFC is strip down.

Step 5. After removing the jacket, inspect the fibre for any damage.

Fibre Cleaver or Precision Cleaver – It is used to cut the optical fibre to provide a clean and precise end face for optical splicing to minimize optical loss. It is equipped with a high-quality durable blade, which can provide cleaving up to 48,000 times before the replacement blade.

Fig.1.7 Fibre cleaver

Practical Activity 5 – Demonstrate the precision cleaver and its operation.

Material Required

OFC, Precision cleaver

Procedure

Step 1. Strip of its outer layer of sample OFC using optical fibre stripper.

Step 2. Clean the stripped fibre using tissue paper dipped in isopropyl alcohol.

Step 3. Now, take the precision cleaver and open its cap as shown in Figure 1.

Fig. 1 Precision cleaver

Step 4. Horizontally, place the stripped optical fibre inside the precision cleaver slot as shown in Figure 2.

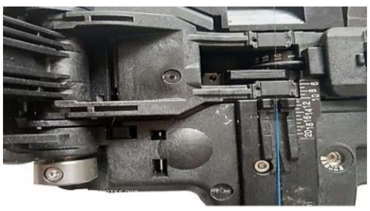


Fig. 2 Fibre placed in the slot of precision cleaver

Step 5. Adjust the blade of the precision cleaver to cut the stripped fibre cable.

Step 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 as shown in Figure 3.

Fig. 3 Closing the cap of cleaver

Step 7. Again, open the cap of precision cleaver. Check the end terminal of stripped fibre.

Step 8. Similarly, repeat the same procedure for the other end of the fibre cable to perform its cleaving.

Scribe – It is a sharp, hard crystal used to scratch or mark the point on the fibre for cleaving. It is used in termination of fibre to remove the excess fibre from the connector ferrule before polishing as shown in Figure 1.8.

Fig 1.8 Scribe

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 as shown in Figure 1.9.

Fig 1.9 Crimping tool

Practical Activity 6 – Demonstrate crimping of OFC using crimping tool.

Material Required

Optical fibre crimper, OFC, SC connector, crimp,

Procedure

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

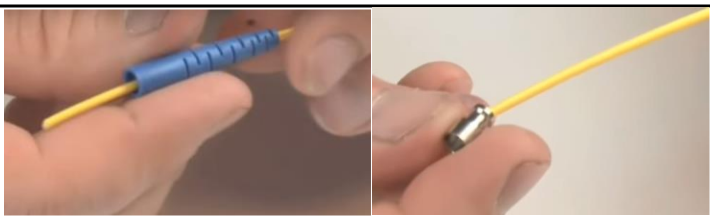


Fig. 1 (a) Insert the boot in the OFC (b) Insert the crimp in the OFC

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

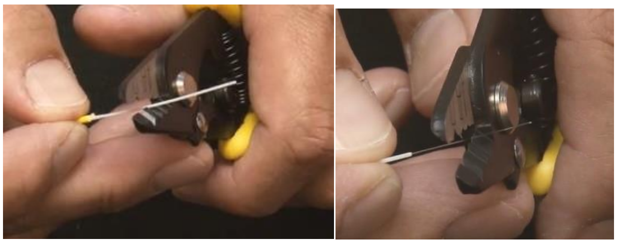


Fig. 2 (a) Placing the buffer layers for stripping in stripper's middle slot (b) Place the cladding layers for stripping in stripper's little slot

Step 3. Clean the fibre using isopropyl solution.

Step 4. Take the bare fibre and insert it inside the ferrule as shown in Figure 3.

Fig. 3 Inserting the bare fibre inside the ferrule

Step 5. Slide and fit the stripped fibre end inside the ferrule as shown in Figure 4.

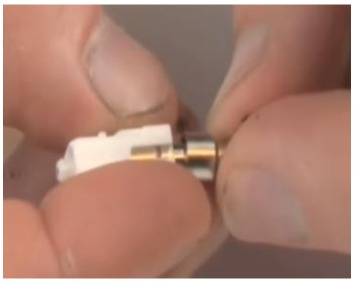


Fig. 4 Inserting stripped fibre inside a ferrule

Step 6. Using crimper, perform the crimping on ferrule as shown in Figure 5.

Fig. 5 Crimping using the crimper

Step 7. Slide the boot over the crimped portion.

Step 8. Now, cut the extra Kevlar of fibre around the ferrule.

Step 9. Cover the ferrule using outer housing as shown in Figure 6.

Fig. 6 Connecting outer housing to the inner body

Step 10. Observe and check the functionality of the connector.

Nose Pliers – 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 as shown in Figure 1.10.

Fig 1.10 Nose Pliers

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 scissor, you should make a bunch all the aramid yarn together, twist them to give a shape of rope, and then cut all the fibres at once. The scissor blades should cut through in 1 to 2 snips as shown in Figure 1.11.

Fig 1.11 Kevlar Scissor

Practical Activity 7 – Demonstrate the use of optical fibre Kevlar scissor.

Material Required

Optical fibre Kevlar scissor, OFC

Procedure

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

Fig. 1 Optical fibre cable

Step 2. Take a Kevlar scissor carefully cut the fibre as shown in Figure 2.

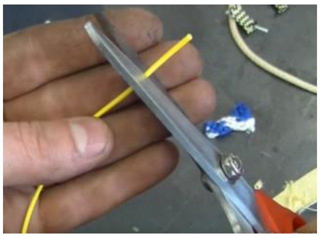


Fig. 2 Cutting the fibre using Kevlar scissor

Step 1. Check that cut must be sharp as shown in Figure 3.

Fig. 3 Check sharpness of terminals

Step 4. Use the Kevlar scissor to cut the Kevlar of the fibre as shown in Figure 4.

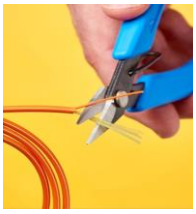


Fig. 4 Cutting the Kevlar of fibre using the Kevlar scissor

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 1.12.

Fig.1.12 Optical Fibre Polishing Tools

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 to be stripping off.

Polishing Mat – It is used as a working mat for the optical fibre connector 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 connector into this polishing tool, lay on polishing paper. Need one for 2.5mm ferrule connectors (ST/SC/FC) and one for 1.25 mm 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 face types such as the physical contact and angled physical contact as shown in Figure 1.13.

Fig. 1.13 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 as shown in Figure 1.14.

Fig. 1.14 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 is 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 as shown in Figure 1.15.

Fig.1.15 Optical fibre Swabs

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 new cleaning surface is available for each cleaning to prevent contamination.

Fig. 1.16 One-click Ferrule Mate Cleaner

Isopropyl Alcohol – It is used to clean fibres and connectors during splicing, termination, testing as shown in Figure 1.17.

Fig. 1.17 Isopropyl Alcohol

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 few drops of isopropyl alcohol above it and then it will clean up the fibre.

Note: Do not touch the wipes with dirty hands or wet hands. Dispose of the used wipes in bin and do not reuse it as shown in Figure 1.18.

Fig. 1.18 Wipes

Gloves – They are used to provide protection to the hand at the time of performing the splicing as shown in Figure 1.19.

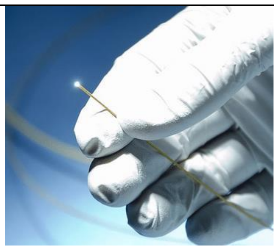


Fig. 1.19 Hand Gloves

Trash Bin – It is used to dispose the scraps of OFC and used wipes as shown in Figure 1.20.

Fig.1.20 Trash bin

Optical Fibre Epoxy Adhesive Tools

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

Epoxy for Connectorization – 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 as shown in Figure 1.21.

Fig. 1.21 Epoxy for Connectorization

Epoxy Application Syringe – It comes with both syringe body and needle dispenser. It is designed to inject the epoxy for connectorization into the optical fibre connectors. A needle dispenser is available together with the syringe body as shown in Figure 1.22.

Fig. 1.22 Epoxy Application Syringe

Fibre Splicing Equipment

Fusion Splice Machine – It is used to join two optical fibres permanently. It supports multi-mode and single mode optical fibres. A LCD touch screen, which provides highly clear graphical interface, is incorporated in the Fusion Splicer machine as shown in Figure 1.23.

Fig.1.23 Fusion Splicer Machine

Practical Activity 8 – Demonstrate the fusion splicing using electric arc.

Materials Required

OFC, Splice machine, Optical Fibre cleaver, Tissue paper, Alcohol, Protection sleeves, Round tube cutter, Fibre stripper.

Procedure

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

Fig. 1 Damaged OFC

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

Step 2. Cut and remove damaged part of fibre using a cable cutter. Now, you will have two pieces of cable.

Step 3. Now, prepare end of each piece. These two pieces can be spliced perfectly without any losses. Figure 2 shows two pieces of cable, which needs to be prepared for splicing.

Fig. 2 Two ends of fibre cable which is to be splice

Step 4. Place one piece of fibre cable it in round tube cutter and adjust the blade using knob to remove its jacket and buffer tube as shown in Figure 3.

Fig. 3 Removing the jacket of the optical fibre cable using round tube cutter

Step 5. Take a tissue paper with some alcohol poured on it to clean the jelly coming out of the fibre as shown in Figure 5.

Fig. 4 Cleaning the jelly using tissue paper

Step 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.

Step 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 5.

Fig. 5 Placing protection sleeve inside the fibre

Step 8. Take the stripping tool and place fibre in its large slot. This will remove the buffer and now, left with cladding as shown in Figure 6.

- **(a)** **(b)** **(c)**

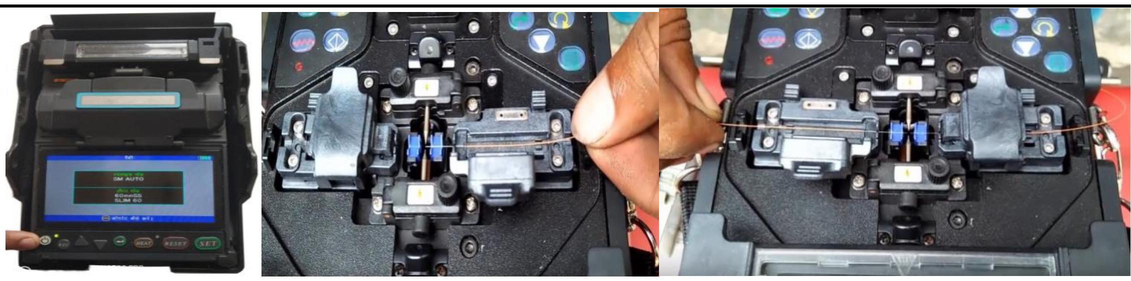
Fig. 7 (a) Stripping the buffer of OFC using optical fibre stripper, (b) Stripped fibre, (c) Cleaning the cladding using tissue paper

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

CAUTION! Do not place your finger inside the cleaver.

Step 10. Repeat the above procedure to prepare one more piece of fibre.

Step 11. Now, bring the fusion splice machine, open its cap to place both the fibres in the dedicated slots as shown in Figure 8.



• (a) (b) (c)

Fig. 8 (a) Fusion splicing machine, (b) Placing the first fibre in fusion splice machine, (c) Placing the second fibre in fusion splice machine

Step 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, performs splicing of the fibres as shown in Figure 9.

Fig. 9 Display unit shows the splicing operation going inside the fusion splice machine

Step 11. 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 as shown in Figure 1.24.

Fig 1.24 Mechanical splices

Practical Activity 9 – Demonstrate the mechanical splicing in OFC.

Materials Required

OFC, Optical fibre mechanical splicer connector, optical fibre cleaver, Tissue paper, Alcohol, Protection sleeves, Round tube cutter, Fibre cutter/stripper.

Procedure

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

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

Step 2. Take a stripped optical fibre placed it in a ferrule. Ferrule is a capillary glass tube under compression with the help of compressing springs.

Step 1. Insert the two fibres inside the glass ferrules. Place these glass ferrules in the alignment sleeve as shown in Figure 1.

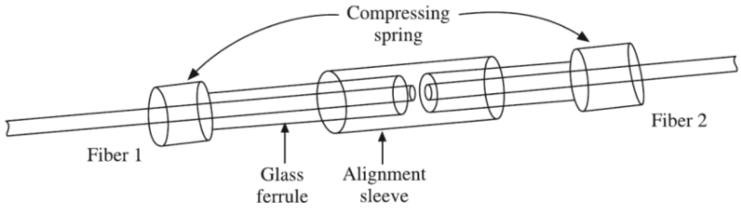


Fig. 1 Mechanical splicing housing

Step 4. Index matching gel is present inside the mechanical splice. This gel helps to couple the light from one fibre end to the other as shown in Figure 2.

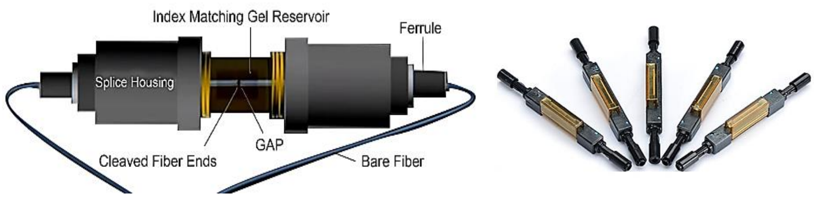


Fig. 2 Mechanical connector

Fusion Splice Protector – It is used to protect the optical fibre joint from atmospheric impacts such as air, moisture, water as shown in Figure 1.25.

Fig 1.25 Fusion splice protector

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 used to connect and align the optical fibres so that the optical light signals that can be transmitted without any interference. They are widely used in telecommunication and data communication networks. Some of the commonly used connectors are as follows.

FC Connector – It is designed to work with screw-type mating mechanism as shown in Figure 1.26.

Fig. 1.26 FC Connector

LC Connector – It is designed to work with the snap-in coupling mechanism as shown in Figure 1.27.

Fig. 1.27 LC Connector

SC Connector – It is designed with a push-pull coupling mechanism as shown in Figure 1.28.

Fig. 1.28 SC Connector

ST Connector – It is designed to work with the thread coupling mechanism as shown in Figure 1.29.

Fig. 1.29 ST Connector

Optical Fibre Adapter

They are utilized in the optical fibre network connection by connecting with the optical fibre connectors. They are designed for both single mode and multi-mode OFC as shown in Figure 1.30. Optical fibre adapters are usually used to connect with optical fibre connectors of similar kinds.

Fig. 1.30 Optical fibre Adapter

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 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 as shown in Figure 1.31.

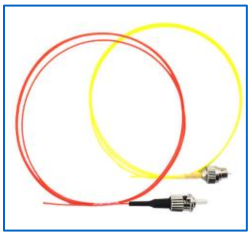


Fig. 1.31 Optical fibre Pigtail

Optical Patch Cord

Optical fibre patch cable, often called optical fibre patch cord or fibre jumper cable, is an OFC terminated with optical fibre connectors on both ends. They are used in the optical fibre networking as shown in Figure 1.32.

Fig. 1.32 Optical fibre Patch Cord

Optical Fibre Attenuator

Sometimes, the optical signals may be too strong for a optical fibre receiver to accept in optical fibre network transmission and this will cause damage to the receiving device. The optical fibre attenuator can be utilized in this situation by reducing the transmission signal power level to a certain level as shown in Figure 1.33.

Fig. 1.33 Optical Fibre Attenuator

Direct Termination Kit

It is used to house the bare optical fibres. The direct termination kits also provide protection to the optical fibres for termination with the optical fibre connectors. Breakout kit is used to directly terminate the bare optical fibre as shown in Figure 1.34.

Fig. 1.34 Direct Termination Kit

Splice Enclosure

It is used to protect stripped optical fibre cable and optical fibre splices from the environment. Outdoor optical fibre enclosures are usually weatherproof with watertight seals as shown in Figure 1.35.

Fig. 1.35 Splice enclosure

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 on 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 photo diode 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 1.36.

Fig. 1.36 Optical Power Meter

Practical Activity 10 – Demonstrate the light source and optical power meter.

Material Required

Optical power meter, OFC with connector, light source.

Procedure

Step 1. Take an optical power meter as shown in Figure 1.

Fig. 1 Optical power meter

Step 2. Take an OFC, connect it to optical power meter port.

Fig. 2 OFC connected in optical power meter

Step 1. Take a light source, connect the other end of the OFC to light source as shown in Figure 3.

Fig. 3 Optical power meter with light source

Step 4. Turn ON the light source, a ray of light enters the OFC.

Step 5. Note down the reading from optical power meter.

Step 6. Now, vary the wavelength of light beam using light source.

Step 7. Observe and tabulate the reading from optical power meter in decibel (dB) and its corresponding wavelength.

Optical fibre Laser 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 as shown in Figure 1.37.

Fig. 1.37 Optical Laser Source

Practical activity 11 – 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

Procedure

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

Fig. 1 Clean the ends of reference cord

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

Fig. 2 Connecting the reference cord to the optical power meter and optical light source

Step 1. Choose the wavelength of 1310nm in light source as shown in Figure 3. Press the "REF" 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 Setting up the optical power meter and light source

Step 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 4.

Fig. 4 Connect the test cable to the light source

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

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

Fig. 5 Reading in the optical power meter

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

Visual Fault Locator – It uses visible light to check OFC continuity. It can also find the faults in the fibre. The laser-powered Visual Fault Locator (VFL) is a cable continuity tester that locates fibres, verifies cable continuity and polarity. This cable continuity tester finds breaks in cables, connectors and splices. Continuous and flashing modes make for easier identification as shown in Figure 1.38. It has a long battery life to use for long hours.

Fig. 1.38 Visual Fault Locator

Practical Activity 12 – Demonstrate the use of Visual Fault Locator.

Material Required

Visual Fault Locator, batteries, fibre cable to be tested

Procedure

Step 1. Take the Visual Fault Locator, a pen like device, shown in the Figure 1. This device is battery operated; hence, it requires two batteries for operation.

Fig. 1 A pen- like device of visual fault locator

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

Fig. 2 Opening of the upper lid of the visual fault locator

Step 1. Then place the batteries and then close the cap shown in the Figure 3.

Fig. 3 Insertion of batteries inside the visual fault locator

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

Fig. 4 Pressing of the button of visual fault indicator

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

Fig. 5 Opening of the other end of the cap of visual fault locator

Step 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 6.

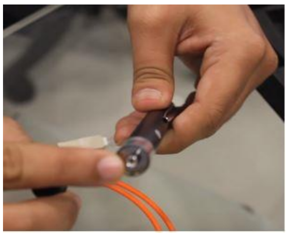


Fig. 6 Checking of the passage of light emission by visual fault indicator

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

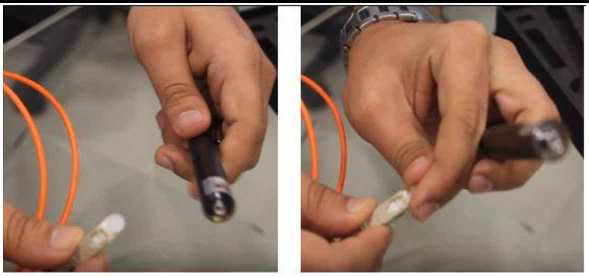


Fig. 7 Connection of the connector to visual fault device

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

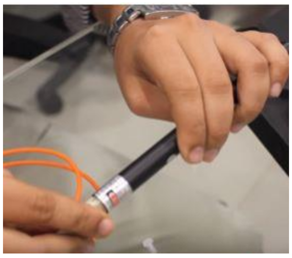


Fig. 8 Mating of the light passage inside the connector of visual fault indicator

Step 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 9.

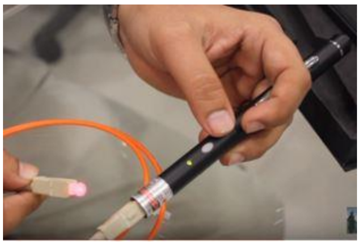


Fig. 9 Checking of the light passage through the fibre

Inspection Microscope – It is used to visualize the end face of a connector to identify any faults/ cracks/scratches as shown in Figure 1.39.

Fig.1.39 Inspection microscope

Practical Activity 13 – Demonstrate the optical fibre inspection microscope.

Material Required

Inspection microscope, OFC

Procedure

Step 1. Take an OFC and inspection microscope. Connect the OFC to the adapter of microscope as shown in Figure 1.

Fig. 1 Input the Fibre which will be checked into the Fibre Insert Entrance

Step 2. Press the switch of microscope to pass the light in the OFC. Then observe it using eyepiece of microscope as shown in Figure 2.

Fig. 2 Seeing from the eyepiece to the microscope

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

Fig. 3 Adjusting the focus control of the microscope

Step 4. Observe and inspect the connector of the OFC.

Optical Time Domain Reflectometer (OTDR) – It is used to calculate the various loss in the OFC. It can identify faults, its 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 back from fibre discontinuities and light continuously back scattered 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. (Figure 1.40) 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 two points on the trace is estimate of optical loss.

Fig. 1.40 Optical Time Domain Reflectometer (OTDR)

Practical Activity 14 – Demonstrate different functional keys and ports in optical time domain reflectometer.

Material Required

Optical time domain reflectometer, notepad, pen

Procedure

Step 1. Consider an optical time domain reflectometer (OTDR).

Step 2. Observe the ports in OTDR namely charging port, measuring range knob, visible laser source, USB port, connector for inspection microscope as shown in Figure 1.

Fig. 1 Ports of optical time domain reflectometer

Step 1. Observe the functional keys namely shortcut keys, numeric keypad, rotary dial, arrow key, power switch, LCD display, as shown in Figure 2.

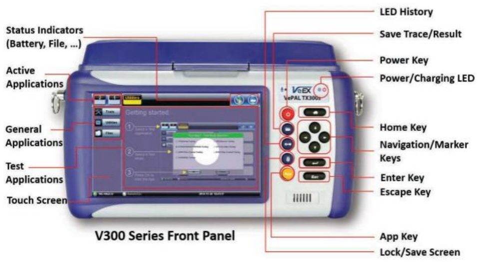


Fig. 2 Functional key interfacing of OTDR

Step 4. Observe the instructional options on LCD screen of OTDR as shown in Figure 3.

Fig. 3 Interfacing icon on the display of OTDR

Step 4. Observe and note down the functions of all keys and ports.

Check Your Progress

A. Multiple choice questions

1. Which of the following tool is use to cut the end of core smoothly? (a) Optical fibre stripper (b) Nose plier (c) Precision Cleaver (d) Scissor
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 the type of the 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 faults (b) Identify any cracks (c) Identify any scratches (d) Identify any breaks
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) Armored cable cutter (c) Epoxy syringe (d) Optical fibre stripper
9. Which of the following is not an equipment? (a) Optical power meter (b) Kevlar scissor (c) Laser power source (c) Optical Time Domain Reflectometer
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 scissor is madeup of hard _________ or ceramic material.
3. For grabbing and pulling pull-cords, or ripcords of optical fibre cable _____ is 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 visualize 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 following statements are 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 preinstalled 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 perform at the terminal point of optical fibre.

D. Short answer questions

1. Define the terms (a) Fibre Stripper (b) Cleaning Swab (c) Rotary Slitter

2. Define the connectors (a) LC Connector (b) FC Connector (c) SC Connector (e) ST connector
3. Name the tools and equipment used for fibre splicing.
4. How the jacket of the metallic-armored cables can be removed?
5. What is the role of optical time domain reflectometer in optical fibre network?
6. Difference between the optical fibre pigtail and optical fibre patch cord.
7. How fusion splicing is 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?

Session 2: Site Visit and Route Inspection

One day Ram, decided to celebrate birthday of his mother. For that, his family started to visit banquet halls in the city. Primary amenities they were looking in the venue are interior and space in the hall, location of the venue, parking area, rooms for the guest. This example shows that to organise any event proper planning and site visit are very important. In the same way, for 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 assist in preparing list of actions to be taken. These designed action plans are useful at the site while installing the cable. Effective site visit will make correct installation of cable and it 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 site visit, the team members allocate the actual equipment locations, route for excavation and conduits. It will assist to overcome the constructional challenges like reaching the vehicle to the installation site and environmental conditions. Complete the details obtain from data collected by site visit. Note, the climatic condition and recommend the change if required. One of the typical situations of site visit by team members is shown in Figure 2.1.

Fig. 2.1 Team performing site visit

Benefits of Site Visit – Following are some of the benefits of site visit.

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

Different Site Condition – In India, geographical area vary in the few kilometres. Keeping this fact of variation in geographical area installation team will plan accordingly. They should prepare the plan as per the requirement of the site condition. Some site conditions, which commonly found in the visit of installation team, are rocks, plateaus, mountain, rivers, highways, railway tracks, farms, forest. Such area must be checked for the transportation reachability. It helps to easily drive the vehicle to the installation site for shifting of the raw material from ware house and also machinery for excavation. The different possibilities of site conditions are shown in Figure 2.2 (a), (b), (c) and (d).

Fig. 2.2 Different site condition (a) Mountain (b) River (c) Forest (d) Farm

ROUTE INSPECTION

Route inspection is the next step after site visit. It will help to inspect the actual path is to be followed for cable laying. It will help to identify the small hurdles, which may go to intervene during the trenching such as electric pole, water pipe, LPG pipeline. It also covers the inspection of land surface. This inspection assists to know the requirement of conduit type that can be used. Depending up on the type of soil at the installation site, trenching can be done manually or by using machinery. In rural areas, trenchers are 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.

Fig. 2.3 Effective route planning

Following steps needs to be performed for route inspection.

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

1. Obtain OFC Route Plan – In route plan, planning team suggest the proposed route for cable laying. This route plan contains information of physical locations such as premises, building, complex, multiplex along the way of cable laying buried cables such as telephone cable, electrical cable as shown in Figure 2.4.

Fig. 2.4 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 as shown in Figure 2.5.

Fig. 2.5 (a) Underground cables (b) Telephone line junction box along the road

It includes the various departments such as state electricity board, water and sanitation department, Municipal Corporation and have to obtain permissions to carry out the installation of OFC cable. The special protection equipment is suggested for installation team to work in unhygienic site. Figure 2.6 shows an example of unhygienic situation at the installation site.

Fig. 2.6 Unhygienic site

2. Verify the Plan through a Route Walk – Preliminary survey shall be carried out for finalizing the drawing for the route of OFC as a part of project planning and execution. The following points may be verified through route walk.

Plan the installation.

Create a detailed, written plan of installation. Major problems can be eliminated by creating a proper planning of the site as shown in Figure 2.7.

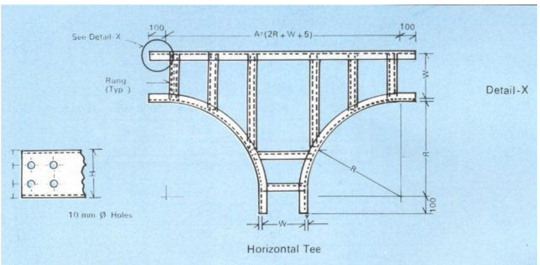


Fig. 2.7 Route plan of cable installation

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

Table 2.1: Requirement list made after route inspection

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

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 operate as shown in Figure 2.8 and Figure 2.9.

Fig. 2.8 Excavation in the open area **Fig. 2.9 Excavation in narrow area using mini excavator**

Avoid laying of cable close to the track of gas pipes or water pipes as shown in Figure 2.10.

Fig. 2.10 (a) OFC close to water pipe (b) Water pipe damage in the excavation

Avoid laying of the cable adjacent to the cultivated Fields as shown in Figure 2.11.

Fig. 2.11 Avoid laying of cable adjacent to cultivating field

Avoid areas, which are prone to water logging as shown in Figure 2.12.

Fig. 2.12 Avoid water logging area

Avoid laying of the cable inside the ground, where soil is composed of cinders, coal and ashes as shown in Figure 2.13.

Fig. 2.13 Ash on the installation ground surface

Avoid the areas near industries because such industries can discharge poisonous chemicals, which can damage the cable as shown in Figure 2.14.

Fig. 2.14 Area near to the chemical industry

Avoid the areas, which require large rock cutting, dense jungle. Because, it will be difficult to approach such areas as shown in Figure 2.15.

Fig. 2.15 (a) Excavation in rock (b) Excavation in forest

Avoid the area, where mega projects likely to be constructed in the near future such as highway project may damage the buried OFC as shown in Figure 2.16.

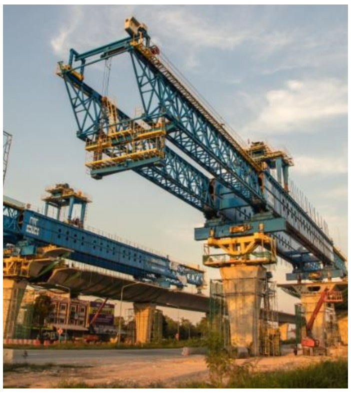


Fig. 2.16 Mega structure highway project

In order to protect the cable from corrosion or moisture damage, it is better to determine the composition of the soil as shown in Figure 2.17.

Fig. 2.17 Performing the soil testing

The requirement of transport vehicles like loading truck, dumper, excavator, trencher for the execution of the work must be considered as shown in Figure 2.18.

Fig. 2.18 Transport vehicles involved in the OFC installation

1. Verify the plan for accessibility and availability of material as per design.
2. Verify construction methods, tools and equipment and splice locations.
3. Check for material storage areas and ventilation.

Fig. 2.19 Warehouse storage and ventilation

Avoid proximity to AC power station areas to avoid electric shock as shown in Figure 2.20.

Fig. 2.20 Electrical substation and transmission tower

In case, installer has to be work near the electrical panel or electrical wire than installer must wear safety gears as shown in Figure 2.21.

Fig. 2.21 Precautionary measures must be performed near the electric panel

After performing above points, make a sketch as per the route walk. Route walk sketch is shown in Figure 2.22.

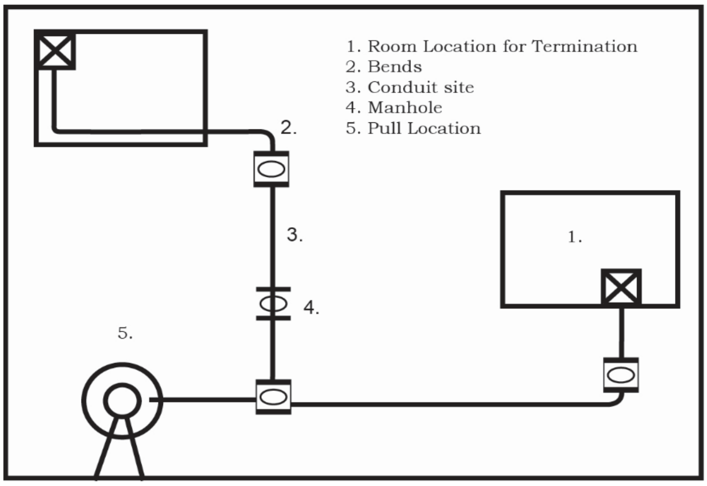


Fig. 2.22 OFC route walk sketch

3. Corrective Action – Next task is to prepare the site for installation by taking corrective action. If required,

1. Take permissions from other departments.
2. Revise route of the cable, splice location, storage location.
3. Arrange for the availability of any special tools such as stone drilling machine.
4. Remove any obstruction along the route. Prepare the site for better productivity.
5. If the route contains sections where the optical cable is subject to high temperatures, provide necessary protection.
6. Take measures to prevent optical cables from direct stress.
7. Determine location where cable reels can be positioned during the installation.
8. Locate and check accessibility of the storage house.

Benefits of Route Inspection – Route inspection provides the following benefits.

1. The issues such as obstructions cannot be known without conducting 'inspection'.
2. It helps to identify the gaps in the plan and actually physical location.
3. It helps to maintain the correct bend radius of cable.
4. It helps to identify the hazards and safety to be followed during installation.
5. Any rework due to lack of proper plan is avoided.
6. Accidents are avoided due to proper planning.

ROUTE INSPECTION REPORT

The team will submit the survey report to authority. It contains all the information of inspection and 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, team shall carry out detail survey for the selected routes and submit the final survey report for approval before implementation.

The final survey report shall include the following:

1. A drawing of proposed route indicates all details of 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.

2. 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.
3. Sections of the links where trench-less digging may be required.
4. Sections where Galvanised Iron (GI) or Reinforced Cement Concrete (RCC) pipe may be required.
5. Location and number of permanent and temporary manholes.
6. Location of all turns, bends and major landmarks.
7. Type, quantity and location of all the splice joints. Care must be taken to minimize the number of splice joints.
8. Section lengths of the underground OFC, total length of each link and drum supply scheduling for all the links.
9. 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.
10. 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 members: ______________________________

Route: ____________ To ______________________

Route length in Km: ________________________

Soil type	
Different area to be cover	Defence area: Railway track: Road: River: Forest: Mountain: Building:
OFC type to be use	
Landmarks	
Number of Bends or turn	
Number of bridges	
Ware house location	
Type of digging to use	
Number of splice joint required	
Length of OFC required	

Type of ducting required	
Number of manpower required	
Name: ____ Designation: ____________________________________ Authorized signature:	

Fig. 2.23 Route inspection report

SAFETY PRECAUTION

- Do not eat food, drink or smoke in an area near to 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, 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 passes over the cables, to avoid harm to glass core of fibre cables.

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 steps 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
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 laying 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 the following statements are True and 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 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 for 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 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 benefits of route inspection?

6. Briefly explain the three steps of route inspection.
7. How to install the cables near existing pipelines?
8. Write at-least 6 steps to execute job at site safely.
9. What are benefits of Route Inspection?
10. Briefly explain the three steps of route inspection.
11. List out precautions to be taken to install fibre.
12. How to do site visit to install the cables.
13. What are the benefits of route plan?

Session 3: Optical Fibre Cable Drum Handling

At the time of installation of optical fibre cable (OFC), large amount raw material is required to be carried to the site by trucks or lorries. OFC can be damaged during loading and unloading of 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 of handling OFC and drum at various installation sites.

CABLE DRUM LOADING

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

1. Use the crane or forklift to place the cable drum on 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 3.1.

Fig. 3.1 Placing the cable drum-using a crane

2. During transportation, the cable drums should not be kept in flat position. It may crush down the layer of the cable and damage the fibre.

3. Cable drum 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 any jerks during transportation as shown in Figure 3.2.

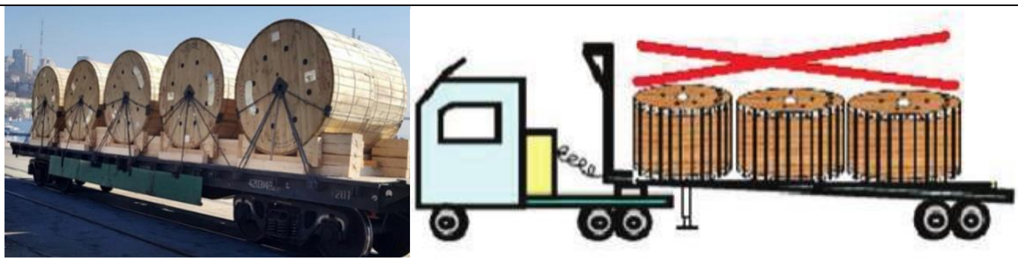


Fig.3.2 Cable drums are tied using slings and chains

4. Wedges should fasten with nail to the platform as shown in Figure 3.3.

Fig. 3.3 (a) Wooden wedge (b) Wedge is placed to block cable drum

3. When drums are in line, flanges have to be straight against each other this way flanges of one drum will not harm the cable of other as shown in Figure 3.4.

Fig.3.4 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, 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.

Drum sizes are typically determined by the flange of drum diameter (D), the drum barrel or drum core (d), the width of the drum (B), and the inside width (b) as shown in Figure 3.5.

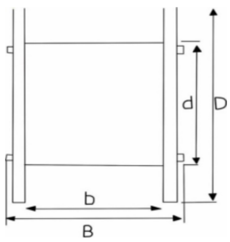


Fig. 3.5 Width of various section of the cable drum

Fig.3.6 Correct drum storage

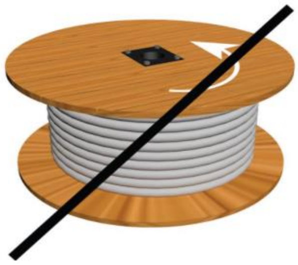


Fig. 3.7 Incorrect drum storage

CABLE DRUM UNLOADING

Following precautions needs to be taken during the cable unloading:

1. The cable drum should not drop on the floor, as the weight of the drum and cable may cause flattening deformation or damage to the cable as shown in Figure 3.8.

Fig. 3.8 Person is directly dropping the cable drum on the floor

2. Roll the drum from a truck onto the receiving platform, which should be at the same height as the tailgate of the truck, else forklift can also be used for unloading of cable drum as shown in Figure 3.9 and Figure 3.10.

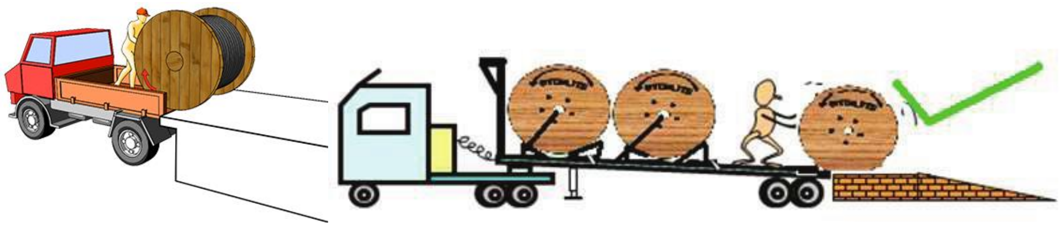
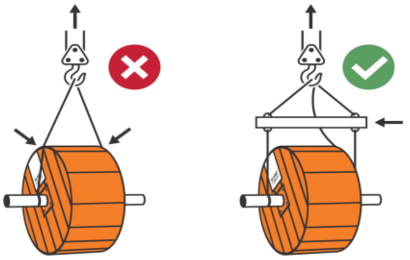


Fig. 3.9 Drum roll on the receiving platform

Fig. 3.10 (a) & (b) Forklift lifting cable drum

3. While shifting the cable drum from one place to other crane should be used. Right way to lift the cable drum is shown in Figure 3.11 (a), (b), (c).



(a)

(b)

(c)

Fig.3.11 Correct way of lifting and shifting the cable drum using a crane (a) (b) (c)

4. On inclined surface or ramp, carefully rolls a drum, so that it should not go out of control.

3. Roll one cable drum at a time and placed 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 case, it is necessary to roll the cable drum for long distance, then it should roll in correct way as shown in Figure 3.12.

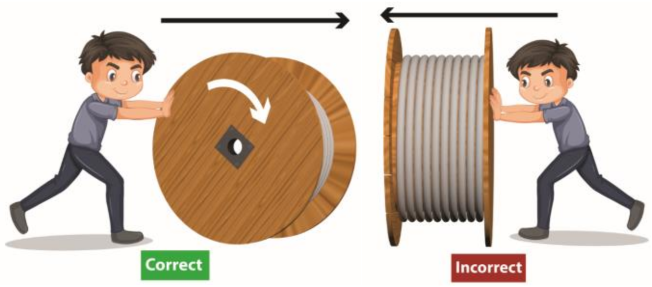


Fig. 3.12 Correct and Incorrect way of rolling the cable drum

3. The cable drum should never be stored or placed on its one flange as shown in Figure 3.13. It should be placed in such a way that both the flanges are same level.

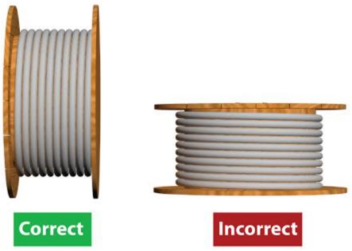


Fig. 3.13 Correct and Incorrect way of placing the cable drum

4. Cable drum should always be stored on a flat surface with blocks placed under the flanges to prevent rolling in either direction as shown in Figure 3.14.

Fig.3.14 Block used to hold the drum

CABLE DRUM UNWRAPPING

Following points needs to be remember at the time of cable unwrapping:

1. Wrap on cable drum plays an important role in protecting cable from damage during transportation. All drums are wrapped by the wooden laggings to protect the cable from minor impacts caused due to rolling the drum over the rough surface as shown in Figure 3.13.

Fig. 3.15 Cable drum with wrapping

2. Do not remove wrap from cable drum until the cable is ready to install.

CABLE STORAGE

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

1. The drums should always be stored in a correct position. Failing to do so may damage the cable.

2. If storage space is limited and it becomes necessary to arrange the cable drum in order to utilize the spaces shown in Figure 3.16.

Fig. 3.16 Cable drum in the warehouse

3. If the wrapper is removed from drum, then their flanges should be lined up in such a way that flanges do not damage the cable of adjacent drums. Unaligned cable drum is shown in Figure 3.17

Fig. 3.17 Unaligned flanges on the floor

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 is recommended as shown in Figure 3.18 (a) & (b).

Fig. 3.18 (a) Cable drums are placed in an open area (b) Cable drums are placed in the shaded area (relevant Figure)

2. If there is requirement to store the cable drums in the open area, then, it should be placed on flat and hard surface, and should be moisture free. This will less harm the wood of the cable drums. In addition, it will avoid the generation of harmful insects in the wood as shown in Figure 3.19.

Fig. 3.19 Cable drum placed on hard and flat surface

3. At the time of heavy rainfall, cover the cable drums by polythene. The drum moisture content should not more than 25%. To protect the drums from these situations in-house storage prefers as shown in Figure 3.20.

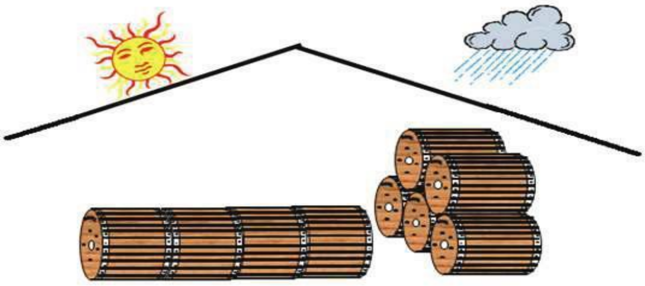


Fig. 3.20 Protection of cable drum from the sun and heavy rainfall

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 damages due to improper handling and check the attenuation level of the signal in the cable.

2. Make sure that specification and information about the cable size and its type must be clearly mentioned on the flange of the cable drum.

3. Specification on the flange include the information such as cable manufacturer name, cable length, cable type, bend radius as shown in Figure 3.21.

Fig. 3.21 Information about cable, printed on cable drum

4. Check drums for the above points as per plan before dispatching it to the installation site.

3. If any fault or mismatching observed in the information printed on the flanges of cable drums, then immediately propose a request for the replacement of a particular 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 strip 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 cable.
3. Carefully, cut the iron strip-using cutter.
4. Put the screwdriver in the gap of batten, and press it down to remove the batten from the flange.
3. Remove batten carefully without damaging the OFC.
6. Remove thermal wrapper applied over the cable.

CABLE INSPECTION

After inspecting the cable drum and relevant information imprint 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, inform the supplier.
3. Locate the inner and outer end of the OFC.
4. Check that there must be cable cap at the 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 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 natural payoff direction is towards the pulling direction.
3. When there is sharp turn at the time of cable laying, it is tough to pull the cable. In such case, make a chamber at the turning point. First pull the cable from one side, and then, feed the cable in another side as shown in Figure 3.22.

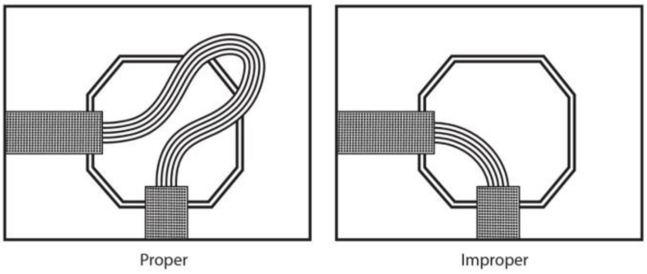


Fig. 3.22 Proper and improper bending of optical fibre cable

Assignment 1

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

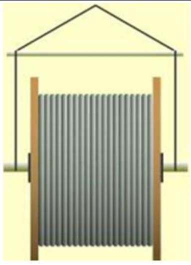
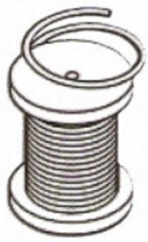
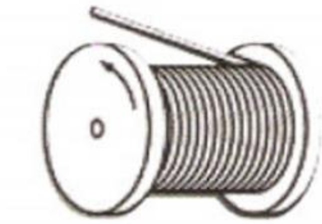
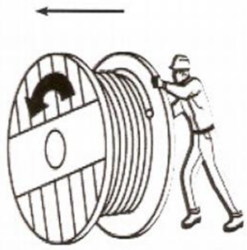
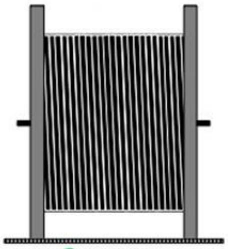
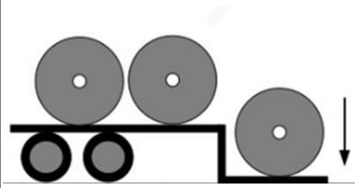
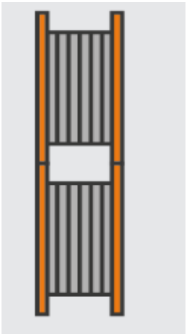
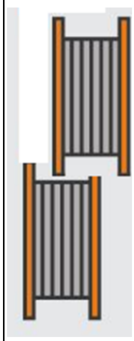
	Correct or incorrect		Correct or incorrect
 Fig. 3.23		 Fig. 3.27	
 Fig. 3.24		 Fig. 3.28	
 Fig. 3.25		 Fig. 3.29	
 Fig. 3.26		 Fig. 3.30	
 Fig. 3.31		 Fig. 3.35	
 Fig. 3.32		 Fig. 3.36	

 Fig. 3.33		 Fig. 3.37	
 Fig. 3.34		 Fig. 3.38	

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 bellow __________. (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 on to 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 tied up the cable drum on the truck? (a) Nails (b) Screw (c) Slings and Chain (d) None of the above
9. Which of the following term 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 material is used to manufacture the cable drum? (a) Plywood (b) Timber (c) Metal (d) All of the above

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 ______ 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, which 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 needs to be considered in storage area of cables?
4. What points needs to be considered while handling the cable drum?
5. List the specification and information printed on the flange of the cable.

Module 3 Cable Installation and Testing of OFC

Module Overview

In this Module Cable installation and testing of optical fiber cables (OFC) are critical processes in establishing reliable telecommunications networks. Installation involves several key steps, including planning the route, preparing the site, and physically laying the cables. Methods such as trenching, duct installation, and aerial mounting are employed based on environmental and logistical considerations. Proper handling and placement are essential to prevent damage to the delicate fibers.

Testing follows installation to ensure the integrity and performance of the network. Techniques such as Optical Time Domain Reflectometry (OTDR) are used to identify faults, measure attenuation, and verify the overall quality of the fiber. Additional tests include checking splice loss, fiber continuity, and signal strength. Accurate testing ensures that the installed network meets performance standards and operational requirements. Together, meticulous installation and thorough testing are crucial for ensuring a robust and efficient optical fiber communication system.

Learning Outcomes

After completing this module, you will be able to:

- Effectively install optical fiber cables following industry standards and best practices.
- Accurately test optical fiber links to evaluate performance, identify faults, and ensure compliance with specifications.

Module Structure

Session 1: Installation of Optical Fibre Cable

Session 2: Testing Optical Fibre Link

Session 1: Installation of Optical Fibre Cable

Installation of optical fibre cable (OFC) is most critical task. Splicer and team members will execute the plan of commissioning. They will complete the task and establish the OFC network. In the previous chapters, you have learned about the optical fibre communication, tools, equipment, site visit, 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 installation of OFC.

OPTICAL FIBRE CABLE INSTALLATION SPECIFICATIONS

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

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

1. Cable specification
2. Environmental specification

1. Cable specification

Cable specification is like a profile of cable. It contains the physical and technical information about the cable. Cable specification 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
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 bend. Higher the radius, greater will be the flexibility of the material. Cable does not perform the transmission of light as we bend the cable beyond the specified bend radius of cable. In this case light will be absorbed by the core and cladding as shown in Figure 1.1.

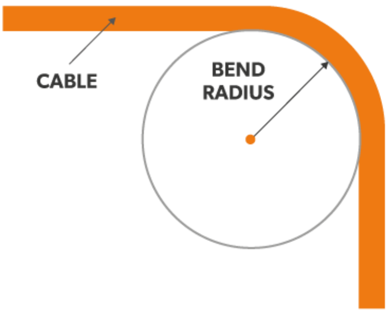


Fig 1.1 Bend radius

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 x 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 of OFC. At that time, OFC bears high tensile force on its surface. This may damage the outer layer of the cable. For this reason, manufacturer specifies the maximum tensile strength of 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 which 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 kind 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 a use of hammer

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

d) Impact Resistance – Action of one object coming forcibly into contact with cables is defined as impact on cable. Cable should be manufactured enough to bear this impact safely.

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

Environmental Specification – Environmental specifications must be met to ensure 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 load
g) High Flexibility
h) Resistance to solvents, petrochemicals, and other chemicals
i) Airtight sealed fibre
j) Radiation resistance

a. Temperature Range of Operation – In different area where fibre cable is going to be installed have different temperature and climatic condition. To ensure the proper internal working of OFC in these climatic conditions, manufacturer provides a range of operating temperature of fibre cable. Exceeding these limits of operating temperature may disturb the internal performance of the cable. Installer should go through the information sheet, which is prepared by cable manufacturer. Typical working temperature range of various applications are shown in the Table 1.2.

Table 1.2

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

c. UV Stability or UV Resistance – Mostly cables are to be placed or installed in the open environment. Then, it is necessary that cable should 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 feature.

d. Resistance to Damage by species – There are varieties of species in our environment. These species may damage the outer jacket of the OFC. Animal may bite the OFC. Sot it may be protected by modifying the construction. Now a days, advance OFC having amour in their outermost layer, protect 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 cable will be getting immersed into water, either permanently or for extended periods of time. 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 during installation. The long-term crush load is for during the entire life of the cable.

g. High Flexibility – As one knows that flexibility is the quality of bending easily without breaking similarly the high flexibility show high quality of bending. In some places there is a need of repetitive bending of OFC. For example, in military field, elevators, etc. Flexibility requirements must be met by both cable materials and by fibres.

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

i. Airtight Sealed Fibre – In applications requiring exposure of the cable to very high-water pressures or high temperatures, the fibre must be airtight sealed to retain its mechanical strength and/or its low attenuation. Airtight sealing is required because contact with moisture (or other chemicals) results in 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 one intends to use a OFC in an environment subjected to ionizing radiation, such as in the core of a nuclear power plant, outer space, or an x-ray chamber, you must 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 ionizing radiation.

INSTALLATION METHOD

In our daily life, everyone is directly or indirectly is a part of wide network. Technology is getting advance day by day. It has increased the data speed and security features in the mobile and computing network. The heavy demand, speed and security features can be provided by optical fibre technology. Optical fibre splicer play a major role in expanding and maintaining the optical fibre network. After the completion of site visit and route inspection, the authorities approve the survey report. The optical fibre splicer then perform installation, testing, troubleshooting, documentation, and restoration of OFC. Installation methods of OFC can be categorized into two ways: (a) a. Underground Installation, and (b) Aerial Installation.

a. Underground Installation

It is also known as trenching method. It is planned process, as number of factors has to be considered, while performing the installation. 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 as shown in Figure 1.2. It is a process to make an underground way for cable placing.

Fig. 1.2 Trench

Trenches can be formed using two methods namely manually using hand tools or by using excavation machineries. If there is a requirement to perform excavation for longer distance using a machinery. Such type of excavation is known as ploughing as shown in Figure 1.3 (a) & (b).

Fig.1.3 (a) Trenching using hand tools (b) Trenching using machinery

After digging, it should be inspected and verified. There should not be any rocks, 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 of more obstacles are present and normally at urban and sub-urban areas for laying OFC as shown in Figure 1.4.

Fig.1.4 Men making the trench in urban area

Points to remember

- Hazardous climatic conditions can also harm the worker. Deficiency of oxygen takes place at some critical workplace may create a breathing issue.
- Gases such methane, carbon monoxide, carbon-di-oxide can cause poisoning, suffocation or death.
- Material and objects can fall in the excavated portion, this can cause serious injuries, it may strike to a worker working in the trench.
- Material such as dirt, rock, stones, including objects such as tools, pipes, and other equipment must be kept 2ft from the place of excavation to avoid any accident.
- Water accumulate in the excavation during rainy season or leakage in water pipe. This will weaken the excavation wall makes them unstable. This will cause hazards to the worker.
- Water must be kept away or pump out of the trench.
- Worker must not stand in the water-logged trench.
- Damaged underground utilities can expose work to the hazard can cause the electric shock if an underground electric cable is struck, or may cause explosion, if gas pipe line is struck, or water logging if water pipe line is struck.
- Prior to digging it is requiring to make a contact to the local utility owner. Mark the area of gas pipeline, water pipeline, underground electric cable. This will make easy while making the trench.
- 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 in maximum speed, trenching width and depth will not go over requirement.

Practical Activity 1 – Demonstrate the way of making the trench.

Material Required

Trenching machine, labour, shield, excavation equipment.

Procedure

Step 1. In initial stage of making the trench, team members must inspect the soil of trench Figure 1.

Fig.1 Testing the type of soil

Step 2. Test will determine the soil type, refer the table 1.

Table 1: Type of soil and their stabilization level

Type of Soil	Level of stabilization
Type A	Most stable type of soil for making trench
Type B	Next stable type of soil for making trench
Type C	Least stable type of soil for making trench

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

Step 4. Generally, trench will form up to the depth of 4ft.

Step 5. Start making a trench using slope, bench, and shield to avoid the collapsing of sidewall as shown in Figure 2.

Fig. 2 Shielding of trench

Fig. 3 Slope in the trench

Fig.4 Bench in the trench

Step 1. These practices will avoid the collapsing of the sidewall.

2. Duct Placement – It is a placement of hollow tubes in the trench. Duct helps in pulling of 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 characteristic of soil where installation is being done. They are made-up of different materials such as concrete, plastic, metals.

Fig. 1.5 Duct made up of concrete is placed to pull the optical fibre cable (Add more image)

3. Cable Placement – At the time of installation of OFC, cable tension is the 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, 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 1.6 shows placing the cable in the trench.

Fig. 1.6 Placing the cable in the trench

Figure 1.7 shows the wrong way to place the cable. Fig. 1.8 shows the correct way to place the cable in pattern of eight.

Fig. 1.7 Wrong way to put the optical fibre cable on the floor

Fig.1.8 Right way to put the optical fibre cable on the floor

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

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

Practical Activity 2 – Demonstrate the cable placement in the pattern of figure of eight.

Material Required

OFC of length 100 feet, hand gloves

Procedure

Step 1. Arrange for an open and flat surface area.

Step 2. Wear hand gloves for protection from OFC.

Step 3. Now, place a cable drum on the cable stand figure 1.

Fig.1

Step 4. Start pulling the optical fibre cable Figure 2.

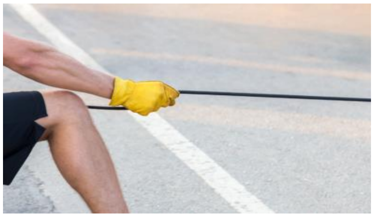


Fig. 2

Step 5. First keep the cable to be pulled from the drum on the ground surface in a circular pattern.

Step 6. If you pull the cable in this circular pattern, it will be entangled.

Step 7. Repeat the step 4. Place the optical fibre cable in the pattern of eight. If you pull the cable it will not be entangled.

Fig. 4 Right way of placing the cable

Step 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 of 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, cable blowing.

(a) Cable Pulling – In some situation, hand-pulling method can be used to place the optical fibre cable for short straight path in short straight path. To do so, cable strengthen member is tie to the pulling rope. Then, slowly optical fibre cable will be pull through the duct Figure 1.9.

Fig. 1.9 Cable Puller machine and pulling rope

In this operation, pulling machine can also be used. This pulling method is generally preferred where underground ducts are not continuous for more than 200 to 300 meters.

Fig. 1.10 Pulling machine pulling the optical fibre cable

Under this condition, there will be manholes to pull the cable. At each manholes, an extra bunch of optical fibre cable is left. Figure 1.11 shows bunch of optical fibre cable in the manhole.

Fig. 1.11 Optical fibre cable kept in manhole in the form of coil

Hence, optical fibre cable installation into a duct using a pulling method is suitable to apply for short distance as shown in Figure 1.12.

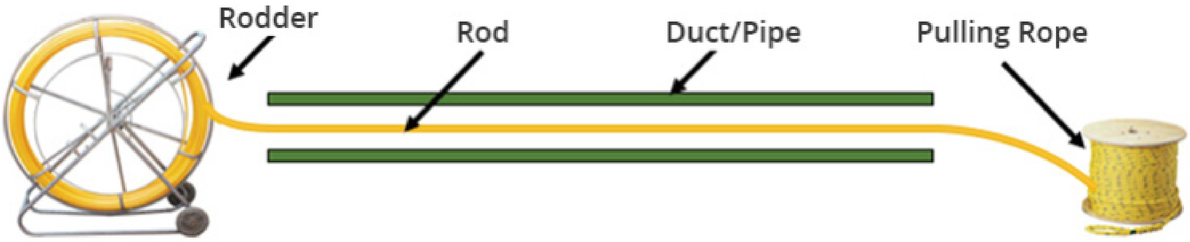


Fig. 1.12 Pulling the optical fibre cable using a rope

(b) Cable Blowing – In this type of installation method, an OFC is feed 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 is applicable to continuous lengths of more than 1000 meter. Figure 1.13 shows the concept of air blowing method.

Fig. 1.13 Air Blowing Method

5. Cable Termination and Splicing – This is the last stage of the underground cable laying process. Termination refer to an end. Therefore, cable termination is the point, where optical fibre network ends. At the terminating point of cable, cap is placed to protect core and cladding from the damage. Route markers and warning tape are used to protect the underground cables from future excavation as shown in Figure 1.14. Underground cable will be buried under a standard depth to avoid the accidental damages.

Fig. 1.14 Route marker and warning tape on the ground surface

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

Practical Activity 3 – Prepare optical fibre cable for splicing.

Material Required

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

Procedure

Step 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.

Step 2. The Kevlar can be trimmed using scissors or Kevlar cutters.

Step 3. Clean, the jelly on buffer tubes with isopropyl wipes.

Step 4. The cable should be fixed in the enclosure according to the recommendations of the manufacturer of the splice enclosure.

Step 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.

Practical Activity 4 – To perform the fusion splicing using electric arc.

Materials Required

Optical fibre cable, Splice machine, Optical Fibre cleaver, Tissue paper, Alcohol, Protection sleeves, Round tube cutter, Fibre stripper.

Procedure

Step 1. Concider a damaged OFC, as shown in Figure 1 for splicing.

Fig. 1 Damaged optical fibre cable

Note: Read the specification printed on the outer coating of OFC. Customize splice machine setting as per its mode (single or multimode).

Step 2. Break the fibre at damaged area into two parts using pliers shown in Figure 2.

Fig. 2 Breaking damaged fibre using plier

Step 3. Now, prepare each end perfectly, so that both broken parts of the fibre can be spliced perfectly without any losses. Figure 3 shows two parts of cable to be prepared for splicing.

Fig. 3 Two ends of fibre cable which is to be splice

Step 4. Now, take one broken parts of fibre cable out of two parts. Take a round cutter and put the fibre inside its jaws at a distance of around 3 to 5 inches away from the cable end to remove its jacket and coating part. Rotate it twice or thrice around the cable. A round cut mark is formed on the cable. Now push the jacket with hand finger towards fibre end to remove it as shown in Figure 4.

Fig. 4 Working of round cutter on the fibre

Step 5. Now, take a tissue paper with little alcohol poured on it to clean the jelly above the bunch of fibre shown in Figure 5.

Fig. 5 Removal of the jelly around bunch of fibres with tissue paper

Step 1. Take any one fibre. This fibre is now used for splicing.

Note – As you have learned the fusion splicing, you have to consider only one fibre out of multiple. But, in actual practise all fibre needs to be spliced in the same way.

Step 7. Take a protection sleeve and put the chosen single fibre inside it. Move it around 5 inches backward from the end of the fibre as shown in Figure 6.

Fig. 6 Placing protection sleeve inside the fibre

Step 8. Take the stripping tool and put this single fibre inside its first slot. This will remove the buffer and now you have left with cladding as shown in Figure 7.

(a)

(b)

(c)

Fig. 7 (a) Stripping the buffer of optical fibre cable using optical fibre stripper, (b) Stripped fibre, (c) Cleaning the cladding using tissue paper

Step 13. Now, cut the edge of cladding using precision cleaver. Fibre in the machine is kept horizontally and the machine blade cuts the fibre ends vertically.

Precaution – Don't place your finger inside the cutter

Step 14. Take other fibre and repeat the same steps to prepare the fibre.

Step 15. Now, take fusion splice machine, open its cover place both the fibres in fusion splice machine as shown in Figure 8.

(a)

(b)

(c)

Fig. 8 (a) Fusion splicing machine, (b) Placing the first fibre in fusion splice machine, (c) Placing the second fibre in fusion splice machine

Step 11. The machine has two steps of operation. Firstly, it aligns the cores of the two fibres to be joined and then the two electrodes inside it performs fusion of the fibre as shown in Figure 9.

Step 17. Now, open the wind protector. Place the spliced fibre with protection sleeve above 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.

Fig. 9 Display unit shows the splicing operation going inside the fusion splice machine

Practical Activity 5 – Demonstrate mechanical splicing of optical fibre cables.

Materials Required

Optical fibre cable, Optical fibre mechanical splicer connector, optical fibre cleaver, Tissue paper, Alcohol, Protection sleeves, Round tube cutter, Fibre cutter/stripper.

Procedure

Step 1. Follow the steps from 1 to 7 of Practical activity 3 for doing mechanical splicing. Only difference is that protection sleeve and method of heating the end of the fibre is not applied.

Note: Heating or electric arc is not used in mechanical splicing.

Step 2. Take a stripped optical fibre placed it in a ferrule. Ferrule is a capillary glass tube under compression with the help of a spring.

Step 3. Inside the ferrule the fibre is properly inserted into the sleeve as shown in Figure 1 and 2.

Step 4. Index matching gel is placed inside the mechanical splice apparatus. This gel helps to couple the light from one Fibre end to other.

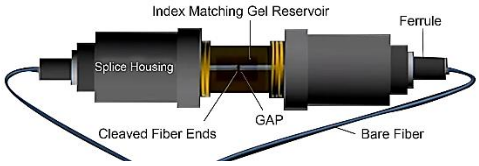


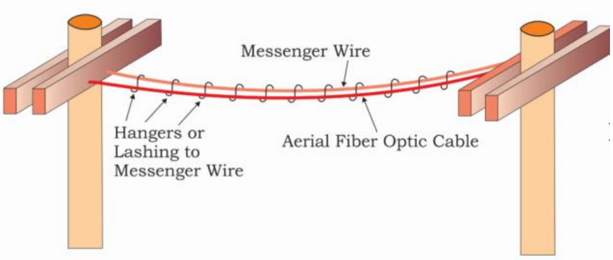
Fig. 1 Mechanical splicing housing

Fig. 2 Mechanical connector

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

b. Aerial Installation – The word aerial defines operating in air, or we can say that operating above the ground. This optical fibre installation method is common now days as shown in Figure 1.15. Aerial method is also known as pole-to-pole installation. To adjust 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 the nature and man-made damage or theft. The aerial cable laying method is not hard to implement as it can utilize the existing overhead pole line to install. This will save the constructional cost and installation time.



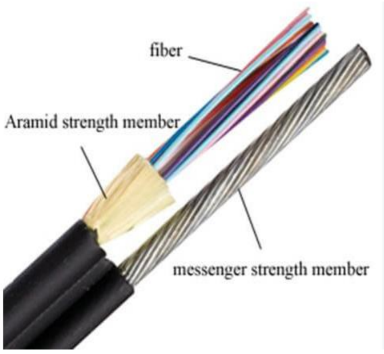


Fig. 1.15 Aerial cabling method

Aerial cabling is easily affected by the natural disasters, such as storm, 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 the underground optical fibre cables.

Threr are two common methods for aerial installation of OFC – (i) Moving Reel Method (ii) Stationary Reel Method

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 cable, how to move the installation vehicle must be clear. Figure 1.16 shows a typical moving reel method.

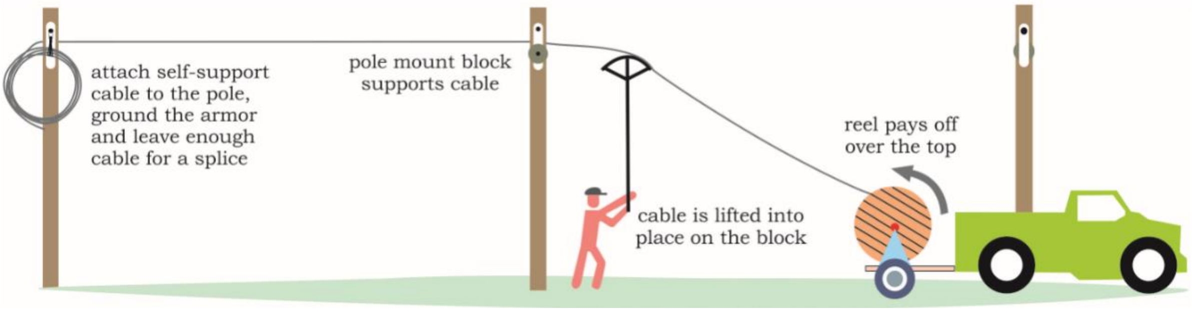


Fig. 1.16 Moving reel method of aerial cabling

2. **Stationary Reel Method –** This method contains three steps namely cable rolls set-up, pulling set-up, cable block placement

(a) Cable Rolls Set-Up – Cable roll should be positioned in-line with the pole. A cable roll must be kept at some distance from the pole. This distance will be twice the height of the pole as shown in the Figure 1.17. Place protective barriers and cones as needed to protect pedestrians.

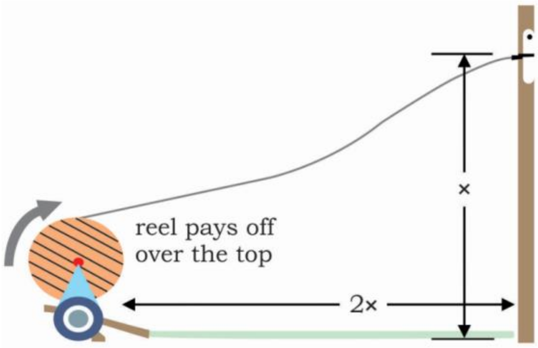


Fig. 1.17 Cable rolls Set-Up

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

Fig. 1.18 Swivel for cable pulling

(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 the Figure 1.20. Typical, cable blocks are shown in Figure 1.19.

Fig. 1.19 Cable blocks

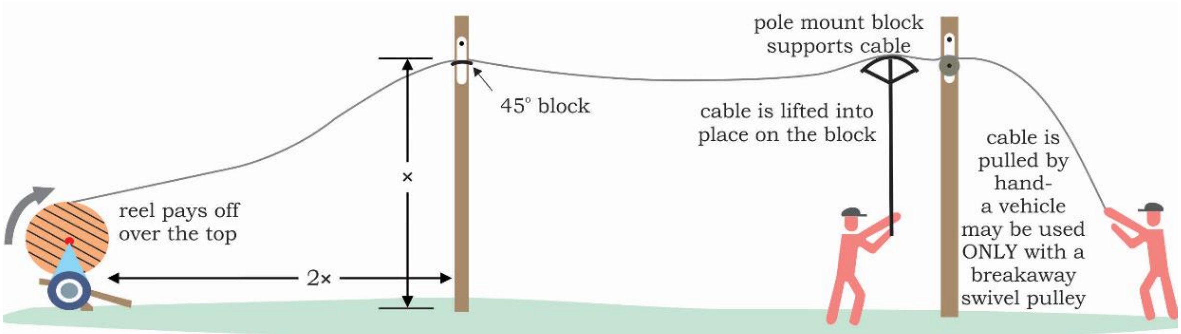


Fig. 1.20 Cable Block Placement

Cable Termination and Splicing

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

SPLICE TRAYS

They are used to hold and protect individual fusion or mechanical spliced optical fibre cable. The splice tray should be matched to the type of splice used. For example, a splice tray designed to house a mechanical splice fibres will not hold a 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.

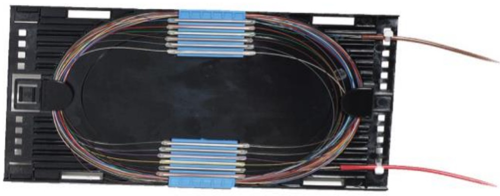


Fig. 1.21 Splice tray

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 Activity 6 – Installation of the optical fibre cable in a splice tray

Material Required

Spice Tray, Optical Fibre Cables, Tools of Fusion Splicing.

Procedure

Step 1. Take a splice tray as shown in the Figure 1.

Fig. 1 Splice tray

Step 2. Consider, loose buffers inside a cable of different colors say orange and blue. Place them in a tray, as shown in Figure 2 and Figure 3.

Fig. 2 Placing the cables of different colours in splice tray

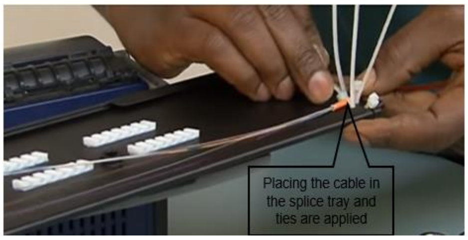


Fig. 3 Placing the cable in splice tray and ties are applied

Step 3. Route fibres into splice tray as shown in Figure 4.

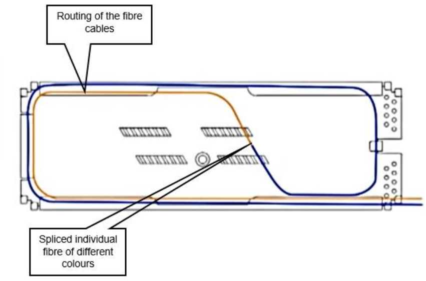


Fig. 4 Routing of fibre in splice tray

Step 4. Spliced fibres and put the protection sleeve over it as shown in Figure 5.

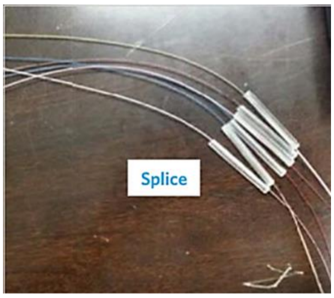


Fig. 5 Spliced fibre

Step 5. Place spliced fibre into the sleeve holders arranged by colour code as shown in Figure 6.

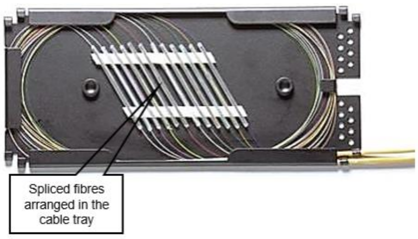


Fig. 6 Spliced fibre arranged in the cable tray

Step 1. In this way, following the steps from 1 to 6 arrange the spliced cables in the tray and tied together shown in the Figure 7.

Fig. 7 Multiple spliced tray arranged and tied together in enclosure

SPLICE ENCLOSURES

Splices trays requires 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 as shown in Figure 1.22.

Fig. 1.22 Optical fibre Splice inside an enclosure

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

1) Horizontal Splice Enclosure – Horizontal type enclosure looks like a flat or cylindrical case as shown in Figure 1.23. They provide space and protection for OFC splicing and joint. They can be used for aerially, buried, or for underground applications.

Fig. 1.23 Horizontal type splice enclosure

2) Vertical Splice Enclosure – Vertical type enclosure looks like a dome; hence, they are also called dome type enclosure as shown in Figure 1.24. They are similar to the horizontal type enclosure.

Fig. 1.24 Vertical splice enclosure

Once, the fibre tray is placed in the enclosure with 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 & connectors and cable connections together in a single unit. It can also work as a protective device to protect optical fibre connections from damage (Figure 1.25).

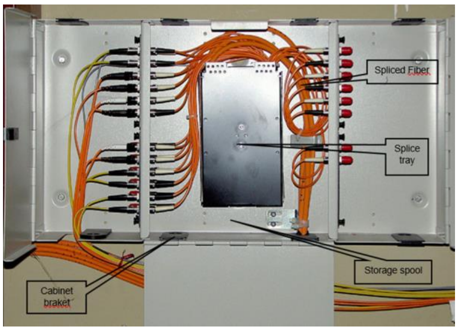


Fig. 1.25 Optical Fibre Distribution Frame (FDF)

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 design like a small box, which can be installed on the wall and is suitable for fibre distribution with small counts as shown in Figure 1.26.

Fig. 1.26 Wall Mount Optical Distribution Frame

2. Floor mount FDF consists of the box and distribution board. It is designed with firm structure to mount on the floor. Side holders making it possible to mount the FDF on the floor as shown in Figure 1.27.

Fig. 1.27 Floor Mount Optical Distribution Frame

3. Rack mount FDF is usually modularity in design with firm structure as shown in Figure 1.28. It can be installed on the rack with more flexibility according to the OFC counts and specifications.

Fig. 1.28 Rack Mount Distribution Frame

Reporting and Documentation

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

The installed optical fibre network of a premises 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 & 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 end user.
- After the installation, if there is any repositioning of equipment the documentation will helps 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 has done.
- Optical fibre type & 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 the test results.
- OTDR test results will be stored separately for the maintenance purpose in future. It can be printouts or in digital format. The digital data file should be stored in database in an arranged manner to make the maintenance easy.

All the cable drum should be marked with type, installation method to be followed, 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 individual 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 cable go, distance between access points, the areas in which installation take more time and many more. Testing information gives the way to find out the degradation overtime.

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

- Documentation of data's in plant location is very essential.
- Databases 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 teams to review.
- Ensure it is available to all the authorities for review.

Following reports should be filled regularly.

- Report on the status update
- Pending issues
- Challenges
- Faults & 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
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. Range of temperature for military operation 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 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 procedures include _____ and _____.
5. Trenching can be performing using ________.
6. Jacket of OFC can be damage 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 maintenance of 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 the installation using an air blowing method?
5. Explain the aerial OFC installation procedures?
6. How the conduct is done using the figure 8 'ing'.
7. How the trimming of 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

Session 2: Testing Optical Fibre Link

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

TESTING OPTICAL FIBRE

Testing is employed 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. Testing confirms their performance, specifications. However, testing is going to check the performance of optical fibre parts, cables and systems. In order to observe the installed system, installation team frequently take feedback and test 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 depends on the geographical nature of installation site and actual layout of the OFC.
4. Lot of time and money can be saved, if the installation team knows the correct signal strength which is to be measured in installed OFC.
5. To verify the correct input and output state of OFC, technician 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, Optical Time Domain Reflectometer (OTDR).

a. Visual Fault Locator – It is an equipment used to visually inspect the fault and leakage of light in the OFC. Let us understand the working of visual fault locator using the Practical activity 1.

Practical Activity 1 - Identify faults using visual fault locator (VFL).

Material required

Visual fault locator

Procedure

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

Fig. 1 Different parts of visual fault locator

Step 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 2.5mm diameter universal adapter is used as shown in Figure 2.

Fig. 2 Adaptor of visual fault locator

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

Fig. 3 Battery slot of visual fault locator

Step 4. Last one is switch, this switch has three mode namely OFF, Continuous Wave (CW) and Glint as shown in Figure 4.

Fig. 4 Three modes of visual fault locator switch

Step 5. In OFF mode, light will not appear.

Step 6. In Continuous Wave (CW) mode, continuous beam of light will come out.

Step 2. 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 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

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

Fig. 1 SC-connector cleaner for 2.5mm diameter

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

Fig. 2 SC-connector connected to the VFL

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

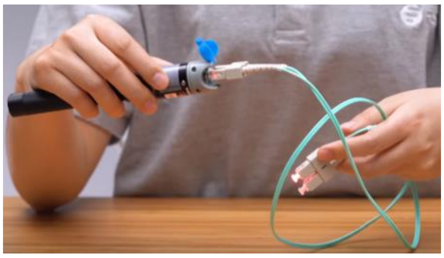


Fig. 3 Light travel from one end to other in SC-connected optical fibre cable

Step 5. Consider an optical fibre with LC connector. Clean, the connector using 1.25mm LC cleaner.

Step 6. As you have learned in Practical Activity 1, VFL adapter diameter is 2.5mm to connect the VFL adapter to LC-connector, which is of diameter 1.25mm interfacing adapter is used as shown in Figure 4.

Fig. 4 2.5 mm to 1.25mm adapter connected to VFL

Step 2. This adapter will convert the VFL 2.5mm diameter to 1.25mm diameter as shown in Figure 5.

Fig. 5 2.5mm to 1.25mm adapter

Step 8. After cleaning the LC-connector, connect the VFL to LC–connector of OFC as shown in Figure 6.

Fig. 6 LC-connector cleaner for 1.25mm diameter

Step 9. Turn on the VFL, observe the light coming out of the end of OFC. If this happens, it shows that the OFC has no damage as shown in Figure 7.

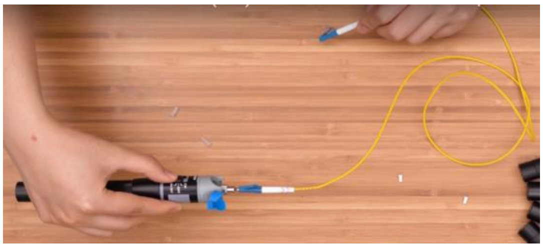


Fig. 7 VFL connected to the LC-connected OFC

b. Inspection Microscope – It is an 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 Activity 3 – Demonstrate the parts and functions of inspection microscope.

Material Required

Inspection microscope

Procedure

Step 1. Consider an inspection microscope. Observe its various parts such as connector adapters, eyepiece, and switch.

Step 2. Start with connector adapter. They are detachable as per the requirement of optical fibre connector as shown in Figure 1.

Fig. 1 Adapter in microscope (a) SC adapter (b) LC adapter

Step 3. Eyepiece has a lens and is used to focus inside the OFC. Focus of lens can be adjusted using the knob on the microscope as shown in Figure 2.

Fig. 2 Adjustable knob of the lens

Step 4. Pressing the switch of inspection microscope will turn it 'ON'. This will provide an image of optical fibre ends and connector ends.

Practical Activity 4 – Demonstrate the inspection of fibre and connectors ends using inspection microscope.

Material Required

Inspection microscope, optical fibre cable

Procedure

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

Fig. 1 Inserting the optical fibre cable into inspection microscope

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

Fig. 2 Adjustable screw of the microscope

Step 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.

c. Optical Time Domain Reflectometer (OTDR) – It is a measuring device in optical fibre system. It measures the various parameters of OFC such as splice loss, measure the cable length and locate the faults as shown in Figure 2.1.

Fig. 2.1 Optical time domain reflectometer

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 analyse the loss at connections and splices. OTDR traces are used for troubleshooting the faults 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 2.2 shows the photons that travels back toward the OTDR are considered as backscattered.

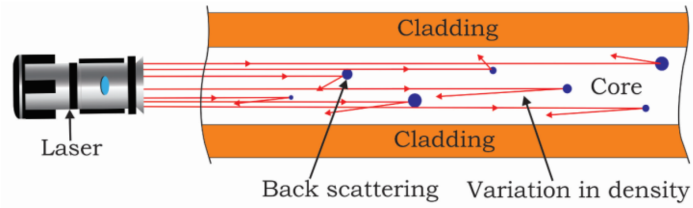


Fig. 2.2 Backscattered Photons

OTDR Operation – A typical OTDR includes eight basic components: the directional coupler, laser generator, time circuit, signal-board computer, Digital Signal Processor (DSP), analogy to digital converter, sample-and-hold circuit, and avalanche photodiode. Figure 2.3 is a block diagram of the OTDR showing light launched from laser through the directional coupler into the optical fibre. The directional coupler direct the light, which is returned by the optical fibre 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 convert 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.

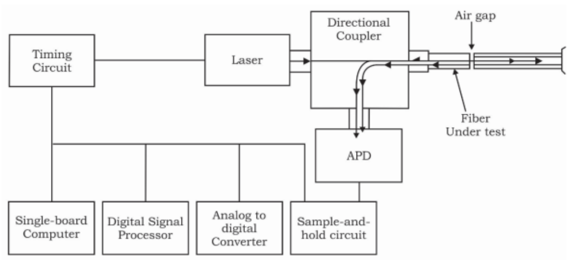


Fig. 2.3 Block representation of OTDR

OTDR Display – The OTDR shows the time or distance on the horizontal axis and amplitude on the vertical axis as shown in Figure 2.4. At horizontal axis, measuring unit is meters or kilometres, and dB (decimal) in vertical axis.

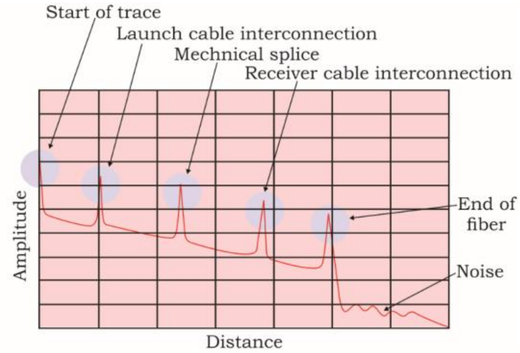


Fig. 2.4 Graphical display of signal in OTDR

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

Practical Activity 5 – Demonstrate the parts of OTDR

Material Required

Optical Time Domain Reflectometer, pen, notepad

Procedure

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

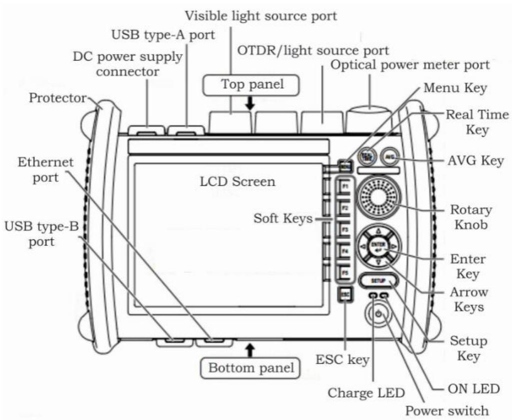


Fig. 1 Different parts of OTDR

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

Power Port – It is the slot through, which 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 – Charging indicator is used to indicate the charging status of OTDR. Power indicator is used to indicate the status of 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 option to control by 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.

Practical Activity 6

To measure the splice loss in optical fibre cable.

Material Required

OTDR, Optical fibre cable, notepad, pen

Procedure

Step 1. Consider an OTDR. Connect it with OFC.

Step 2. Consider, a spice joint in the OFC.

Step 3. Now, launch the light pulse into the OFC and observe the graph in the OTDR.

Step 4. Observe the splice loss in the graph. Trace it using OTDR as shown in Figure 1.

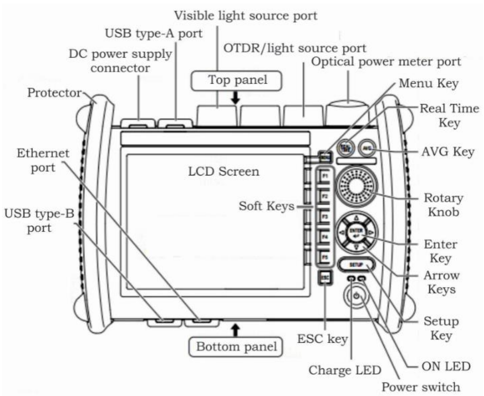


Fig. 1 Splice loss trace in OTDR

Step 5. Amount of light loss at the splice joint in decibel, is displayed by the OTDR.

Step 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 (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) Optical time domain reflectometer (b) Visual fault locator (c) Inspection microscopy (d) Connector
3. The word baseline trace or trace is a familiar term used in ____ instrument. (a) Optical time domain reflectometer (OTDR) (b) Visual fault locator (c) Inspection microscopy (d) Power meter
4. Splice loss can be determined using ____ Instrument. (a) Optical time domain reflectometer (OTDR) (b) Visual fault locator (c) Inspection microscopy (d) Power Meter
5. Which of the following instrument have the adjustable knob control? (a) Optical time domain reflectometer (OTDR) (b) Visual fault locator (c) Inspection microscopy (d) Power Meter
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 instrument has ethernet port connectivity? (a) Optical time domain reflectometer (OTDR) (b) Visual fault locator (c) Inspection microscopy (d) Connector
8. Which of the following function of 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 instrument term glint is used. (a) Optical time domain reflectometer (OTDR) (b) Visual fault locator (c) Inspection microscopy (d) Power Meter
10. In which of the following instrument term CW or Continuity Wave mode is used. (a) Optical time domain reflectometer (OTDR) (b) Visual fault locator (c) Inspection microscopy (d) Power Meter

B. Fill in the blanks

1. Visual fault locator has __________ modes.
2. In continuous mode of visual fault locator, light beam is __________.
3. Diameter of LC connector is __________.
4. Diameter of SC connector is __________.
5. Visual microscope uses ________ part to focus the optical fibre cable.
6. In visual microscope, adjustable ______ is used to align the optical fibre cable.
7. In optical time domain reflectometer, ________ is use to connect a memory device or USB printer.
8. In optical time domain reflectometer, ________ is use to connect the OTDR to the personal computer.

9. In optical fibre cable, reflection due to change in reflective index is known as _________.
10. In OTDR display, horizontal axis represents ________ and vertical axis represents ________.

C. State whether True or False

1. Amount of light loss in decibel is displayed by the OTDR.
2. Digital signal processing is not performed by the OTDR.
3. Two batteries of 10V is use 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 (c) Connector Cleaner (d) Inspection Microscope

Module 4. Health & Safety Measures

Module Overview

In this module, we will discuss about Health and safety measures are critical to ensuring a secure working environment, particularly in fields like optical fiber installation and electrical work. Key precautions include wearing appropriate personal protective equipment (PPE) such as insulated gloves, safety boots, helmets, and safety glasses to prevent injuries. Workers should avoid direct contact with live wires and follow proper procedures for handling electrical equipment to minimize the risk of electric shocks or burns.

Regularly inspecting tools and cables for damage, maintaining proper insulation, and using grounding techniques are essential for preventing accidents. Fire extinguishers must be readily accessible, and employees should be trained in their correct usage, especially for different fire types. In the case of emergencies like electric shock or fire, having first-aid knowledge, including CPR, is vital. Ensuring that safety guidelines are followed and ergonomics are considered can significantly reduce work-related injuries, promoting a healthier, safer workplace environment.

Learning Outcomes

After completing this module, you will be able to:

- Demonstrate the ability to identify workplace hazards, implement safety measures, and apply emergency procedures effectively.

Module Structure

Session 1: Occupational Health and Safety

Session 1. Occupational Health and Safety

The splical of optical fibre cable (OFC) work can expose to several workplace hazards. It includes the hazards ranging from laser light sources to ladders. Optical fibre splicer is responsible for their own safety as well as for the safety of co-workers. In this chapter you will understand the working environment in 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 encounter in the splicing workplace and different methods to work safely.

PERSONAL PROTECTIVE EQUIPMENT

The kind of Personal Protective Equipment (PPE) required around a machine will depend on the machine and the task performing by 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 1.1.

Fig. 1.1 Personal Protection Equipment (PPE)

Safety Helmets – The splicer technician must wear a safety helmet at the installation site as shown in Figure 1.2. It protects from being hit by any falling material or objects.

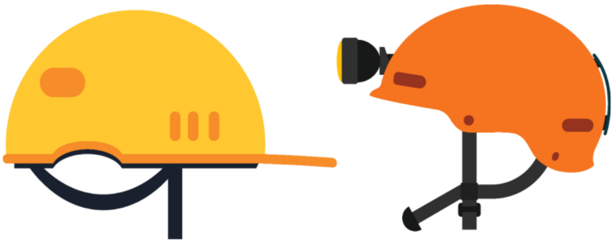


Fig. 1.2 Safety Helmet

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 look directly to the laser light, it will damage the retina. Impact of LASER light is shown in Figure 1.3.

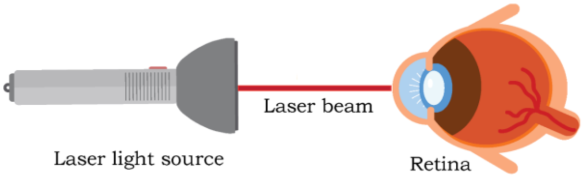


Fig. 1.3 Protection of light against LASER light

Whenever, technician is performing testing of OFC, it is necessary to wear safety glasses as shown in Figure 1.4.

Fig. 1.4 Safety glass or goggles

Respiratory Protection – Respiratory or dust masks as shown in Figure 1.5 are used to wear, when carrying out tasks that create inhalable dust or fumes, when handling certain chemicals or working in dusty environments.

Fig. 1.5 Respiratory or dust masks

Clothing – Do not wear loose clothes. Loose clothes like T-shirt, belt, unbuttoned jacket or even loose shoelaces, can stick up in moving part of machine. Hence, avoid wearing these types of clothes. Safety clothes are shown in Figure 1.6.

Fig. 1.6 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 1.7.

Fig. 1.7 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 is shown in Figure 1.8.

Fig. 1.8 Hand Gloves

Fibre particles can become lodged in clothing and can later get into food, drinks, and be ingested by other means. A coat also insures clothes protection from small particles is shown in Figure 1.9.

Fig. 1.9 Coat and Reflecting jacket for protection

Always use insulated tools as shown in Figure 1.10, while working.

Fig. 1.10 Insulated tools

CHEMICAL HAZARDS

If chemicals are storedi mproperly, there can be a possibility of chemical leak. So, place the chemicals at correct place to avoid any accident as shown in Figure 1.11.

Fig. 1.11 Improper storage of chemical

Mishandling of chemicals due to inadequate training or negligence as shown in Figure 1.12.

Fig. 1.12 Mishandling of Chemicals

Diseases and environmental illnesses can be caused by exposure to toxic substances at the workplace as shown in Figure 1.13.

Fig. 1.13 Exposure of toxic substance can cause illness

After a person has been exposed to chemical hazards at the workplace as shown in Figure 1.14, 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. 1.14 Read all labels imprint on the box to work safely

FIRE EXTINGUISHER

It is a basic protection device used to extinguish and controlling the fire. It is a cylindrical, having a pressurized gas or powder containing an agent, which is discharged to extinguish a fire. Fire extinguisher is shown in Figure 1.15.

Fig. 1.15 Fire extinguisher

Different parts of fire extinguisher are shown in the Figure 1.16.

Fig. 1.16 Parts of fire extinguisher

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

Step 1. Identify the safety pin of the fire extinguisher, which is generally present in its handle as shown in Figure 1.17. Pull the safety pin.

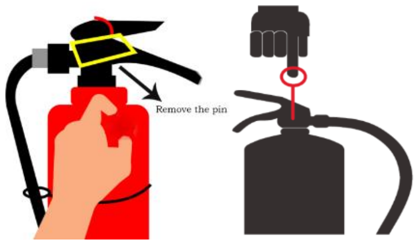


Fig. 1.17 Removing the pin

Step 2. Remove the seal from the handle as shown in Figure 1.18.

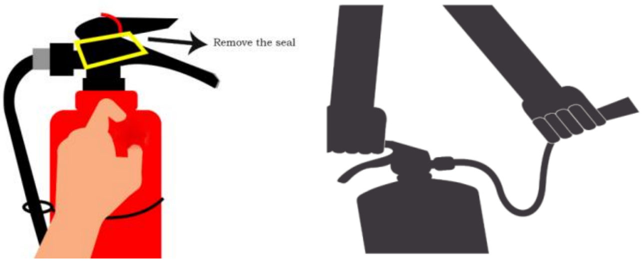


Fig. 1.18 Removing the seal

Step 3. Use the fire extinguisher by squeezing the lever and sweep it over the fire as shown in Figure 1.19.

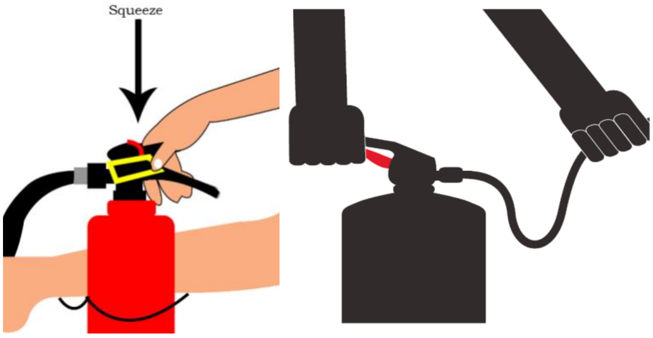


Fig. 1.19 Squeezing the handle

Depending up on the cause of fire, different fire extinguishers are used. Various types of fire extinguishers are as follows.

Class A – This type of fire extinguisher is used, when the cause of fire is paper, wood, cloth, plastic as shown in Figure 1.20.

Fig. 1.20 Class A type fire extinguisher

Class B – This type of fire extinguisher is used, when the cause fire is gasoline, grease, oil, and many more as shown in Figure 1.21.

Fig. 1.21 Class B type fire extinguisher

Class C – This type of fire extinguisher is used, when the cause of fire are electrical cables, wires, equipment and many more as shown in Figure 1.22.

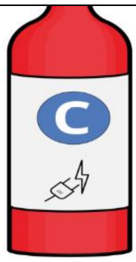


Fig. 1.22 Class C type fire extinguisher

Class D – This type of fire extinguisher is used, when the cause of fire is combustible metal as shown in Figure 1.23.

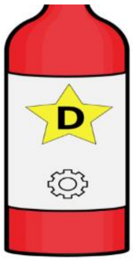


Fig. 1.23 Class D type fire extinguisher

Class K – This type of fire extinguisher is used, when the cause of fire are materials present in the kitchen as shown in Figure 1.24.

Fig. 1.24 Class K type fire extinguisher

FIRST AID

At the workplace site with cables, accident can cause many injuries. Injury can be minimized 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 is the major concern. When an accident occurs, due to the effect of muscle cramping, a victim is often incapable of moving or release himself/herself from the contact of live wire or electrical conductor. Caution should be primary consideration during any accident or emergency as shown in Figure 1.25.

Fig. 1.25 First aid kit

While, working around the electrical panel or during the installation of OFC adjacent to the electrical substations or transformers or electric poles, accident may occur resulting in an electric shock. In case of medical emergency, Cardiopulmonary resuscitation (CPR) can help to save life during a cardiac or breathing emergency. Steps to perform the CPR are shown in the Figure 1.26, 1.27, 1.21.

Fig. 1.26 Chest Compression

Fig. 1.27 Open the mouth for airway

Fig. 1.28 Rescue breathing

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

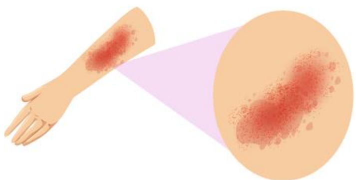
Site Safety – Many of the locations optical fibre components may be in areas that require special safety precautions. It may include construction sites, enclosed areas, locations near high-voltage power lines, or areas requiring access by ladder. Always follow the on-site safety requirements and observe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

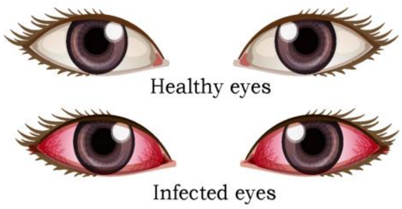
Materials Safety – Optical fibre splicing and termination uses various chemical cleaners and adhesives as part of the processes. Normal handling procedures for these substances should be observed. Always work in well-ventilated areas. Avoid skin contact as much as possible, and stop using chemicals that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

Know More.....

Primary treatments for exposure to isopropyl alcohol used to clean fibres or cables are present in Table 1.1.

Table 1.1: Primary Treatments for Isopropyl Exposure

Type of exposure	Isopropyl	
	Effect of exposure	Emergency treatment[1]
Inhalation  Fig.1.29 Inhalation	Irritation of upper respiratory tacks  Fig.1.30 Irritation	Move victim to area having fresh air. Perform artificial respiration, if breathing is irregular  Fig.1.31 Artificial respiration
Ingestion Fig.1.32	Nausea, Vomiting  Fig. 1.33 Vomiting	Give drinking water to the victim. Seek for medical assistance Fig.1.34
Contact with skin  Fig. 1.35 Reaction due to chemical on skin	Skin Irritation  Fig. 1.36 Irritation	Wipe off the affected area of skin and wash with the soap and water.  Fig. 1.37 Washing hands
Contact with eyes Fig.1.38	Eyes Irritation	Wipe eyes with plenty of water for 15 min

	 Fig. 1.39 Eye Irritation	 Fig. 1.40 Washing of the 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 optical fibre cable as it will going to 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 for using the fire extinguisher? (a) Identify the safety pin of 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 wall
4. When 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 is the safety items technician 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 unconsciousness 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 uses 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 body of affected person be kept in straight position and should be laid down on even spot.

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 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 first aid box.
5. Write down the steps for correct way of operating a fire extinguisher in case of a fire emergency.

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 from defects in the glass crystalline structure.

Acceptance Angle: Half the vertex angle of the cone within which light may be successfully coupled into a Multi-mode 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 for one channel of television needs atleast 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 : An protective acrylate/plastic coating 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 color coded tape in a cable or within a color coded plastic tube in a loose tube cable.

Center 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 center of all parts of the emitted spectrum.

Chromatic Dispersion : This is mainly a problem with LASER systems. 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 is having the 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 for providing 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 : Core of the fibre is made up of glass through which light propagates. It is having the 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 totally 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 term defined as spreading of light in fibre optics. In 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. Photodetector.

Frequency : The number of times in a second an electric signal or electromagnetic wave, completes a cycle

Ferrule : A tube which holds a Fibre for alignment. It is a 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 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 center of the core and decreases smoothly with radius toward the cladding.

Hardware: For Terminating the fibre and splicing the fibre hardware is required for protection and management 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. LED's 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, 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, jumpers between equipment and generally less than 3 meters long.

Ionizing 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. Jacket also called as buffer is used to protect the fibre from physical damages, 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 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. LED's emit light over wider angles and wider spectral widths than lasers.

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

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 um.

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 use 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 micrometers high and have periods of a few millimeters. They can occur due to coating, cabling, installation and 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 "Singlemode" fibres when operated at wavelengths below cutoff). Modal bandwidth arises because of the different arrival times of the various modes. Synonym for inter modal distortion.

Modal noise : Fluctuation in optical power because of the interaction of power traveling 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 Singlemode fibre whereas several hundred modes propagate in a Multimode fibre.

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

Monomode fibre : See Singlemode fibre.

Multi fibre 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 ionizing radiation : Electromagnetic radiation that does not turn an atom into an ion. Examples are visible light and radio waves.

Nonmetallic 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 propagate within the fibre.

Open : A broken fibre.

Optical Power : It is measured in "dBm", or decibels referenced to one mili-watt of power. While 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 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 characterizing a fibre. An optical pulse is sent down a fibre and the resulting backscattered light and reflected light back to the input is displayed as a function of distance on a screen. The instrument is useful for measuring fibre loss, 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 plant 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 use to couple light between it and another fibre.

Plug, connector : The cylindrical or conical ferrule portion of a connector with the fibre fastened inside.

Polarization : 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 traveling 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.

Polarization maintaining fibre : A Singlemode fibre that transmits light without changing its state of polarization. Synonym for polarization 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)

Preform : 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 sub atomic 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 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 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 nonmetallic 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 (SiO2) Silica exists in nature both in free form as in quartz and in combined form as in the 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.

Singlemode fibre: A fibre having a small core diameter and in which only one mode (the fundamental mode which may consist of two polarizations) 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 out side 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 0.04 and 0.4 tan.

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 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 plant.

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, dispersion is expressed in terms of wavelength. Wavelength is inversely proportional to the frequency of light. It means if frequency increases wavelength decreases and vice -versa.

Answer

Module 1. Fiber Optic Communication and Splicing

Session 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 200,000 km/s).

C. State True or False

1. (T) 2. (F) 3. (F) 4. (F) 5. (T) 6. (F) 7. (T)

Session 2. Splicing

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 to 1.0 dB/Km (2) 0.1 dB/Km (3) Splicing (4) The buffer coating (5) The splice

Module 2. Tools and Equipment and Route Inspection

Session 1. 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 6. LCD display 7. Inspection microscope 8. Light source 9. Dust 10. Loose tube

C. True or False

1. (F) 2. (T) 3. (T) 4. (T) 5. (T) 6. (F) 7. (T) 8. (F) 9. (F) 10. (T)

Session 2. 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. Armored fibre cable

C. State True or False

1. (F) 2. (T) 3. (T) 4. (T) 5. (F) 6. (T) 7. (F) 8. (T) 9. (T) 10. (F)

Session 3. 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

Module 3. Cable Installation and Testing of OFC

Session 1. 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 and testing 9. Friction 10. Mechanized trenching.

Session 2. 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 and signal strength (or attenuation in dB).

C. True or False

1. (T) 2. (F) 3. (F) 4. (F) 5. (T) 6. (T) 7. (T) 8. (T) 9. (T)

Module 4. Health & Safety Measures

Session 1. 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 3. CPR (Cardiopulmonary Resuscitation) 4. Class D 5. Electric shock.

C. True or False

1. (T) 2. (T) 3. (T) 4. (T) 5. (T) 6. (T) 7. (F)