Draft Study Material

विद्यया ऽमृतमश्नुते

एन सी ई आर टी
NCERT

OPTICAL FIBRE TECHNICIAN

(Job Role)

(Qualification Pack: Ref. Id. TEL/Q6401)
Sector: Telecom

(Grade XI)

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.

Deepak Paliwal
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Date: 19 September, 2024

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Module 1 — Fundamentals of optical fiber technology

Module Overview

In this module introduces students to the essential concepts of optical fiber technology, focusing on its fundamental principles and applications. Students will explore the structure, types, and properties of optical fibers, emphasizing their role in modern communication systems. The mechanisms of light transmission through optical fibers, covering key principles such as total internal reflection and the impact of various factors on signal integrity. Familiarize students with the different types of light sources, such as LEDs and lasers, and the detectors used in optical fiber systems, highlighting their significance in data transmission. By the end of the module, students will gain a comprehensive understanding of optical fiber technology, preparing them for advanced studies and practical applications in the field of telecommunications and beyond.

Learning Outcomes

After completing this module, you will be able to:

- Understand the structure, types, and applications of optical fibers.
- Grasp the principles of light propagation, including total internal reflection and factors affecting transmission.
- Differentiate between light sources and detectors used in optical fiber systems and their selection criteria.

Module Structure

Session 1: Basics of optical fiber

Session 2: Light propagation

Session 3: Light source and detector

Session 1: Basics of optical fiber

All of us know about the famous Hindi movie "sholay". One-day Ram's father announces at home that he wants to watch a "sholay" movie. Ram searches all channels in a television to see that if that movie is currently being played. But unfortunately, it was not so. Now, Ram downloads the "sholay" movie in fraction of minutes and he started playing movie on television. Naturally, Ram's father was very happy.

How this was possible for ram. This is possible because Ram's landline phone is providing the internet broadband services. The Landline cable is an optical fiber cable through which data at high speed can be downloaded. In this chapter, we are going to study about the telecom sector, role of an optical fiber technician, basics of optical fiber, need of optical fiber communication, advantages and disadvantages of optical fiber communication. In addition, we will discuss various applications of optical fiber.

TELECOM INDUSTRY

In this digital era, we are living in the fast growing world. Today technology is upgrading day by day. One of the developing sector is telecom sector on which whole communication system depend. Telecom sector includes mobile communication, satellite communication, TV and broadcasting, Optical fiber communication, cellular communication as shown in Figure 1.1. Advance technologies boosting the data transfer capacity of network. With invent of high data transfer medium one can see the match, which is played at different part of the world. This live streaming is possible because of the high data transfer capability of the medium. Innovation in carrying the data at high speed is greatly benefiting the telecommunication industry. Optical fiber is the fastest way to transfer the data. This is possible as data is transfer in the form of light and we know that speed of light is the fastest possible speed on the global.

Fig. 1.1 Applications of telecommunication (a) Mobile communication (b) Base-station of satellite communication (c) TV broadcasting (d) Cellular communication

CONCEPT OF COMMUNICATION

Communication is the process of transferring data or information from one end to other end. Communication must include three basic elements i.e. Transmitter, Receiver and Medium as shown in the Figure 1.2 (a) and (b).

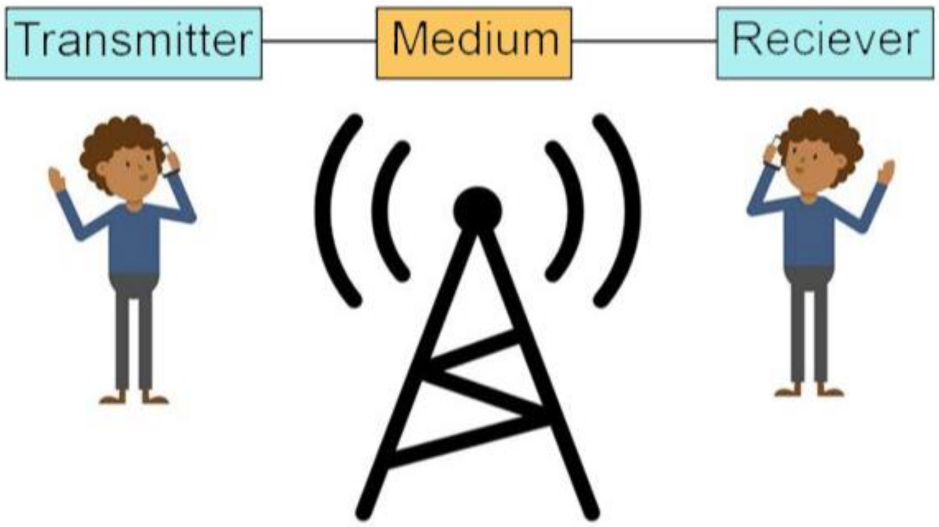


Fig. 1.2 (a) Elements of Communication System

Fig. 1.2 (b) In Indian Railways using walkie-talkie loco pilot is act as transmitter, guard act as receiver and medium will be air

Transmitter – It act as source, which generate information. It is responsible for sending the information. For example, if you are sending email to your friend via a computer then you will be the sender or your system will be the sending station or transmitter.

Medium – This is the virtual or physical path using which information will move forward. Medium also called as transmission medium. If transmission medium is optical fiber cable then it is known as optical fiber communication. For example, a LAN cable can be considered as medium, which connect one computer to other.

Receiver – It receives and retrieve back the information, which is send by the transmitter. The person for whom message is composed is the receiver. For example, recipient of your email will be the receiver.

ROLE OF OPTICAL fiber TECHNICIAN

fiber industry is one of the leading industry in the global. There is vast opportunities for a graduate to perform optical fiber installation and maintenance. Certification in the optical fiber technician can educate a person to establish the optical fiber network. Technician is also responsible for the maintenance of optical fiber network as shown in Figure 1.3. Now a days, optical fiber technicians works in industries. Optical fiber technician is a professional who works in the telecommunication industry. The main duty of the technician is to install and repair fiber optic cables. Optical fiber technology uses fiber cable for transmitting data. These fibers are composed of glass. For this reason, special training and guidelines are to be followed by the professional optical fiber technician. To install the optical fiber network, teamwork is required. Optical fiber technician must have employability skills to coordinate with the team members and client. Once the optical network is established, there is a requirement to maintain whole setup of optical network. This is equally important for a technician to identify the faults at different location and diagnose the identified faults. Technician also responsibly to calculate the link loss budget, which will define the overall estimated loss in the optical fiber network.

Fig. 1.3 Different role of optical fiber technician (a) Technician perform the route inspection and supervise trenching (b) Laying of optical fiber cable (c) Performing splicing (d) Fault identification and maintaining the optical fiber cable

TERMS USED IN OPTICAL fiber CABLE

1. Common terms in optical fiber communication

Signal – It is an electromagnetic representation of data.

Signaling – It is the act of propagating a signal over a suitable medium.

Frequency – the number of times in a second an electric signal or electromagnetic wave completes a cycle.

Mode – A single electromagnetic field pattern i.e. think of a ray of light that travels in fiber.

2. Terms used in optical fiber termination

Patch panel – Provides a centralized location for patching fibers, testing, monitoring and restoring cables as shown in Figure 1.4.

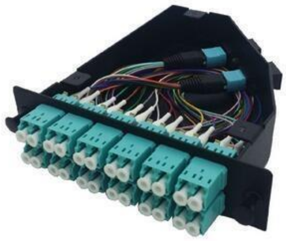


Fig. 1.4 Patch panel

Connector – A non-permanent device for connecting two fibers or fibers to equipment where they are expected to be disconnected occasionally for testing or re-routing. It also provides protection to both fibers as shown in Figure 1.5.

Fig. 1.5 Optical fiber connector

Ferrule – A tube, which holds a fiber for alignment, usually part of a connector

3. Terms used in optical fiber splicing

Mechanical Splice – A splice where the fibers are join by mechanical force as shown in Figure 1.6.

Fig. 1.6 Mechanical splice machine

Fusion Splice – A splice created by fusing two fibers together using electric arc as shown in Figure 1.7.

Fig. 1.7 Fusion splice machine

4. Terms used in optical fiber test equipment

Optical Power Meter– An instrument that measures optical power as shown in Figure 1.8.

Fig. 1.8 Optical fiber power meter

Optical Loss Test Set (OLTS)– it is a setup to measure the loss occurred in the fiber as shown in Figure 1.9.

Fig. 1.9 Optical loss test setup

Optical Microscope – Used to inspect the dirt inside the fiber and connector as shown in Figure 1.10.

Fig. 1.10 Optical microscope for dirt identification

Optical Time Domain Reflectometer (OTDR) – Optical time domain reflectometer is an equipment use measure the amount of reflection made in the optical fiber cable as shown in Figure 1.11. It also assist to calculate the loss in optical fiber cable.

Fig. 1.11 Optical Time Domain Reflectometer

5. Terms used in optical fiber measurement

Attenuation – The reduction in optical power as it passes along a fiber, usually expressed in decibels (dB).

Bandwidth – The range of signal frequencies within which a fiber optic network will operate.

Chromatic Dispersion – A property of optical fiber due to which different wavelengths travel at different speeds and arrive at different times, resulting in spreading of a pulse in an optical wave guide.

Decibels (dB) – A unit of measurement for optical power. A 10dB means a reduction in power by 10 times.

Optical Loss – The amount of optical power lost during transmission of through fiber, splices, couplers expressed in dB.

Optical Power – It defines the power of light, which is use in optical fiber communication.

Back Reflection – Light reflected from the terminal of optical fiber due to difference in refractive indices of air and glass.

Power Budget – The total amount of power lost in the link. It defines maximum loss occur in the optical fiber cable.

Refractive Index – It define speed of light in a material.

Wavelength – It is use to define the colour of light, it is expressed in nanometres (nm) or microns (m).

METRIC SYSTEM

Optical fiber technology utilizes the metric system as standard for measurement. Some of the common terms for measurement are meter, kilometre, micron, nanometer. fiber optic cable length are generally expressed in meter or kilometer.

(a) Meter– 3.28 feet, 39.37 inches.

(b) Kilometer– 1000 meters or 3281 feet

(c) Micron– One millionth of a meter. This is the common term of measurement for fiber diameters, most of which are 125 microns in outside diameter. For example, 25 microns equal 0.001 inch.

(d) Nanometer– One billionth of a meter. This term is commonly used in the optical fiber industry to express wavelength of transmitted light, e.g. 850 or 1300 nm.

OPTICAL fiber

Optical fibers are simple threads like human hairs. Optical fibers are made up of glass or plastic. The light propagates from one end to another end through these optical fibers. Figure 1.12 shows a typical metal wire carries the data in the form of an electrical signal. However, optical fiber cable carries a data in the form of digitally encoded signal.

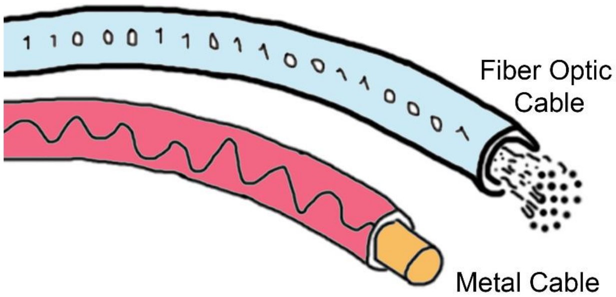
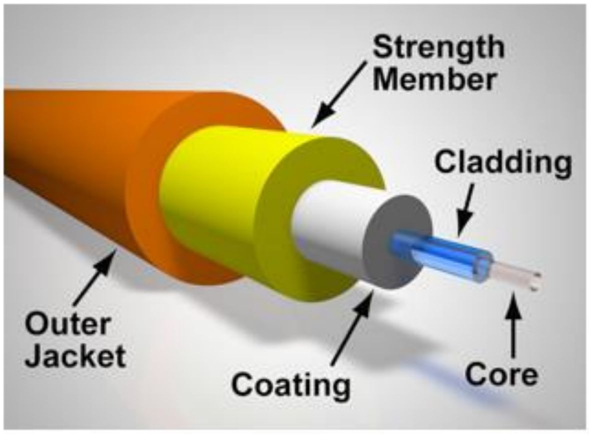


Fig. 1.12 Light as an output of optical fiber cable and electrical signal as an output of electrical cable

Table 1.1 shows the brief comparison between the optical fiber cable and electrical wire. This will help to under the strength of optical fiber cable in communication system.

Table 1.1 Comparison between optical and electrical cable

Parameter	**Optical fiber cable**	**Electrical cable**
Data or signal transmission speed	Very high	High
Spark hazard	No	Yes
Bandwidth	Higher	lower
Durability	High	Low
Cost	High	Cheap
Security	High	Low



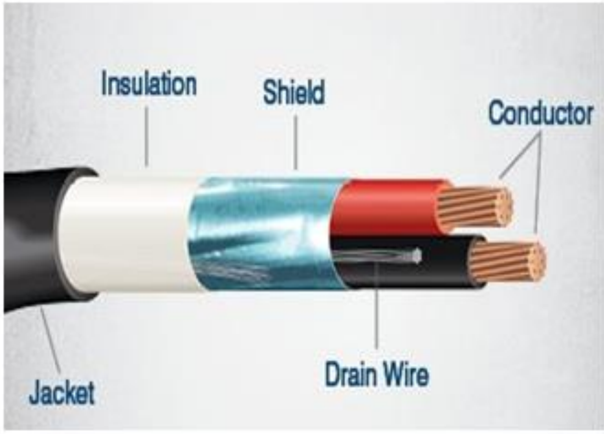


Fig. 1.13 Comparison between (a) Optical fiber cable (b) Electrical cable

Example-fiber optics are used for data transmission in high-level data security like fields of military, aerospace, aircrafts, hydrophones for SONARs.

Assignment 1

1. List down the different sectors where optical fiber are used.
2. Search on the internet, home appliances that utilises optical fiber.

BASIC STRUCTURE OF AN OPTICAL fiber

We have discussed that an optical fiber have thread like thickness. However, it is interesting to know about, its internal parts. Basic structure of an optical fiber will have following parts–

1. Core
2. Cladding
3. Buffer
4. Strength member
5. Jacket

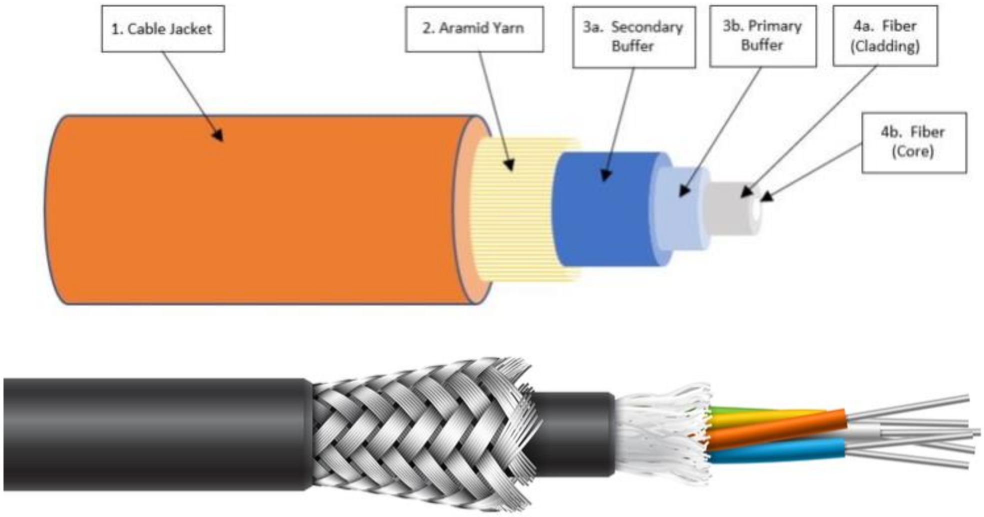


Fig. 1.14 Different layers in optical fiber cable

(a) Core – It is thinnest and innermost part of an optical fiber as shown in Figure 1.15(a) and (b). It is made up of glass. Through this core data travel from one end to another in the form of light.

(b) Cladding – It is the outer layer of optical material surrounding the core. It reflects the light back into the core. It helps to trap the light in the core using an optical technique. These techniques will discuss in the chapter 2. Figure 1.15 (a) and (b) shows structure of cladding in optical fiber cable.

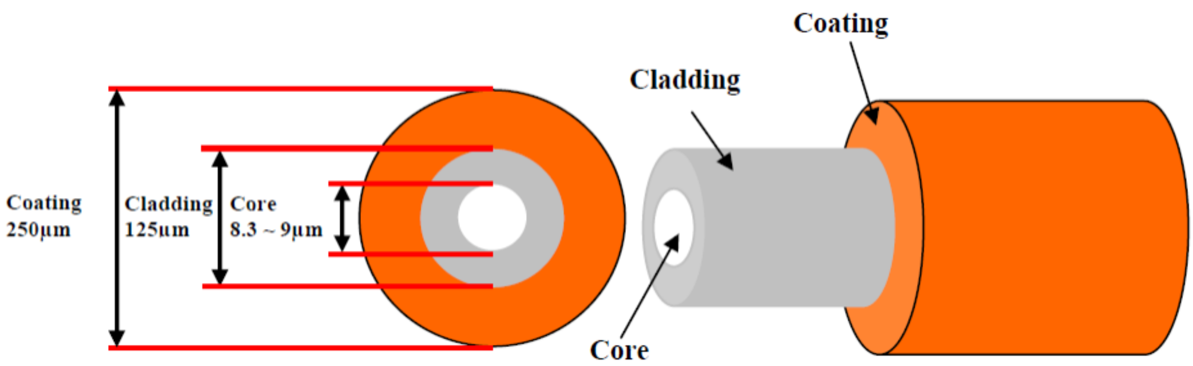


Fig. 1.15 (a) Cross sectional view (b) Side view of optical fiber cable

Core and cladding of optical fiber are available in different diameter. Some of the core and cladding mentioned in table 1.2.

Table 1.2 Core cladding diameter in different optical fiber cable

	Single mode optical fiber (Diameter in µm)	Multimode optical fiber-Step index (Diameter in µm)			Multimode optical fiber-Graded index (Diameter in µm)		
Core	8-6	32.5	60	600	50	32.5	85
Cladding	125	125	140	1200	125	125	125

c) Buffer – As we learned, core and cladding is the part through which light propagate in optical fiber. But, it is necessary to provide protection to the core and cladding from external and environmental damage. Buffer is one such layer, which provide this protection. It is made up of hard-plastic coating. Types of buffer are loose tube buffering, tight buffering.

Loose Tube Buffering – Loose tube buffering consist of a buffer layer that has a diameter much larger than the diameter of the fiber, as shown in Figure 1.16. In other words, it allow the fiber to move independently into the buffer. An optical gel is filled to protect the fiber from water. These are designed for harsh environment like dense forest, heavy rain falling area.

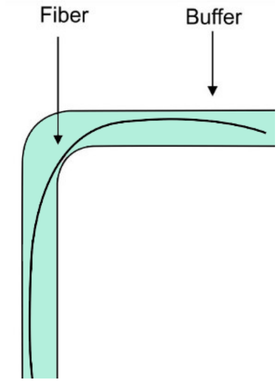


Fig. 1.16 Loose tube buffer

Tight Buffering - Tight tube buffering consists of a buffer layer in which optical fibers attached tightly as shown in Figure 1.17 and 1.18. In other words, it does not allow fiber to move independently into the buffer. Tight-buffered cable are mostly used for indoors.

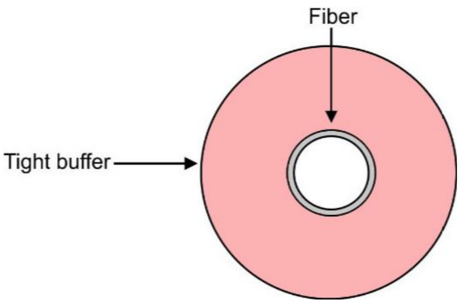


Fig. 1.17 Tight buffer uses buffer attached to the fiber coating

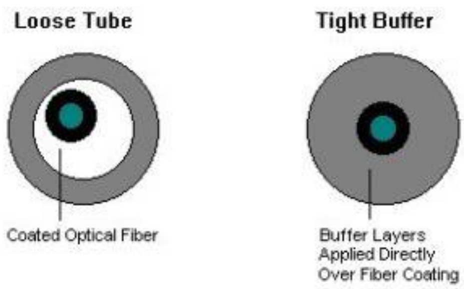


Fig. 1.18 Front view of buffer in optical fiber cable

d) Strength Members – In some extreme environmental condition, only hard plastic layer in buffer is not sufficient. For this an additive are also added to increase the tensile strength of optical cable. Strength members are those additive, which is between the buffer and the outer jacket as shown in Figure 1.19. It also protect the fiber against stretching and excessive bending. Materials like Aramid yarns, fiberglass are used for making strength member.

Aramid yarns – Aramid yarns are fibers made by chemical synthesis as shown in Figure 1.19. They are lighter, flexible, and fire-resistant. Aramid yarn usually known as Kevlar.

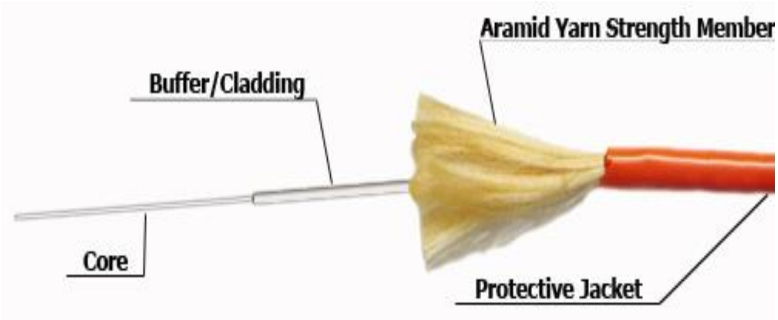


Fig. 1.19 Aramid yarns in optical fiber cable

Fiberglass – Fiberglass is made up of extremely fine fibers of glass. They are used to protect optical fiber from heavy load. fiberglass is shown in Figure 1.20.

Fig. 1.20 Epoxy rods

e) Jacket– Jacket is the protective layer over strength material of an optical fiber. This part must protect the fiber from the worst outside environment, including sunlight, ice, equipment accidents. Jacket are made of plastic material. Material that are used in the manufacturing of jacket includes Polyvinyl Chloride (PVC), Polyethylene, Polyvinyl di fluoride (PVDF). Some cables contain multiple layers of jacketing and strength members, as shown in Figure 1.21. In such cables, the outermost layer is known as sheath.

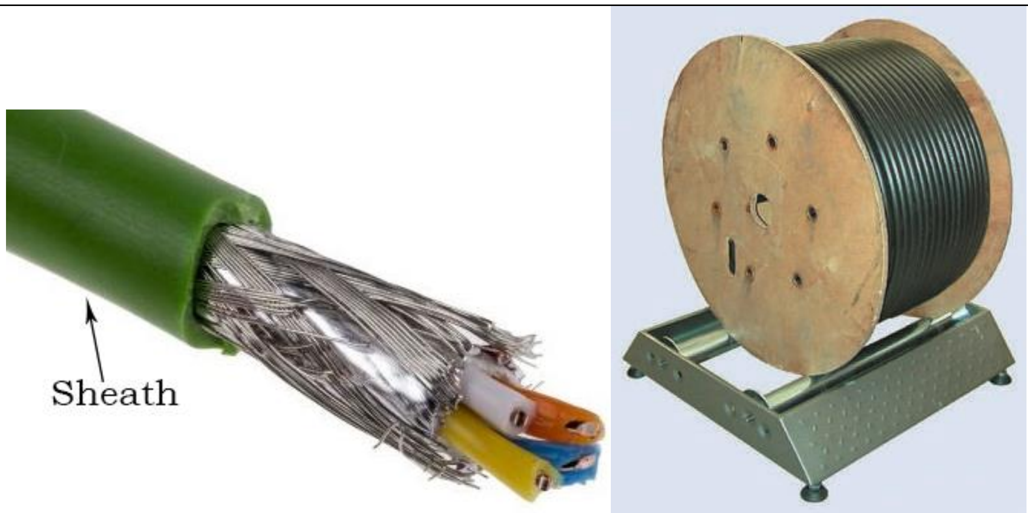


Fig. 1.21 (a) Sheath as an outer layer of a cable with multiple jacket on separate fiber

(b) Cable in drum representing sheath

Example: Following table 1.3 illustrates material used to manufacture optical fiber.

Table 1.3 Material for construction of optical fiber cable

Part of optical fiber cable	**Material required for manufacturing**
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

Practical activity 1

Demonstration of protecting layers in optical fiber cable.

Material required

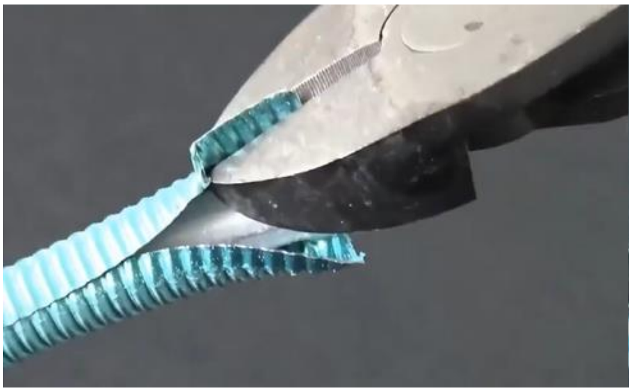
Optical fiber cable, cable stripper, cutter.

Procedure

Step 1. Take an optical fiber cable, which must have buffer, jacket, sheath as shown in Figure 1.

(a) Optical fiber cable

(b) Cable Cutter removing sheath



(c) Cutting strength material

(d) Removing strength material

Fig. 1

Step 2. First, observe the sheath of an optical fiber cable. Take cable stripper to remove the outermost layer of the optical fiber cable. After removing the sheath, number of optical cable can be seen and each optical fiber cable is protected by jackets as shown in Figure 2.

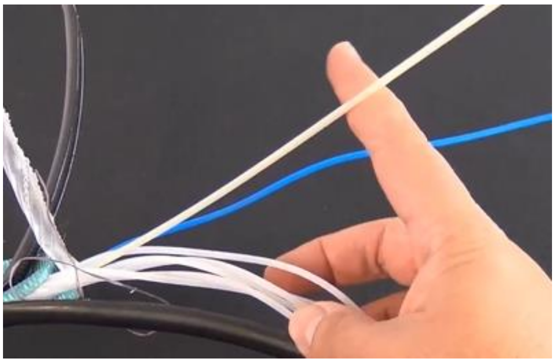


Fig. 2 Jackets in optical fiber cable

Step 3. Now, hold anyone jacket, using cable stripper remove the jacket as shown in Figure 3.

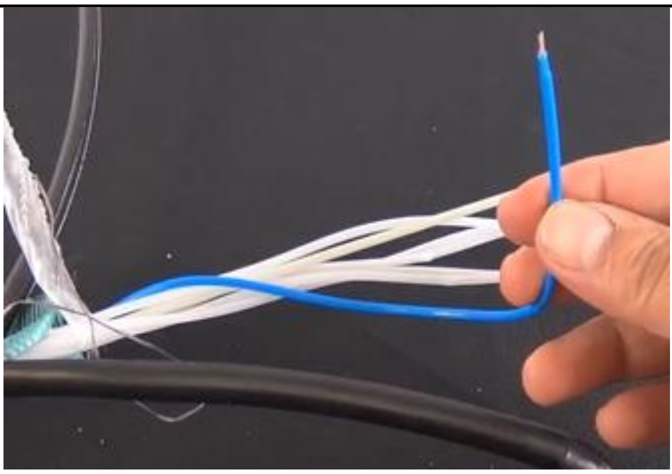


Fig. 3 Holding one jacket for jacket removable

Step 4. Lastly, using cutter cut the jacket of optical fiber cable, then after you will be able to see the buffer, which is innermost protective layer in an optical fiber as shown in Figure 4.

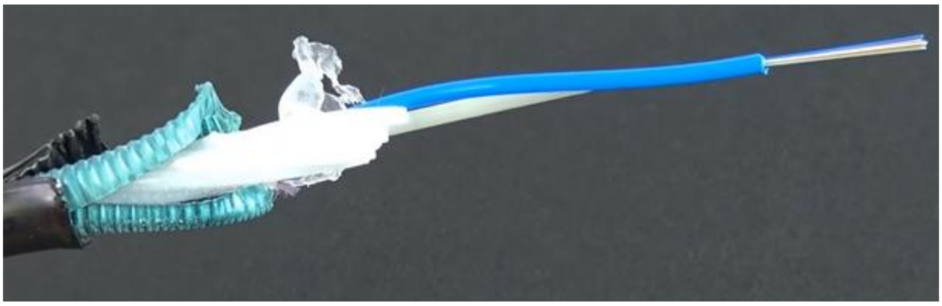


Fig. 4 Buffers in optical fiber cable

Step 5. Observe the different protective layers and material, which are used for their manufacturing.

Assignment 2. Match the following components of fiber with their appropriate feature.

Components of fiber	Feature
Loose Tube buffering	It reflects the light back into the core. It traps the light in the core using an optical technique.
Strength member	The outermost jacket that contain multiple layers of jacketing and strength members
Core	It run between the buffer and the outer jacket
Cladding	The cable consists of a buffer layer that has an inner diameter much larger than the diameter of the fiber.
Tight Buffering	Buffering consists of a buffer layer in which optical fibers attached tightly
Sheath jacket	It is the thin glass centre of the fiber where the light travels.

Practical Activity 2. Identify core and cladding in optical fiber cable.

Material required

Wire stripper, optical fiber cable, tissue paper, isopropyl solution.

Procedure

Step 1. Consider an optical fiber cable.

Fig. 1 Optical fiber cable

Step 2. Now, using cable stripper remove the outer protection layers of an optical fiber cable, repeat the steps performed in practical activity 1.

Step 3. Now, take an optical fiber stripper, insert the optical fiber cable in the middle slot of stripper as shown in Figure 2. This will strip the buffer layers. Now you left with cladding layer.

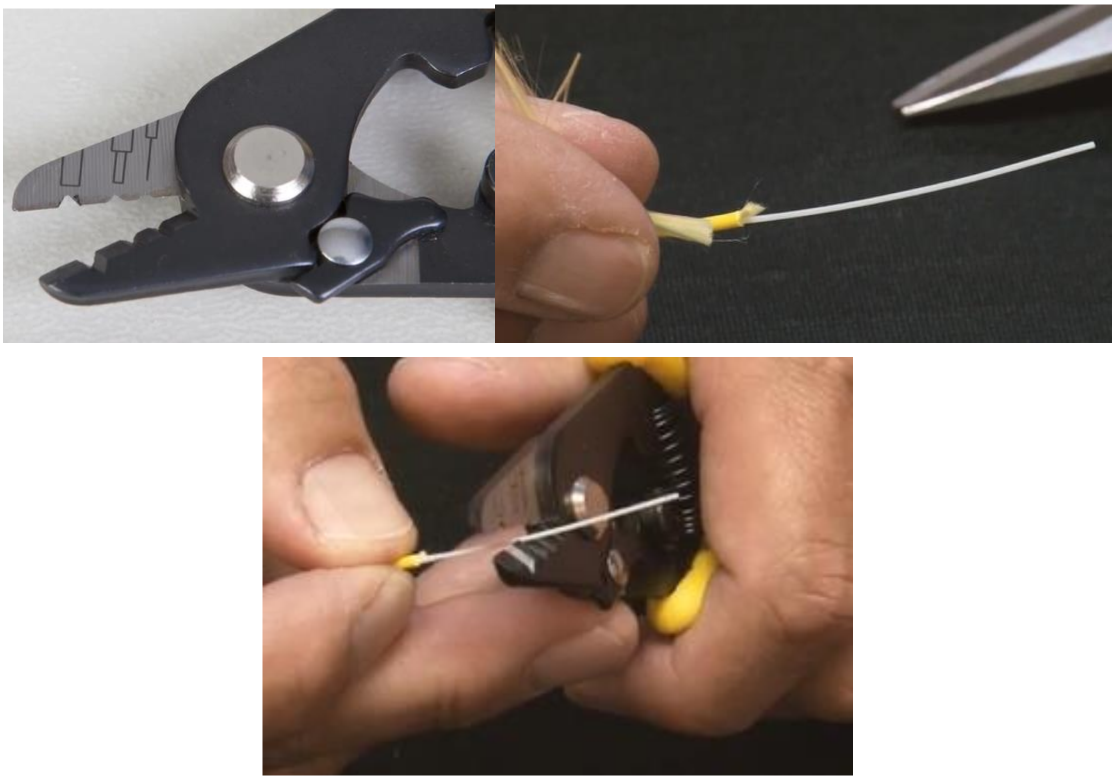


Fig. 2 (a) Three slots of optical fiber cable stripper (b) Buffer layers of OFC (c) Stripped fiber is placed in middle slot of optical fiber stripper

4. Clean the cladding of an optical fiber using tissue paper poured into isopropyl solution as shown in Figure 3.

Fig. 3 Cleaning the optical fiber using tissue paper

Step 5. Again take an optical fiber stripper, this time insert the optical fiber cable in the little slot. This will remove the cladding from the optical fiber as shown in Figure 4.

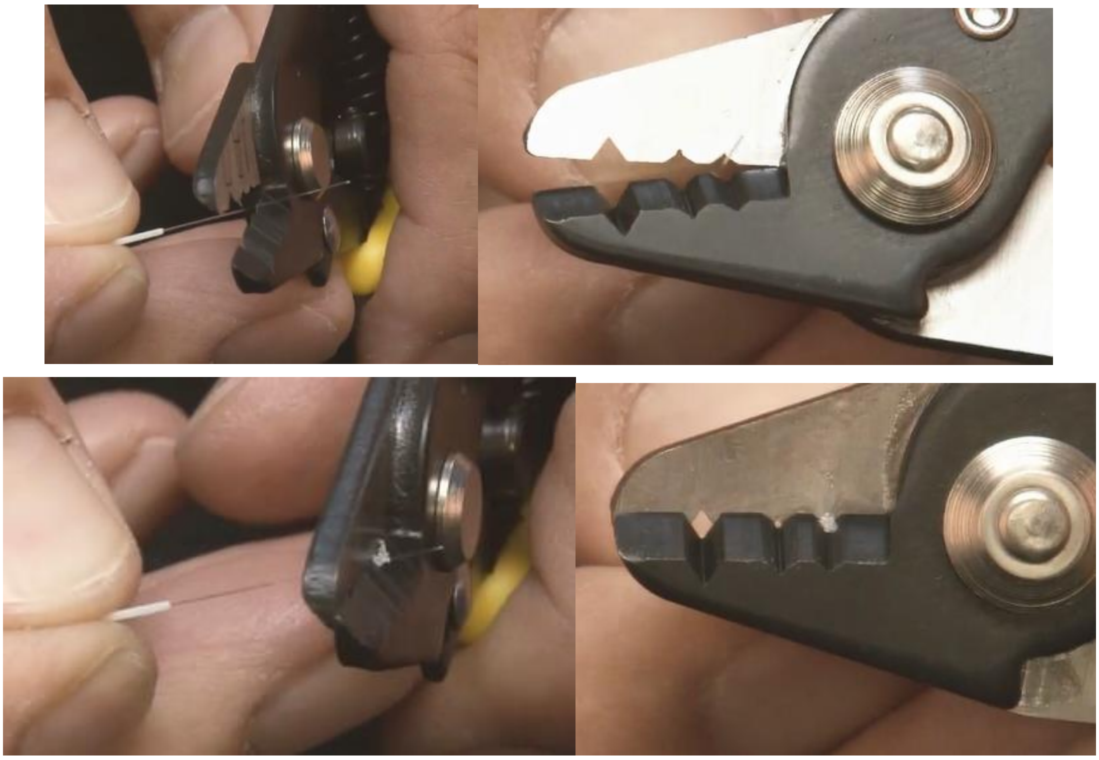


Fig.4 (a) Placing cladding portion of OFC in little slot (c) Side view of placing the OFC in little slot (c) Squeeze the stripper removes the cladding (d) Side view of cladding removable in stripper

Step 6. Observe the core and cladding and visualise the difference in diameter of core and cladding.

ELEMENTS OF AN OPTICAL fiber COMMUNICATION SYSTEM

In optical fiber communication, major elements are transmitter, receiver and optical fiber as a propagation medium as shown in Figure 1.22. The transmitter stage consists of drive circuitry and light source such as Light Emitting Diode or LASER. The receiver stage consists of photo-detector such as photo-diode or PIN Diode, an amplifier and a signal restorer. Now, we will discuss in detail the stages of optical fiber communication system.

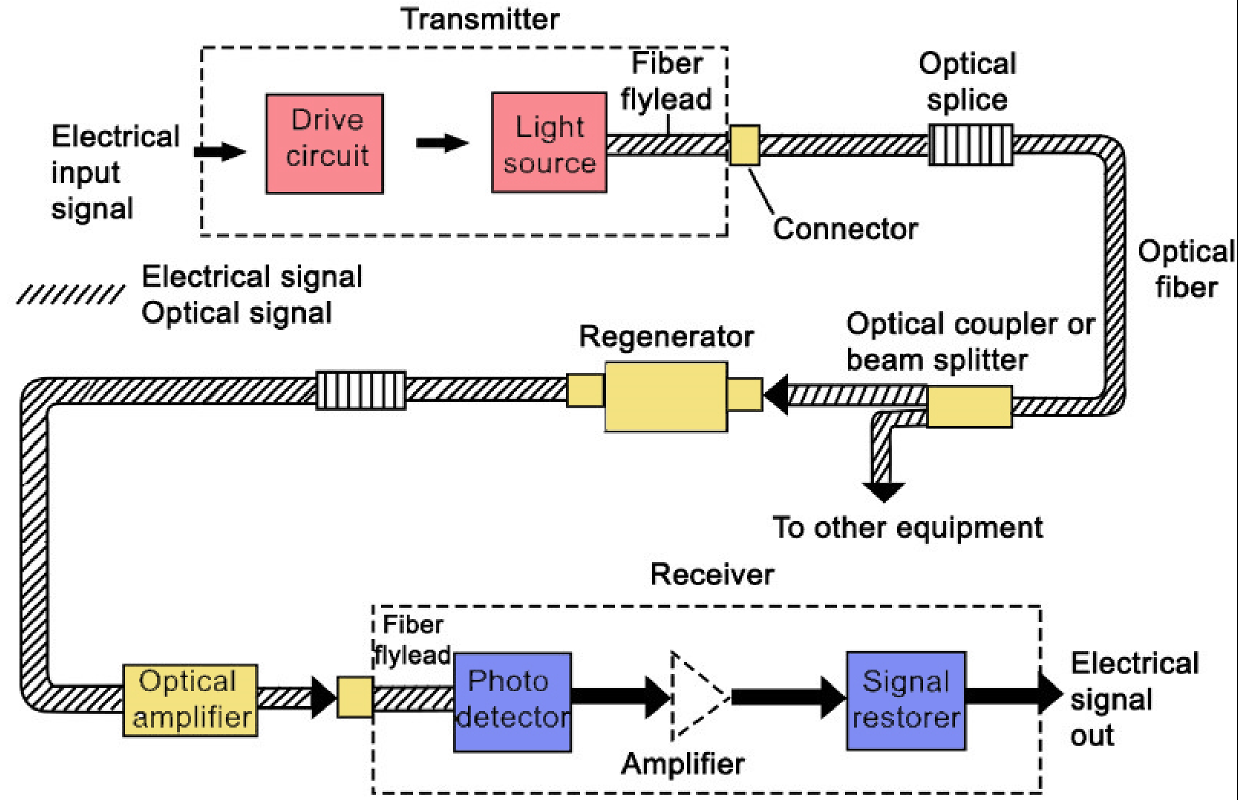


Fig. 1.22 Elements of optical fiber communication system

1. Transmitter – The transmitter transmits optical signal to the fiber cable. A transmitter consist of an interface circuit, a driver circuit and an optical source as shown in Figure 1.23.

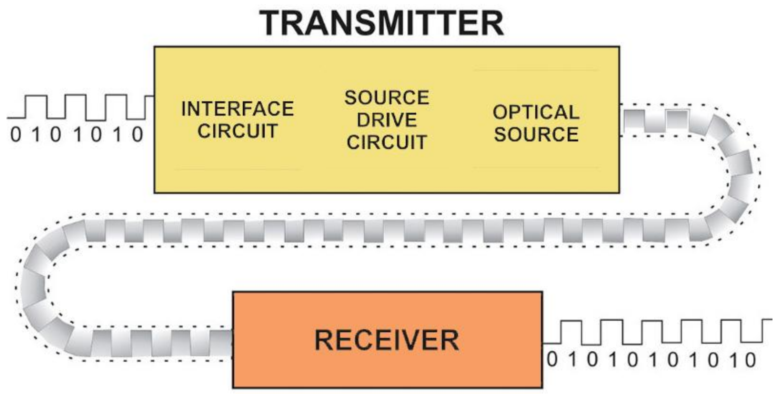


Fig. 1.23 Transmitter of optical fiber communication system

Interface circuit – It makes an interface between the input and transmitter circuitry.

Driver circuit – It processes the input electrical signal, which contains information and feeds to the light source.

Optical source– It produce the light signal for the optical fiber. It can be LED or LASER

2. Transmission Channel – It consist of an optical fiber cable, between transmitter and receiver. This transmission channel transmits optical signal from one end to another. Other components in fiber optics are as follows–

Optical Splitter– Optical fiber splitter directs the beam of light from main fiber to two or more fibers. Optical splitter is shown in Figure 1.24.

Fig. 1.24 Optical splitter

Optical Connector – It is for temporary joints between two individual optical fibers that are broken or to be joined for communication. Optical connector is shown in Figure 1.25.

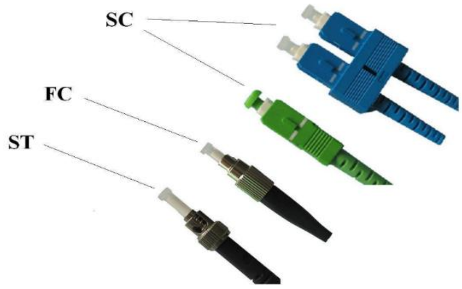


Fig. 1.25 Various optical connector

Optical Splice – It is used to permanently join optical fibers which are broken. Fusion splice machine is shown in Figure 1.26.

Fig. 1.26 Fusion splice machine

3. Receiver – Optical signal is used as input to the optical receiver. Receiver stage consist of photo detector, signal amplifier and signal restorer as shown in Figure 1.27.

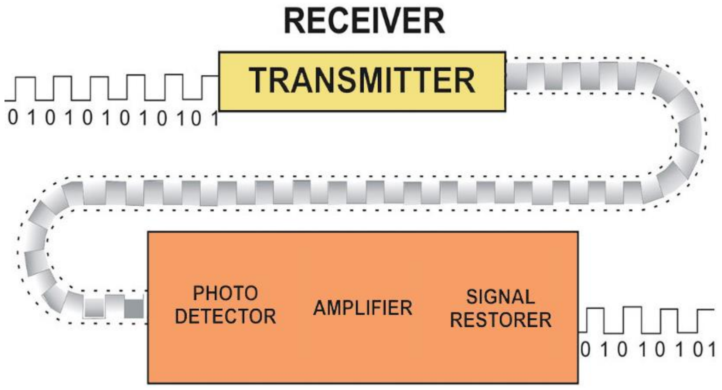


Fig. 1.27 Receiver of optical fiber

Photo-detector – It converts optical signal into electrical signal

Signal amplifier – It is used to improve signal quality by removing the noise to achieve better quality of the signal.

Signal restorer – It converts amplified signal for restoring.

Assignment 6

Element of optical fiber communication	Feature
Transmitter	....
Interface Circuit	....
Driver Circuit	....
Optical Source	....
Optical Receiver	....
Transmission Channel	....
Optical Coupler or Splitter	....
Optical Connector	....
Optical Splice	....

DIFFERENT OPTICAL fiber CABLES ON THE BASIS ON CONSTRUCTION

Optical fiber cable are the medium in which data is transfer from one place to another. In market, we will find variety of optical fiber cables. Availability of optical fiber cables are based on the use, location, and future expansion needs. Different combinations of buffer type, strength members, and jackets can be used to create cables to meet the needs of a wide variety of industries and users. Let us look at some of the commonly available optical fiber cables.

Cordage – The simple type of cables are called as cord or cordage. The two common types of cordage are simplex and duplex cordage.

Simplex Cordage – Simplex cordage as shown in Figure 1.28 consists of a single fiber with a tight buffer, an aramid yarn strength member and a PVC jacket.

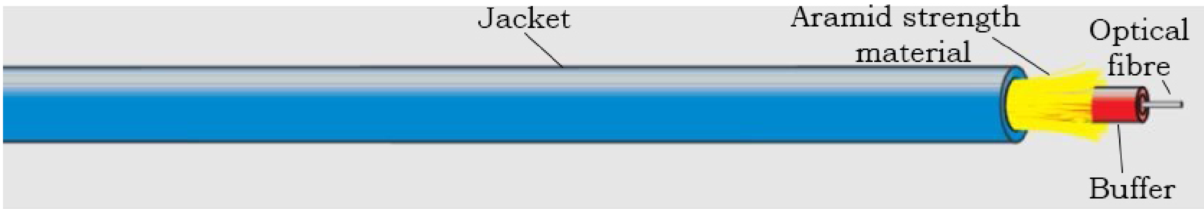


Fig. 1.28 Simplex Cordage

Duplex Cordage – Duplex cordage, also known as zip cord, is similar in appearance to household electrical cords. Duplex cordage is a convenient way to combine two simplex cords to achieve duplex or two-way transmissions as shown in Figure 1.29.

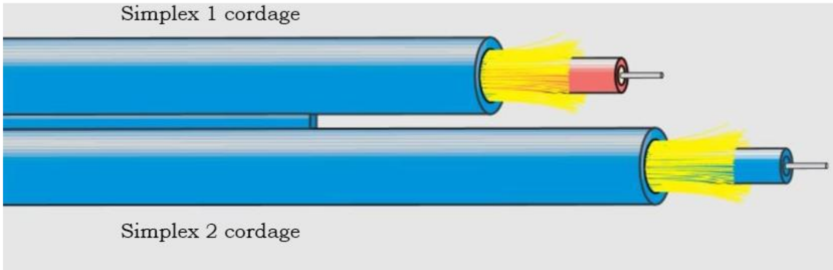


Fig. 1.29 Duplex Cordage

Distribution Cable – When it is necessary to run a large number of optical fibers through a building, distribution cable is often used. Distribution cable consists of multiple tight-buffered fibers bundled in a jacket with a strength member as shown in Figure 1.30.

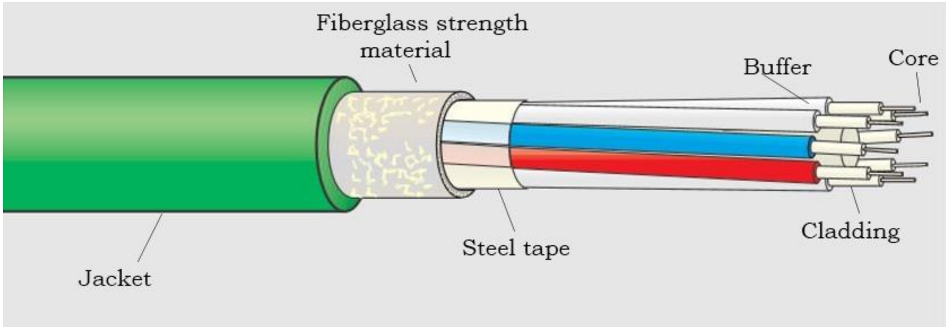


Fig. 1.30 Distribution cables with sub cables

Breakout Cable – Breakout cables consist of two or more simplex cables bundled around a central strength member and covered with an outer jacket, as shown in Figure 1.31. Like distribution cable, breakout cables may be run through a building wall.

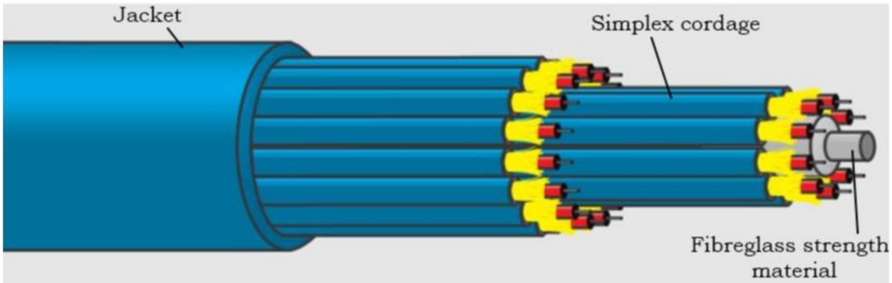


Fig. 1.31 Breakout cable contains simplex cords bundled around a central strength member

More to know

Patch cable or patch lead is a connector used to connect one electronic or optical device to another for signal routing. A picture of patch cord is shown in Figure 1.32.

Fig. 1.32 Patch cord

Armoured Cable – Armoured cable consists of a cable surrounded by a steel or aluminum jacket. It is then covered with a polyethylene jacket to protect it from moisture and abrasion as shown in Figure 1.33.

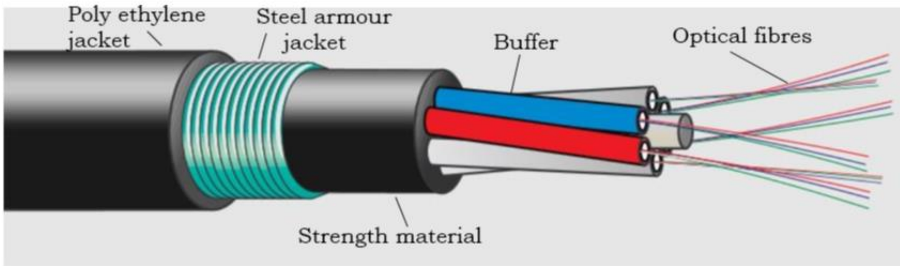


Fig. 1.33 Armoured cable protects the fiber from harsh conditions and gnawing animals

Messenger Cable – When there is need to suspend optical fiber cable between two poles, the strength members alone are not enough to support the weight of the cable. Installers must use a messenger cable, which incorporates a steel or dielectric line known as a messenger to take the weight of the cable as shown in Figure 1.34.

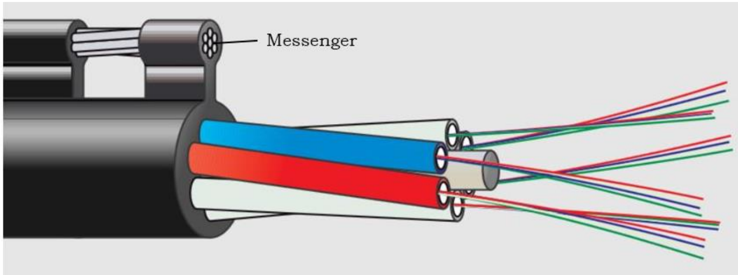


Fig. 1.34 Messenger cable used for aerial installations

Ribbon Cable – In this cable coated optical fibers are arrange side by side. Mylar tape is used to bind together the optical fibers, over which a buffer layers is formed as shown in Figure 1.35. This will require less space and installation time.

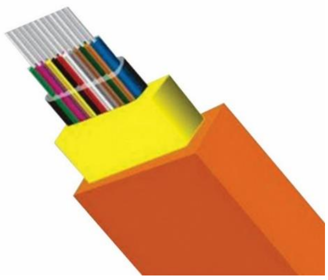


Fig. 1.35 Ribbon cables consist of parallel fibers bonded together

Composite Cable – Composite cable is designed to carry optical fiber and current-carrying electrical conductors in the same run. As shown in Figure 1.36 composite cable consists of optical fibers along with electrical metallic conductor. In composite cable, both light signal and electrical signal can travel simultaneously.

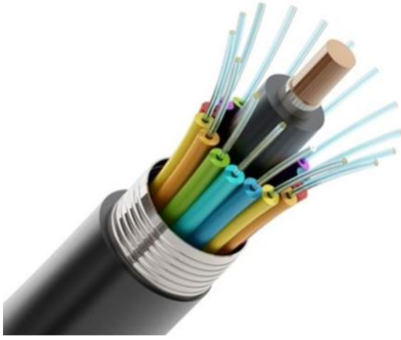


Fig. 1.36 Composite cable carries fiber and copper cable

Assignment 3

Identify the following cables and write their names.

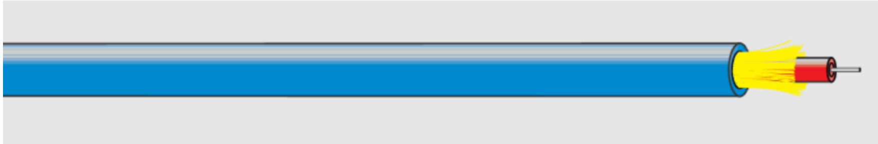


Fig. 1 ....

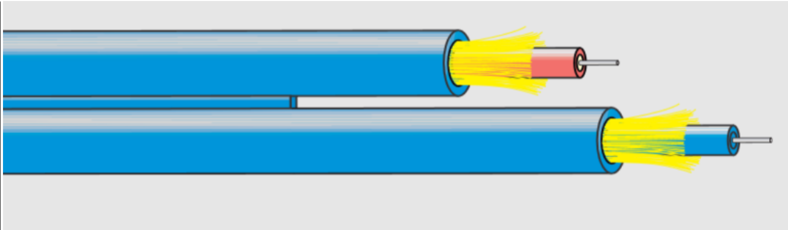


Fig. 2 ....

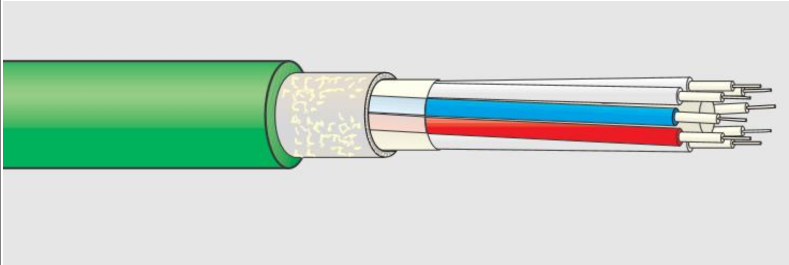


Fig. 3 ....

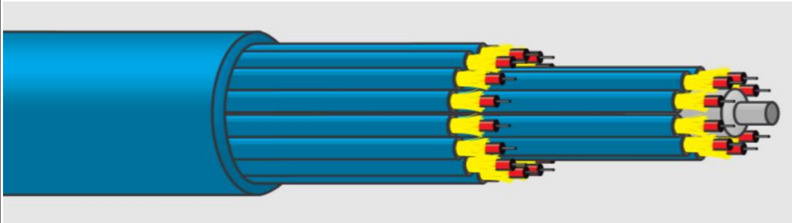


Fig. 4 ....

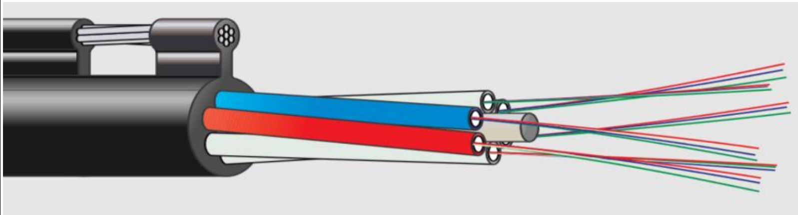


Fig. 5 ....

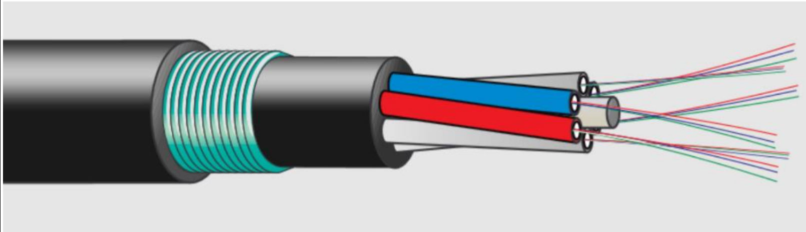


Fig. 6 ....

Assignment 4

Write the specific feature of the optical fiber cable, which distinguishes them from each other in one sentence.

Name of the cable	Application of cable
Simplex Cordage	
Duplex Cordage	
Distribution Cable	
Breakout Cable	
Armoured Cable	
Messenger Cable	
Ribbon Cable	
Submarine Cable	
Hybrid Cable	
Composite Cable	

Assignment 5

Identify names of different parts from the options given to mark the same in Figure 1.

Central Strength Member, fibers, Loose Tube, Jelly Compound, Aramid Yarn, Corrugated Steel Tape, Outer Jacket PE

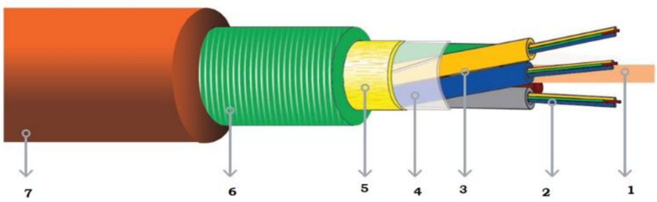


Fig. 1

APPLICATION OF OPTICAL FIBER

Fiber optic cables have revolutionized the communication technology. As they are the fastest means of data transmission. Optical fiber technology is implemented in every sector. After introduction of optical fiber cable in Cyber world, internet speed changed drastically. Some of the sector in which optical fiber technology is enhancing are internet, high definition television, telephone, military, space technology, computer networking.

1. Internet

fiber optic cables transmit large amounts of data at very high speed. This technology is therefore widely used in internet cables as shown in Figure 1.37. As compared to traditional copper wires, fiber optic cables are less bulky, lighter, and more flexible and carry more data.

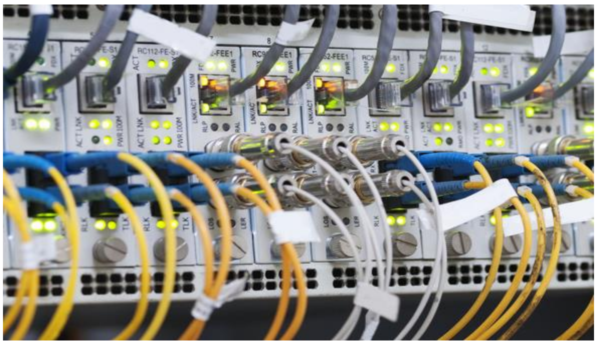


Fig. 1.37 Optical fiber cables connected to the switch to distribute internet connection

2. High definition Television

The use of optical fiber cables in the transmission of signals has grown explosively over the years. These cables are ideal for transmitting signals for high definition televisions, because they have greater bandwidth and speed as shown in Figure 1.38.

Fig. 1.38 Optical fiber is connected to audio input of HD television

3. Telephone

Calling telephones within or outside the country has never been so easy. With the use of fiber optic communication, you can connect faster and have clear conversations.

Fig. 1.39 Telephone line extender uses optical fiber cable

4. Computer Networking

Networking between computers in a single building or across nearby building is made easier and faster with the use of optical fiber cable.

Fig. 1.40 Optical cable connected in router used networking

5. Medical science

Optical fiber cables are widely used in the fields of medicine and research. Optical communication is an important part of surgical methods, popularly known as endoscopy as shown in Figure 1.41.

Fig. 1.41 Optical fiber in medical equipment

6. Military and Space

With the high level of data security required in military and aerospace applications, fiber optic cables offer the ideal solution for data transmission in these areas as shown in Figure 1.42.

Fig. 1.42 (a) Indian Army Tactical Communication System utilise optical fiber technology (b) ISRO's GSAT-19 Satellite use optical fiber technology

ADVANTAGES OF OPTICAL fiber COMMUNICATION

Small in size and lighter weight

Greater bandwidth

High data rate

Less attenuation

Ruggedness and flexibility

Less electromagnetic interference

Metal free

Electrical isolation

DISADVANTAGES OF OPTICAL fiber CABLE

a) Splicing is difficult to perform.

b) Huge amount of money is required for install.

c) Highly susceptible to cuts or damaged during installation.

Check Your Progress

A. Multiple Choice Questions

1. Which of the following is innermost layer in optical fiber. (a) Cladding (b) Jacket (c) Buffer (d) Core
2. Aramid yarn is used in which of the following layer. (a) Buffer (b) Strength material (c) Jacket (d) Cladding
3. In which of the following cable have both optical fiber and metal conductor for transmission of light and electrical signal. (a) Armoured cable (b) Ribbon cable (c) Composite cable (d) Messenger cable
4. In which cable optical fibers are arrange side by side in one row. (a) Ribbon cable (b) Composite cable (c) Messenger cable (d) Armoured cable
5. Strength member is also known as __________ (a) Polyester elastomer (b) Kevlar (c) Polymer (d) Polyethylene
6. The component in the optical fiber communication system that converts light energy into electrical energy is the (a) Transmitter (b) Receiver (c) Optical fiber (d) Coupler

7. What was one of the earliest advantages that light held over other forms of communication? (a) Ability to communicate complex ideas (b) Ability to carry messages quickly (c) Ability to carry messages privately (d) Ability to carry coded messages
8. Optical optics fiber will play a critical role in realizing the dream of ____________India (a) Analog India (b) Digital India (c) Modern India (d) Traditional India
9. Which of the following is not the element of communication? (a) Sender (b) Receiver (c) Medium (d) Node
10. Which of the following is diameter of single mode optical fiber. (a) 8.5 – 9 μm (b) 9-10 μm (c) 86 μm (d) 10-11 μm

B. Fill in the blanks

1. Signal is __________ representation of data.
2. Alexander Graham Bell invented a device called __________
3. Optical fibers are simple threads like __________
4. LASER or LED is the __________ for optical fiber transmission.
5. Receiver stage consists of __________, __________ and __________
6. The basic structure of an optical fiber consists of four parts, __________, __________ __________ and __________
7. In single mode operation the diameter of cladding is __________
8. In multi-mode mode operation the diameter of cladding is __________
9. Optical fiber cable transmit encode __________ signal.
10. Core is made up of __________

C. True or False

1. Noise is desired signal.
2. Photon is a discrete quantity of light energy.
3. Glass is opaque material.
4. Light is confined in core of an optical fiber cable.
5. The fiber optic cable is a small and compact cable, and it is highly susceptible to cuts or damages during installation or construction activities
6. Data rate is much lower in a fiber hence more information can be carried fiber than copper cables
7. Fiber optic cables cannot be used in the fields of medicine and research.
8. Radiation may either be "electromagnetic," which is usually considered to travel in the form of waves, or "particles"
9. Non-wired media means communication is established without material as a medium.
10. LASER or LED is the light source for optical fiber transmission.

D. Short Answer Questions

1. List down the features of optical fiber cables.
2. How optical fiber communication system works?
3. Why is communication necessary? What is importance of communication?
4. Name the elements of optical fiber communication.
5. How optical fibers are used in medical treatment?
6. Write features of each element used in optical fiber communication in one sentence.

Session 2: Light Propagation

We see a variety of objects in the world around us. However, we are unable to see anything in a dark room. On lighting up the room, things become visible. What makes things visible? During the day, the sunlight helps us to see objects. An object reflects light that falls on it. This reflected light, when received by our eyes, enables us to see things. There are a number of common wonderful phenomena associated with light such as image formation by mirrors, the twinkling of stars, the beautiful colours of a rainbow, bending of light by a medium and so on. A study of the properties of light helps us to explore them. By observing the common optical phenomena around us, we may conclude that light seems to travel in straight lines.

In this chapter, we shall study the phenomena of reflection, various laws of reflection and refraction of light. These basic concepts will help us in the study of optical phenomena. In this Chapter, we will learn about the nature of light, which allow it to propagate inside an optical fiber.

PROPAGATION OF LIGHT

Light can exhibit both wave nature and particle nature at the same time. In particle nature, energy carried by light comes in separate bundles called photons. Sunlight as shown in Figure 2.1 shows, it contain bundles of photons.

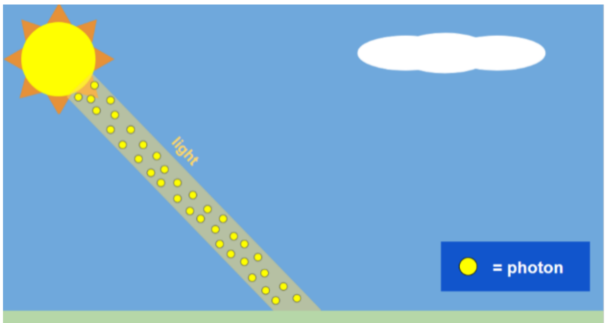


Fig. 2.1 Particle nature of light

In wave nature, light is like an electromagnetic wave travels with speed 'c' in vaccum. Much of the time, light behaves like a wave. If we put the oil in water, we can be able to see the wave nature of light as shown in Figure 2.2 (a)

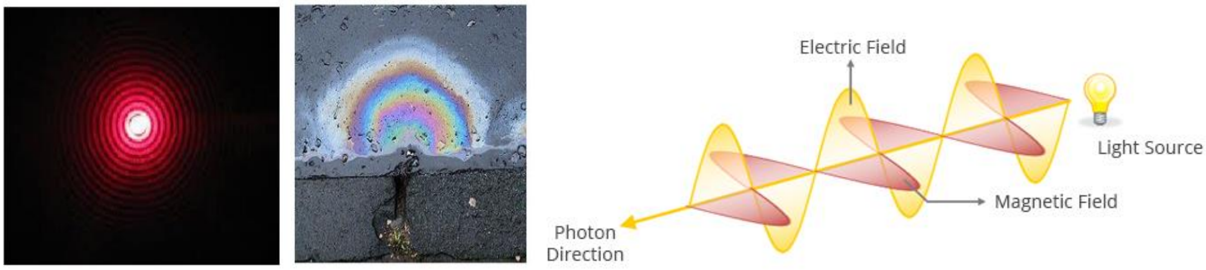


Fig. 2.2 (a) Wave nature of light (b) Light as electromagnetic wave

Light waves are transverse waves as they oscillate in the direction perpendicular to the direction of wave travel as shown in Figure 2.2 (b).

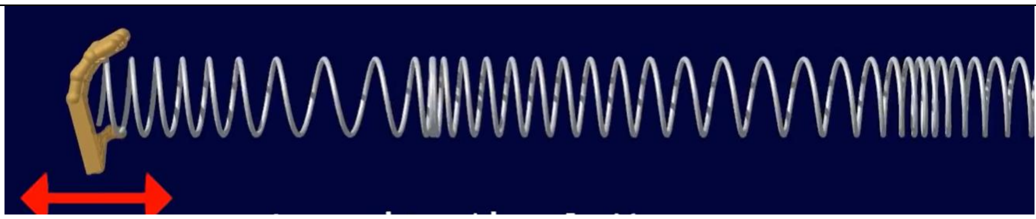


Fig. 2.3 (a) Propagation pattern of longitudinal wave

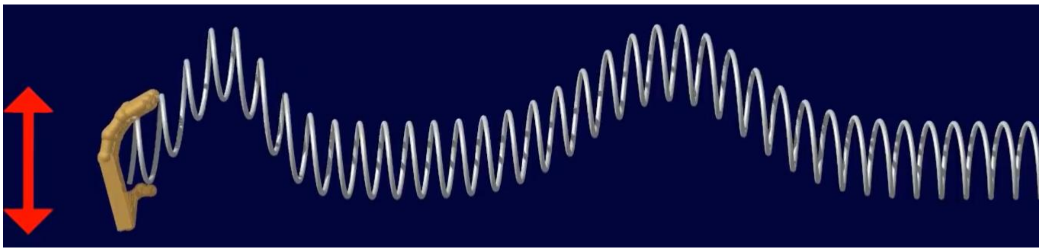


Fig. 2.3 (b) Propagation pattern of transverse wave

If you through a stone in a still water. Wave will get develop. The path followed by the water is transverse in nature.

ELECTROMAGNETIC SPECTRUM

The electromagnetic spectrum is the term use to describe the entire range of waves. Spectrum include infrared radiation, visible region, ultraviolet radiation, microwaves, radio waves, X-Rays, gamma rays. Light is also known as visible light or visible spectrum. Figure 2.4 shows the complete spectrum from radio waves to gamma rays. The seven color, which we see in our daily life, belongs to visible spectrum of electromagnetic spectrum. Human with naked eyes can visualise, visible region only. However, in optical fiber technology, wavelength range, which is going to use are infrared, visible, and ultraviolet.

The energy of light depends on its frequency. Higher the frequency, greater is the energy. Light is also characterized by its wavelength. Shorter the wavelength, higher is the frequency. Visible light wavelength is from 380 nanometers i.e. violet to 750 nanometers i.e. red. Infrared radiation has longer wavelength than visible light. Most fiber optic systems use infrared light between 800 and 1550 nanometers. This region is referred to as the near infrared (near-IR).

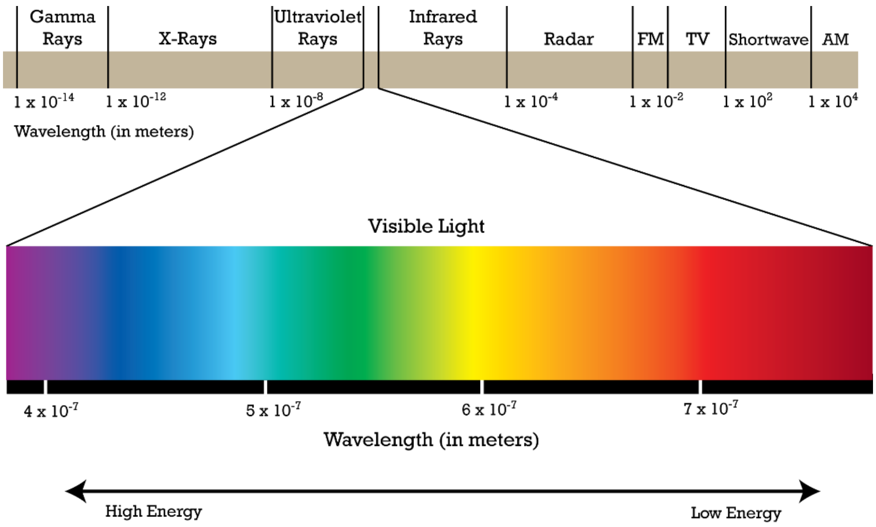


Fig. 2.4 Electromagnetic Spectrum

Range and application of different waves

Long radio waves

Wavelength range– 1000 m to 10000000 m

Application– Longwave radio, Long distance communication as shown in Figure 2.5.

Fig. 2.5 Long radio waves in satellite communication

AM radio waves

Wavelength range– 10 m to 1000 m

Application– Long distance TV broadcast as shown in Figure 2.6.

Fig. 2.6 AM radio waves in television broadcast

Short radio waves

Wavelength range– 0.001 m to 10 m.

Application– Television and FM radio, microwave, mobile communication as shown in Figure 2.7.

Fig. 2.7 Short radio waves in (a) Mobile communication (b) Microwave oven

Infrared Radiation

Wavelength range– 700 nm to 0.001 m

Application– In remote control, IR sensors as shown in Figure 2.8.

Fig. 2.8 Infrared radiation in TV remote

Visible Light

Wavelength range– 700 nm to 400 nm

Application – Traffic light, Railway signal, vehicle head and tail lamp, tube light, bulb etc as shown in Figure 2.9.

Fig. 2.9 Visible light in (a) Traffic signal (b) Railway signal

Ultraviolet

Wavelength range– 400 nm to 1 nm

Application– In water purification. It is shown in Figure 2.10.

Fig. 2.10 Ultraviolet radiation in water purification

X-Rays

Wavelength range – 1nm to 0.01 nm

Application – In medical equipment. It is shown in Figure 2.11.

Fig. 2.11 X-ray machine for medical diagnosis

Gamma Rays

Wavelength range – 0.01 nm to 0.0001 nm

Application – In medical equipment. It is shown in Figure 2.12.

Fig. 2.12 Gamma rays is used in diagnosis of cancer

REFLECTION AND REFRACTION OF LIGHT

Light travels in a straight line. However, if any obstacle comes in way of light, either it will bypass or diverted to some other direction. The speed of light depends on the medium through which it passes. When it falls on a plane opaque surface, it will bounce back, say light strikes the mirror, these phenomena are known as reflection. When it passes from one medium to another, say from air to water it bends, these phenomena are known as refraction.

1. Reflection

Considering, one polished surface of glass such as a mirror. You can see your image in a mirror because the light from the mirror get reflect back. Ray diagram of reflection is shown in Figure 2.13.

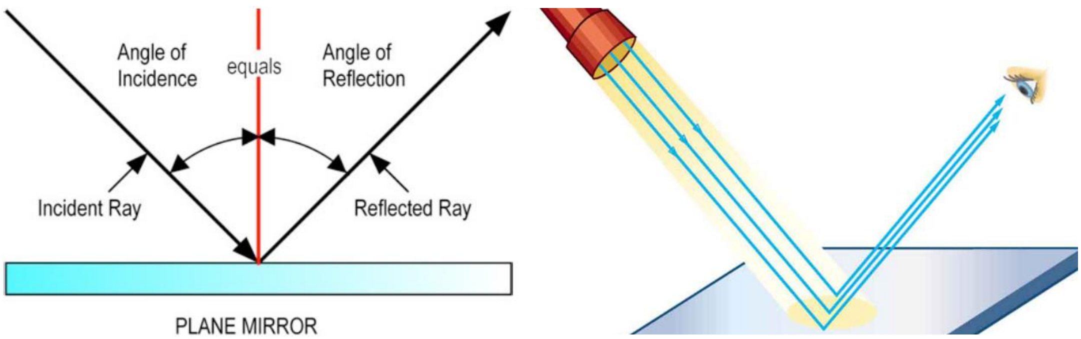


Fig. 2.13 Reflection of light (a) Ray diagram showing the reflection phenomenon (b) Torch light incident on plan mirror, illustrate the reflection

The incoming light ray striking on plane reflecting surface is incident ray. The light ray moving away from the reflecting surface is reflected ray as shown in Figure 2.13.

Point on the surface through which light reflects back. At this point, considering an imaginary line, which is perpendicular to the reflecting surface is known as normal as shown in Figure 2.13. The most important characteristic of these rays is their angles, they are measured with respect to the normal. The angle of incidence is measured between incident ray and normal. The angle of reflection is measured between reflected ray and normal as shown in Figure 2.13.

You are familiar with the laws of reflection of light. Let us recall these laws–

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

(ii) The incident ray, the normal at the point of incidence and the reflected ray, all lie in the same plane.

Practical Activity 1. Demonstrate the law of reflection using a plane mirror.

Materials Required

Thermacol sheet, white sheet of paper, paper pins, mirror, pencil, protractor and scale.

Procedure

Step 1. Take a plane white sheet. Place it on thermacol and fix it using pins as shown in Figure 1.

Fig. 1 Plane white sheet on the thermacol

Step 2. Draw a horizontal line using a scale as shown in Figure 2.

Fig. 2 Straight line drawn on the white sheet

Step 3. Draw an incident ray on the horizontal line which is drawn in above step as shown in Figure 3.

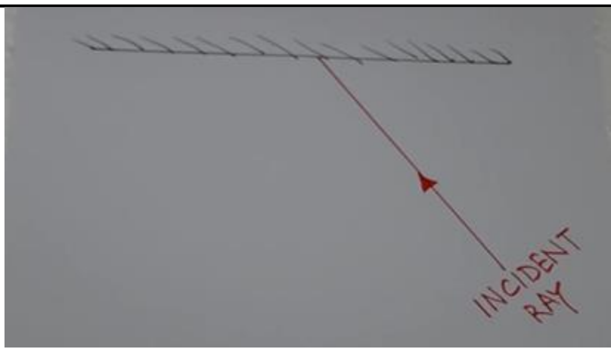


Fig. 3 Incident ray at certain angle to horizontal line

Step 4. Now place the mirror in vertical position using clips as shown in Figure 4.

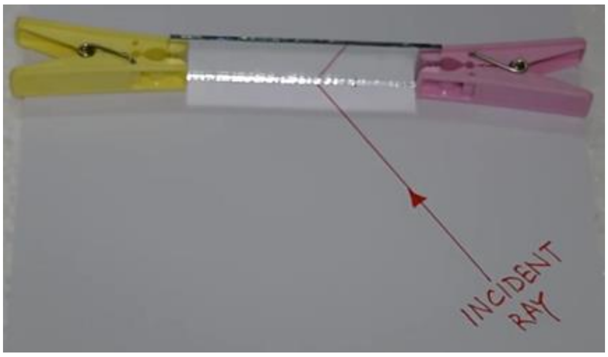


Fig. 4

Step 5. Trace back the imaginary line, which is reflecting in mirror, mark the point for remembrance as shown in Figure 5.

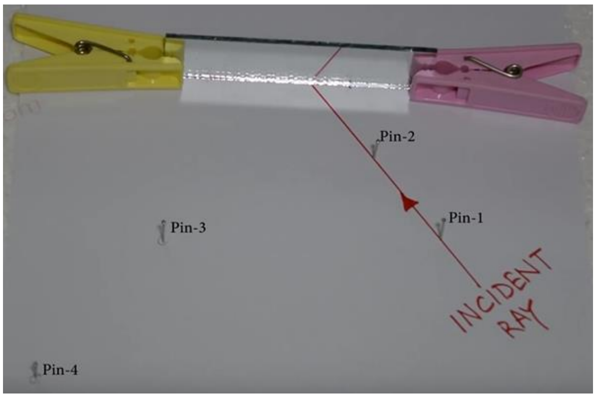


Fig. 5

Step 6. Draw a line to join these points, mark it as reflected ray as shown in Figure 6.

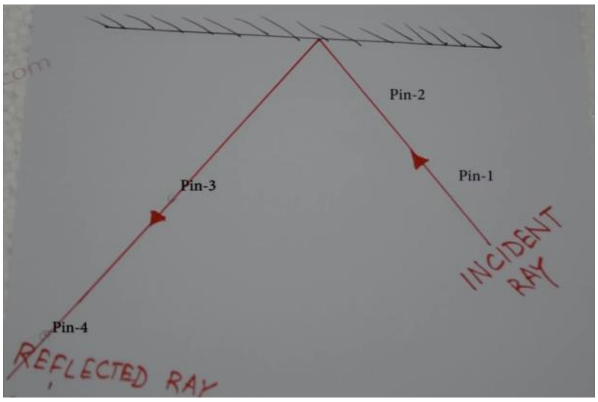


Fig. 6

Step 7. Now place a protector on the horizontal line. At point of incidence, draw a perpendicular as shown in Figure 7. Mark it as normal.

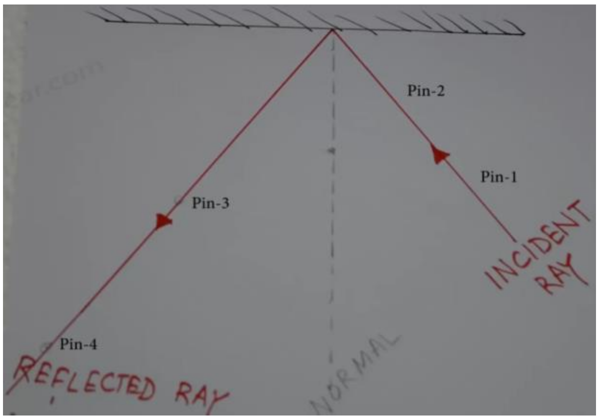


Fig. 7

Step 8. Now place the protector on the normal, measure an angle with an incident ray. Mark it as angle of incidence and note down the angle as shown in Figure 8.

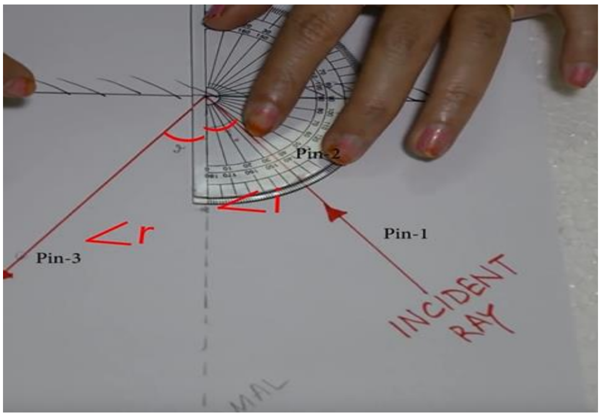


Fig. 8

Step 9. In the same way, place a protector on the normal, measure an angle with a reflected ray. Mark it as angle of reflection and note down the angle as shown in Figure 9.

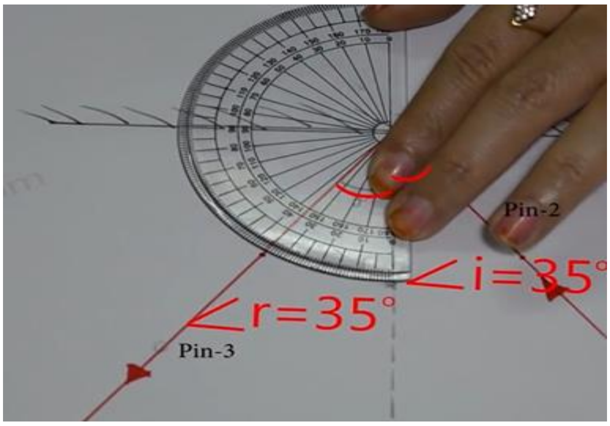


Fig. 9

Step 10. Observe and compare angle of incidence and reflection. You will find both are equal. This proofs the first law of reflection.

2. Refraction

Light seems to travel along straight-line paths in a transparent medium. What happens when light enters from one transparent medium to another? Does it still move along a straight-line path or change its direction? We shall recall some of our day-to-day experiences. If we partly immersed a pencil in a glass of water appears to be bend as shown in Figure 2.14(b). These observations indicate that light does not travel in the same direction in all media. It appears that when traveling from one medium to another, the direction of propagation of light in the second medium changes. This phenomenon is known as refraction of light as shown in Figure 2.14(a). When light ray enter from denser medium to rare medium it bends away from the normal. When it enters from rare medium to denser medium it bends towards the normal.

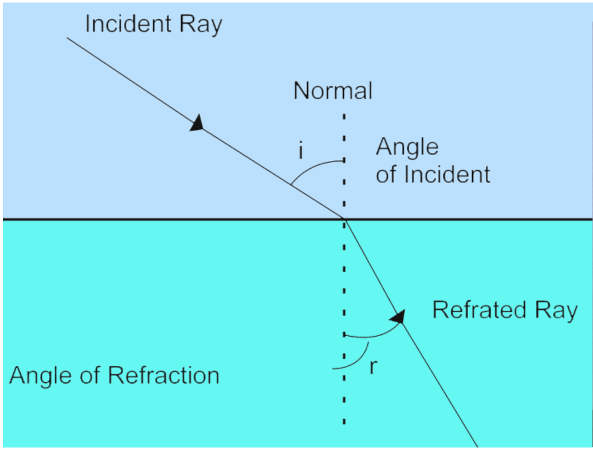


Fig. 2.14 (a) Ray diagram shows refraction of light (b) Pencil in a glass of water shows refraction

Practical activity 2. Demonstrate the concept of refraction.

Material required

Thermacol sheet, Rectangular glass slab, sketch pen, ruler, transparent tub with water, laser light, protector, white sheet.

Procedure

Step 1. Take a white paper fix it on the thermacol sheet.

Step 2. Take a glass slab. Draw outline of a glass slab on a piece of paper as shown in Figure 1.

Fig. 1

Step 3. Take a protector. Draw a normal on the surface, which encounters light as shown in Figure 2.

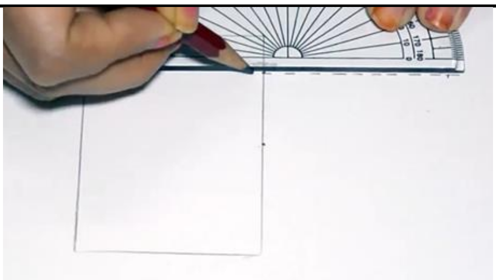


Fig. 2

Step 4. Take a protector and ruler. Draw an incident ray with angle of incidence 30^0 as shown in Figure 3.

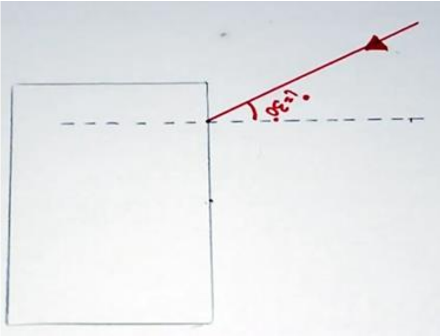


Fig. 3

Step 5. Take ruler, extend an incident ray just to verify, if the emergent ray is parallel to the incident ray as shown in Figure 4.

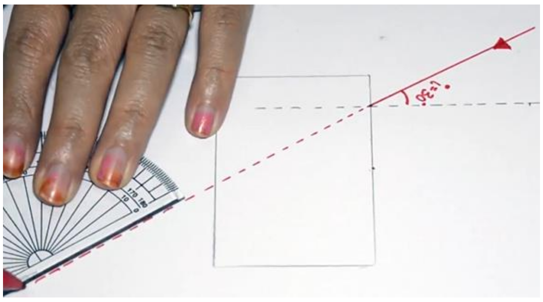


Fig. 4

Step 6. Take a protector and ruler. Draw an incident ray with angle of incidence 60^0 as shown in Figure 5. Again, extend the incident ray.

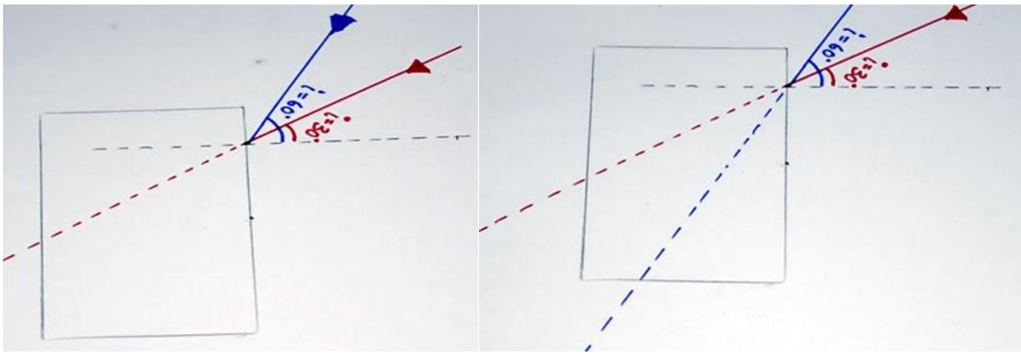


Fig. 5

Step 7. Place the transparent water tub over the sheet of paper as shown in Figure 6.

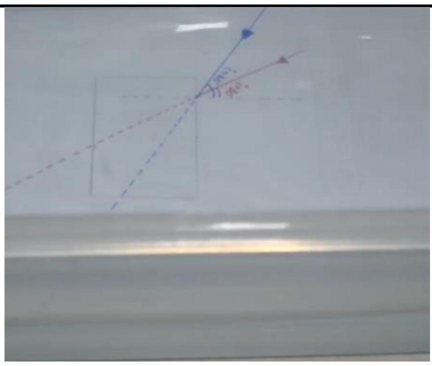


Fig. 6

Step 8. Project laser light at $i=60^0$ and observe the emergent ray as shown in Figure 7. Measure the angle of emergent using protector.

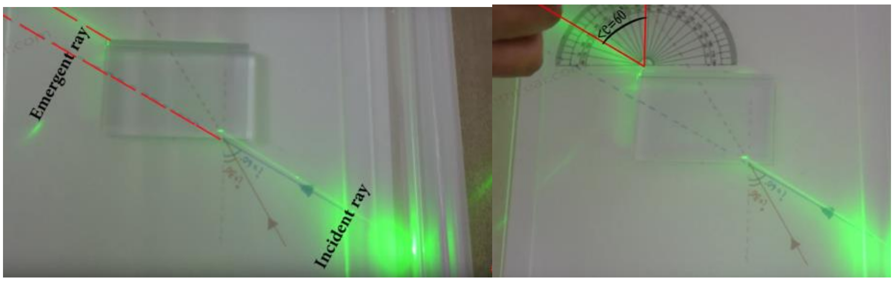


Fig. 7

Step 9. Repeat the similar operation with other incident ray, which is at 30^0.

Step 10. Observe the angle of emergent ray, you will find that angle of incidence and angle of emergent are equal.

Step 11. You will also observe, both the incident rays when enters from air to glass slab they bend towards the normal as air has less refractive index and glass slab is more refractive index.

Step 12. When the laser beam comes out from glass slab to air again. It will bend away from the normal.

Step 13. These observation will help to understand the concept of refraction.

The following are the laws of refraction of light.

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

(ii) The ratio of sine of angle of incidence to the sine of 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 value is called the refractive index. Let us study about refractive index in some detail.

3. Refractive Index

Refractive index of a material is a dimensionless. Refractive index determines the speed with which light beam travel in a medium.

$n=c/v$, where c is the speed of light in vaccum, v is the speed of light in medium.

You have already studied 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 depends up on the extent of refractive index of medium. Speed of propagation of light varies in different medium. It turns out that light propagates with different speeds in different medium. Light travels fastest in vacuum with speed of 3×10^8 m/s. In air, the speed of light is only marginally less, compared to that in vacuum. It reduces considerably in glass or water.

The refractive index of several medium is given in Table 2.1. From the table 2.1 you know that the refractive index of water, $n_w = 1.33$. This means that the ratio of the speed of light in air and the speed of light in water is equal to 1.33.

Considering an example, if a coin is placed in a beaker containing water. The coin will look upward with reference to it exact position as shown in Figure 2.15, this is due to change in refractive index of air and water.

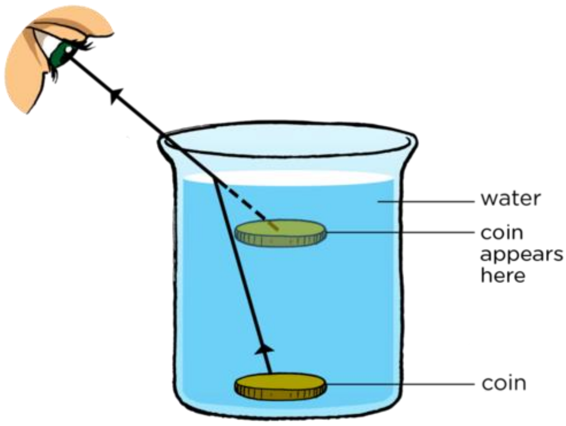


Fig. 2.15 Refractive index of glass, water, air

Table 2.1 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: $n = C/V = 3\times10^8 / 2\times10^8 = 1.5$

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

Assignment 1

A ray of light traveling in air enters into water. Does the light ray bend towards the normal or away from the normal? Why?

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.

You are given kerosene, turpentine and water. In which of these does the light travel fastest? Use the information given in table 2.1.

The refractive index of diamond is 2.42. What is the meaning of this statement?

A medium is having a refractive index of 2.5, what is the speed of light in medium.

5. Total internal reflection

When light hits an interface between two different media, it can behave in two different ways. Typically, the light partially refract and partially reflect.

Consider an example of glass and air as shown in Figure 2.16. Figure 2.16 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 glass at a particular angle called as 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.

As we know, about the critical angle, when light is propagating from glass to air, for all angles less than a certain critical angle, the light gets transmitted through. In case of critical angle, when light traveling from a higher refractive index medium to a lower refractive index medium will be refracted at 90°; in other words, refracted along the interface of two mediums as shown in Figure 2.16. If the light hits the interface at any angle larger than this critical angle, it will not pass through to the second medium at all. Instead, all of it will be reflected back into the first medium, this process of total internal reflection.

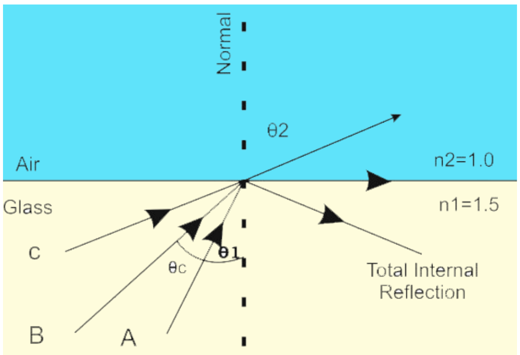


Fig. 2.16 Total internal refraction by air and glass interface

The best application of the total internal reflection is used in the optical fiber communication. The propagation of light inside the fiber occurs by the method of the total internal reflection.

Figure 2.17 shows propagation of light through optical fiber with total internal reflection inside the core. The refractive index of core is larger than the 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 fiber 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 fiber up to long distances.

Table 2.2 Refractive Index of core and cladding

	Single mode optical fiber	**Multimode optical fiber**
Core	1.45	1.425-1.480
Cladding	1.44	1.417-1.460

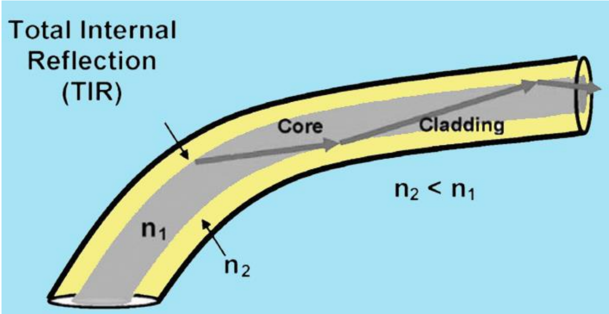


Fig. 2.17 Propagation of light in fiber by Total Internal Reflection

Several terms are used to illustrate the propagation of light inside the fiber, these terms are - Numerical Aperture, Acceptance Angle and Acceptance cone of the fiber.

6. Numerical Aperture (NA)

NA is the light gathering ability of an optical fiber. More the NA, the more efficient will be fiber. It is also known as Figure of merit. The NA is related to refractive index of core (n_1), cladding (n_2) and outside 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

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

Practical Activity 3. Demonstrate to measure the numerical aperture 'NA' of optical fiber cable.

Material required

Light source, optical fiber cable, power meter

Procedure

Step 1. Take optical fiber cables and connect them as shown in Figure 1.

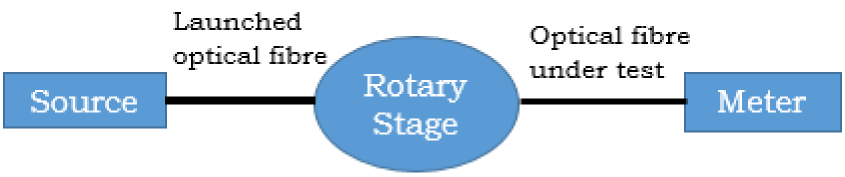


Fig. 1

Step 2. Align the two fibers along all axis i.e. X,Y,Z. So as to maximize the reading on the power meter.

Step 3. Bring the two fibers as close as possible, but make sure that they do not touch each other.

Step 4. Rotate the rotary stage by two degree, make sure that the two ferrules of the two connectors do not touch.

Step 5. Now, rotate the rotary stage to the opposite direction by two degree.

Step 6. Record the reading on the power meter for every angle.

Step 7. Check the condition shown in Figure 2, launch and receive fiber are aligned and maximum power will transfer from the launch to receive fiber.

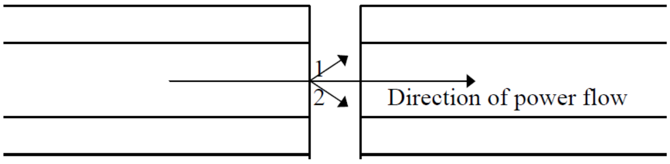


Fig. 2

Step 8. Check the condition, the receive fiber is at an angle to the launched fiber as shown in Figure 3. Observe the ray 1, it will never going to be guided inside the receive fiber. This will reduced the power in receive fiber.

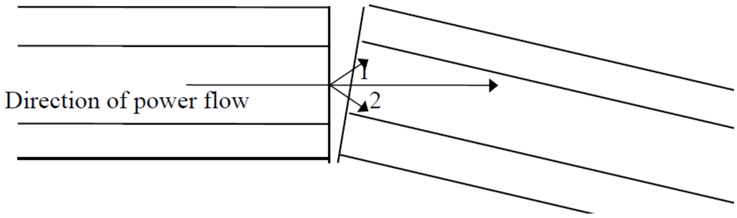


Fig. 3

Step 9. Observe that, if we continuously increase the angle of receive fiber to the launched fiber more drop in power.

Step 10. Record the power, coming out of receive fiber for every 2° increment in angle between launched and received fiber.

Table 2.1 Observation table

Angle	Power in launched fiber	Power in received fiber
-6^0		
-4^0		
-2^0		
0^0		
2^0		
4^0		
6^0		

Step 11. Plot the graph for table 1. Plot angles on the X-axis and the power on the Y-axis. After plotting the values in graph, it will be look like in Figure 4.

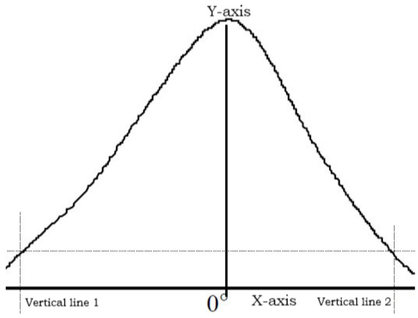


Fig. 4

Step 12. Read the angle between the two vertical lines as shown in Figure 4, divide it by 2, and take the sin of that angle. This is the Numerical Aperture of that fiber.

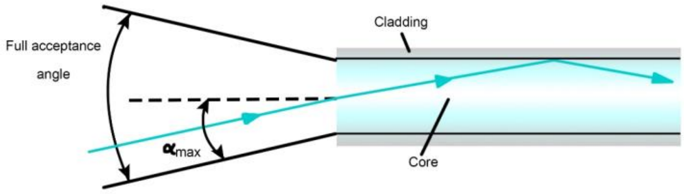
7. Acceptance angle

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

Relation between NA and acceptance angle– NA = Sin α

8. Acceptance cone

It is the cone in which light incident at acceptance angle or less than the acceptance angle and then the light can propagate through the fiber after total internal reflection.



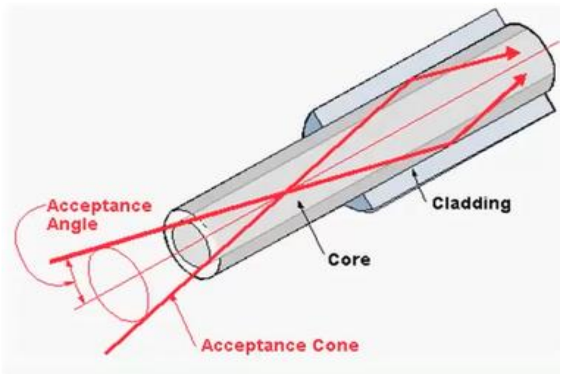


Fig. 2.18 Light propagation through the optical fiber

CLASSIFICATION OF OPTICAL FIBER

Optical fibers can be classified based on the materials used and modes of propagation of light. “Mode” refers to number of paths for the light rays within the optical fiber cable.

Material based classification– Based on the material optical fibers are classified into two types– Glass fibers and Plastic fibers

1. Glass fibers – Most of the optical fibers are made up of glass. Glass contains a material known as silica. Silica is made from the sand.

2. Plastic fibers – Plastic made fibers are obtained from polymers like Poly Methyl Meta acrylate (PMMA), polyethylene (PE), polystyrene (PS). They are useful in the harsh environment where greater strength is required.

Modes based classification – When the light is guided through the optical fiber, it exhibits certain modes. These modes can be thought of as a ray of light. Modes of the fiber are classified into two types named as single mode and multi-mode fibers as shown in Figure 2.19. Multi-mode fibers are classified as step index and graded index.

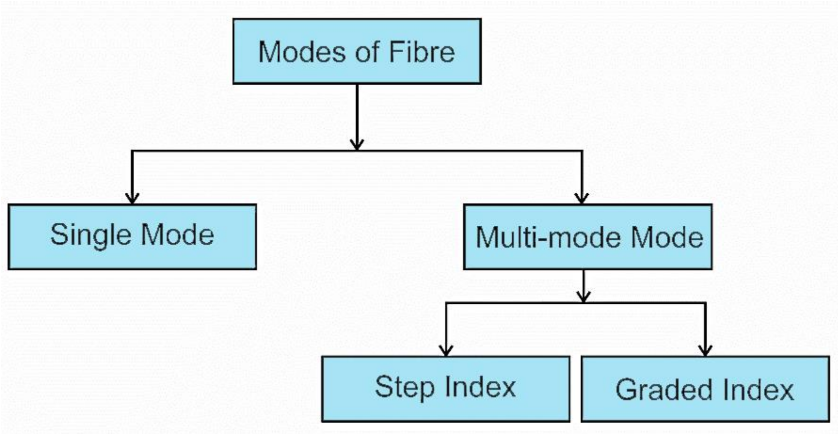


Fig. 2.19 Modes of the fiber

1. Single mode – As the name suggests in case of single mode only one light ray is used to send the data for transmission as shown in Figure 2.20.

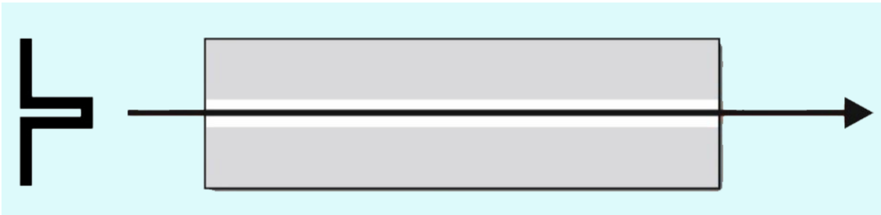


Fig. 2.20 Single mode fiber

2. Multimode fiber – As name implies, multi-mode allows more than one ray like two, three or more than that propagate along the fiber. The multiple modes from a light source move through the core in different paths as shown in Figure 2.21.

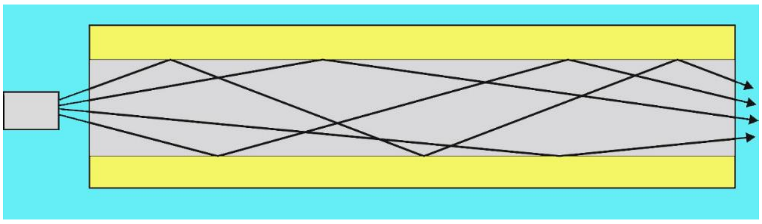


Fig. 2.21 Multimode fiber

Practical activity 3. Identify the single mode and multimode fiber

Material required

Optical fiber cable, Laser source, connector, plain white sheet.

Procedure

Step 1. Take an optical fiber cable using connector connect the laser light at one end.

Step 2. Take the other end of optical fiber cable focus on white paper.

Step 3. Observe the diameter of LASER light, which is coming out of fiber. If diameter is too broad that define it is multimode fiber or if diameter is too small that define it is single mode fiber.

Assignment 3

Suppose you have a LED light source and you want to pass the light through the fiber cable. What type of fiber you will use and why? How much light is propagated through the fiber end (use both single mode and multi-mode fiber and compare the result). Similarly, use a LASER light and analyses it for the same.

Multi-mode can further be divided into step index and graded index.

a) Step index fibers – In step index fibers, refractive index of core and cladding is in the form of staircase, which means that there is sudden change in the refractive index of core and cladding. In such fiber, light rays propagate in zigzag manner inside the core as shown in Figure 2.22.

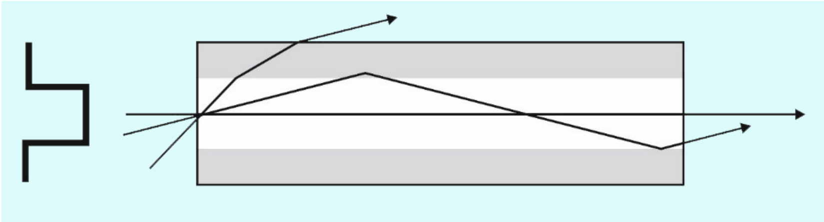


Fig. 2.22 Step index fiber

b) Graded index fibers – In graded index fiber, core itself has number of layers. The layer which is close to the axis of optical fiber has more refractive index as compare to the next layers. Or we can say that if we move from axis of optical fiber toward the cladding within the core refractive index decreases as shown in Figure 2.23. Finally, at the interfacing point of core-cladding, light will get reflected back into the core.

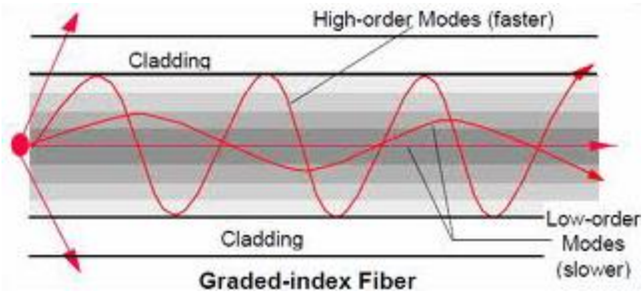
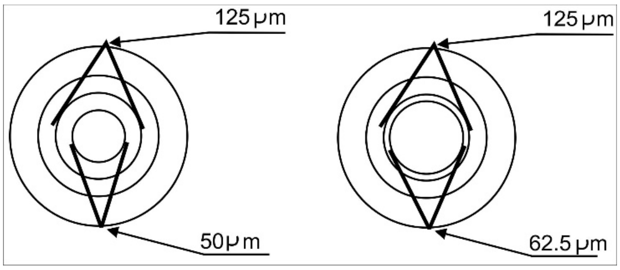


Fig. 2.23 Graded index fiber

Comparison of Single Mode and Multi-Mode

Sn	Single mode	Multimode
1	Only a single light ray passes through the core of the fiber.	More than one light ray travels along the fiber core.
	The core diameter of single mode fiber is about 8-6 micrometre (μm) whereas cladding diameter is about 125 micrometres (μm) as shown in Figure 2.18. Fig. 2.24 Core diameter of single mode fiber	The core diameter of multimode fiber is about 50 micrometre (μm) and 62.5 micrometre (μm) whereas cladding diameter is about 125 micrometres (μm) as shown in Figure 2.18.

		 Fig. 2.25 Core diameter of multimode fiber
3	Single mode fibers are used for long distance communication 50 to 60 Km	Multi-mode fibers are used for short distance communication such as building or campus up to 10-15 Km
4	Single mode fiber has higher bandwidth and less attenuation	Multi-mode fiber has lower bandwidth and higher attenuation.
5	Single mode fiber allows less dispersion	Multi-mode fiber allows more dispersion.
6	LASER (Light Amplification by Stimulated Emission of Radiation) beam are used to pass the light in the fiber.	LED (Light Emitting Diode) is used to pass the light in the fiber.

Losses in Optical fibers

Losses in optical fiber may occur while transmission. Due to decrease in the intensity of the light or spreading of the light in different direction, the signal carrying information/data may become weak and not be able to transmit the data at faster rate. This is because of degraded signal. This degradation of signal may occur due to attenuation and dispersion. Figure 2.26 shows the signal degradation in optical fiber.

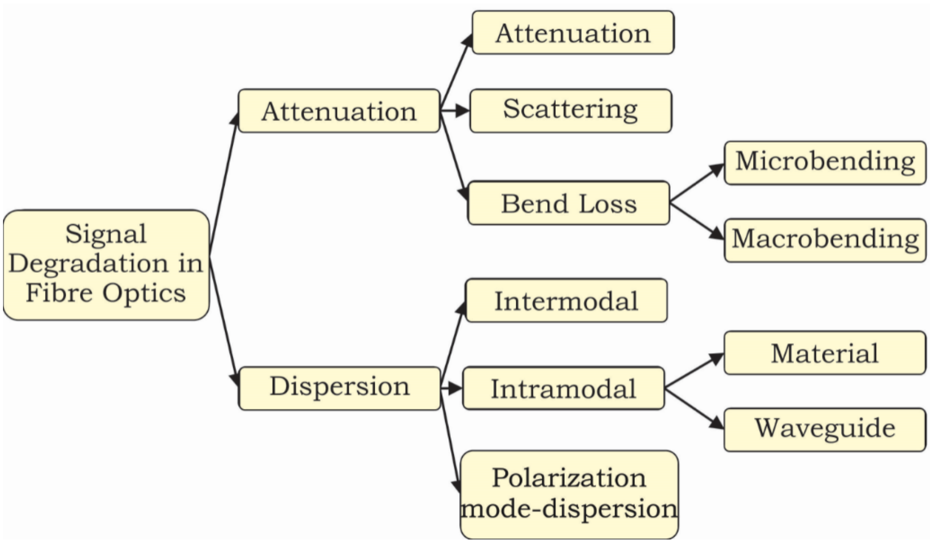


Fig. 2.26 Signal degradation and its classification in optical fiber

There are various types of losses in optical fiber. Some of them are explained below.

ATTENUATION

The strength of the light signal goes on decreasing as it travels along the length of fiber as shown in Figure 2.27. Attenuation is measured in logarithmic unit of decibel (dB).

Consider an example, 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 amplifier or repeater are required to regain the strength of the signal. The attenuation is caused due to the absorption, scattering loss and bending loss in optical fibers.

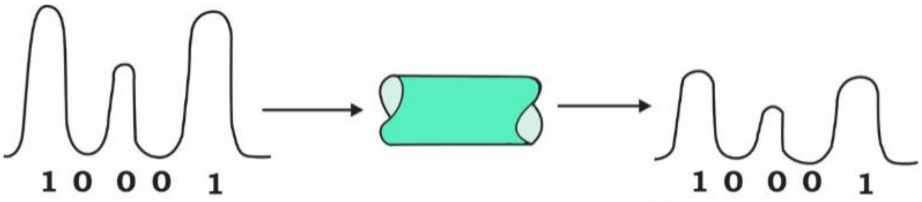


Fig. 2.27 Attenuation loss in the optical fiber

Consider an example, a signal is transferring from one end of fiber to other end. Measure the signal strength at first end, measure the signal strength at another end as shown in Figure 2.28. Now, compare and you will observe some difference.

Fig. 2.28 Attenuation loss at end of optical fiber

a) Absorption – Attenuation is caused due to fiber material. The fiber material absorbs light and its energy is converted to heat due to presence of the impurities in the fiber material.

b) Scattering – Scattering means light is dispersed in all directions as shown in Figure 2.29. It is caused because of the structural imperfection in the fiber material.

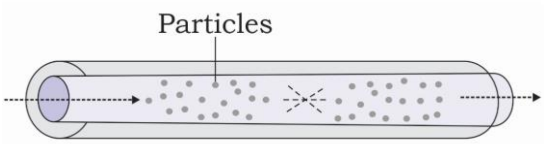


Fig. 2.29 Scattering of light by optical fiber

c) Bend loss – Incorrect fiber optic handling is one of the common problems that can results in fiber optic loss, like bend loss as shown in Figure 2.30. When fiber optical cable is bend, it causes the loss of light in the fiber. There are two general types of bends. The first is micro bending and second is macro bending.

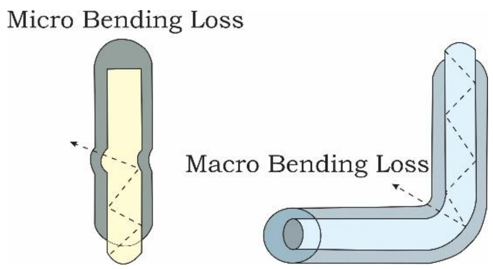


Fig. 2.30 Macro and micro bending of optical fiber

Practical activity 4. Demonstrate to calculate macro bending loss in optical fiber cable.

Material required

Optical fiber, LASER, Connector, optical power meter

Procedure

Step 1. Take an optical fiber cable, connect an laser light at one of the terminal of optical fiber cable using connector.

Step 2. Now, make sure that optical fiber cable does not have any bend. Take an optical power meter, connect at another end of optical fiber. Observe and note down the reading.

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

Step 4. Now compare the two reading you will observe a change in the reading. Reading taken during the bending of cable is much lesser. This defines the macro bending loss.

DISPERSION

Dispersion refers to the broadening or spreading of the light pulse as they travel through the fiber. Overlapping of the two signal pulses at the output of the fiber end creates error at the receiver output in transmission channel. It limits the information carrying capacity of the fiber as shown in Figure 2.23.

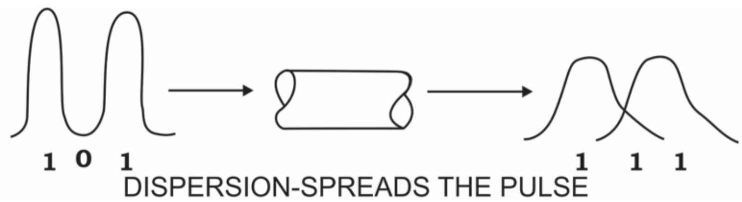


Fig. 2.31 Dispersion of the optical fiber

Dispersion is classified as – a) Inter-modal dispersion and b) Intra-modal dispersion

a) Inter-modal dispersion – Inter-modal dispersion occurs in multi-mode fiber as shown in Figure 2.32. When a light pulse is injected into the fiber, some part of light energy does not reach the end of the fiber simultaneously. In multi-mode fibers different rays travel inside the fibers with different velocity and they arrive at the fiber end at different times. However, sometimes there is overlapping of the rays at the fiber output. Because of this, the ray spreads or dispersed and it is difficult to distinguish between them at the output of the receiver. For example, if we are sending 101 as digital bit then at receiver it is received as 111.

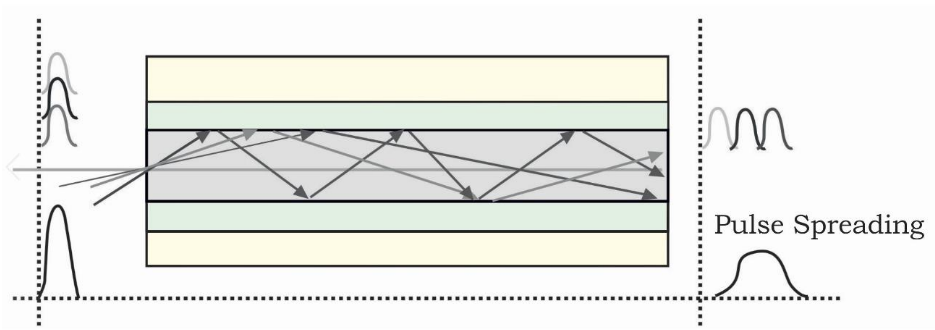


Fig. 2.32 Inter-modal Dispersion

b) Intramodal or Chromatic dispersion– Intramodal is also known as chromatic dispersion. Intramodal dispersion mainly occurs in single mode fiber as shown in Figure 2.33. Basically, chroma word represents colour. Intramodal dispersion occurs because a light pulse is made up of different wavelengths, each traveling at different speeds down the fiber. For example, white light has seven colours and when it passes through the fiber the blue light travels faster and red-light travels slower.

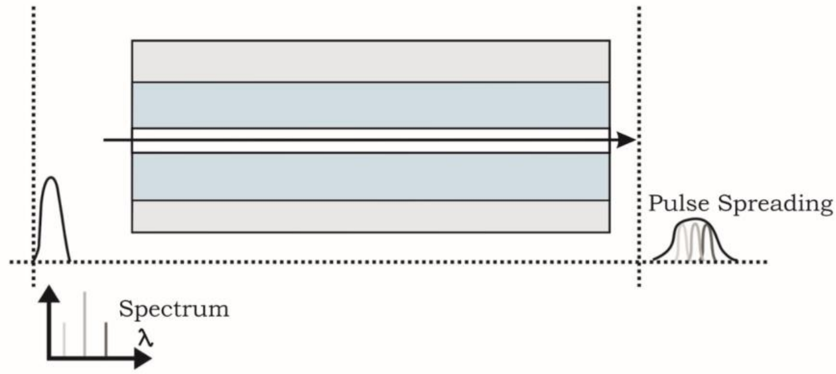


Fig. 2.33 Intramodal or Chromatic dispersion

Intramodal is divided into two parts– Material dispersion, Waveguide dispersion

Material dispersion – Due to dispersive nature of the glass material dispersion occurs. For example, Prism made up of glass and when white light is passed, it split into seven colours as shown in Figure 2.34. This type of dispersion is due to the property of material in fiberglass, which leads to spreading of the light inside the fiber and they arrive at fiber end at different times.

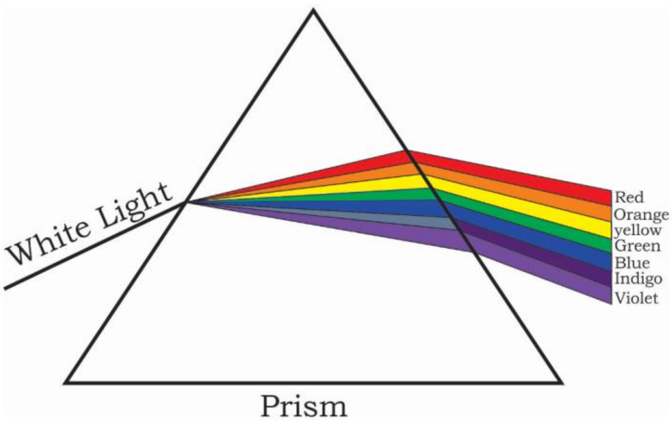


Fig. 2.34 Light is passed it split into seven colours by glass prism

Waveguide dispersion – This type of dispersion occurs because a single mode fiber restricts about 80% of the optical power to the core while rest 20% light propagates in the cladding. Light enters in the cladding of optical fiber cable due to different wavelength as shown in Figure 2.35. This type of dispersion mainly occurs in single mode fiber.

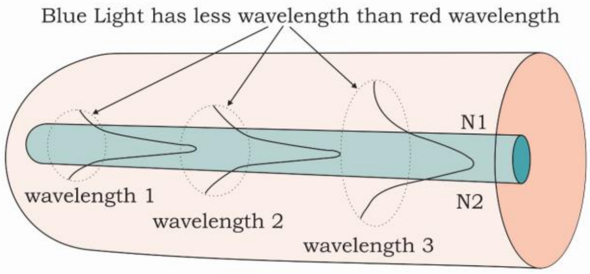


Fig. 2.35 Waveguide dispersion

Practical activity 5. Demonstrate the dispersion of white light using prism.

Material required

Dark room, Light source, Plane white paper, prism.

Procedure

Step 1. Consider a prism, clean its surface. Placed it on the white plane paper as shown in Figure 1.

Fig. 1

Step 2. Now, place a light source as shown in Figure 2.

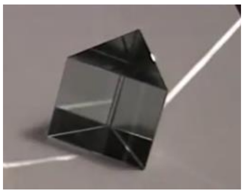


Fig. 2

Step 3. In dark room, turn ON the light source as shown in Figure 3.

Fig. 3

Observe light is divided into seven colours.

Check Your Progress

A. Multiple Choice Questions

1. In which of the following pattern electric and magnetic components of EM waves oriented. (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 light possess (a) Be neither a wave nor a particle (b) Be primarily a wave (c) Have characteristics of both a wave and a particle (d) Be primarily a particle
3. Which of the following forms of electromagnetic wave has a lowest 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 medium B has 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°

B. Fill in the blanks

1. Speed of light from coming from the sun to earth is_______________.
2. Refraction at the air -water interface leads to____________ of light.
3. If light is passed through the glass to air and angle of transmitted light is greater than the critical angle then it leads to___________________
4. White light coming from the sun is composed of_______ colours.
5. Phenomena of Total Internal Reflection takes place in___________ cable.
6. Light through the optical fiber propagates inside core at a speed of ____________.

C. True and False

1. If white light is passed through the prism the light splits into seven colours.
2. Total internal reflection is a method which allows the light to pass through the cladding part of the fiber
3. Diameter of the core is larger than the cladding
4. Buffer-coating is made up of steel.
5. Buffering to the core- cladding provides protection of the fiber.
6. Speed of light becomes larger when it travels from rarer medium to denser medium.
7. Speed of light becomes lesser when it travels from denser medium to rarer medium.

D. Answer in short

1. Why optical fiber core and cladding is covered with buffer-coating?

2. List the seven colours of the rainbow and draw them in your notebook.
3. What is electromagnetic spectrum?
4. For what range of electromagnetic spectrum optical fiber are used.
5. How light is injected into optical fiber?
6. What type of information is carried by light i.e. analog or digital and state the reason?
7. If signal gets weakened, then what measure is taken to restore it?

Session 3: Light Source and Detector

Light source plays a significant part in an optical fiber communication system. The basic optical fiber system consists of transmitter, optical fiber and receiver. The transmitter has a light source, which is modulated by a suitable drive circuit. Optical sources are the active components. Their primary function is to convert the electrical energy into the light energy. The optical signal is then coupled into the optical fiber cable. The most commonly sources of light are light emitting diode and Light Amplification by Stimulated Emission of Radiation (LASER). In this chapter, we will study about the light sources and detectors used in optical fiber transmission

LIGHT EMITTING DIODE

A basic LED is a light source. It has P-region and N-region as shown in Figure 3.1(a). When the LED is forward biased i.e. positive terminal of DC voltage is applied to the P-region and negative terminal of voltage to the N-region as shown in Figure 3.1(b). In forward bias, LED pass the electric current. As current flows through the LED, the junction where the p-type and n-type regions combine, emits random photons. This process is referred to as spontaneous emission.

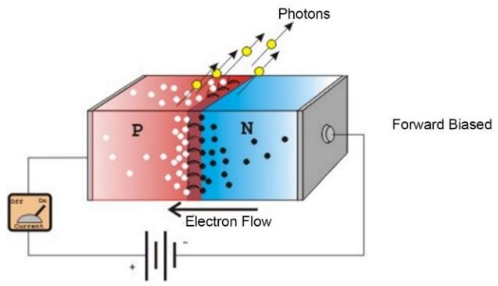


Fig. 3.1(a) P-N junction of the LED

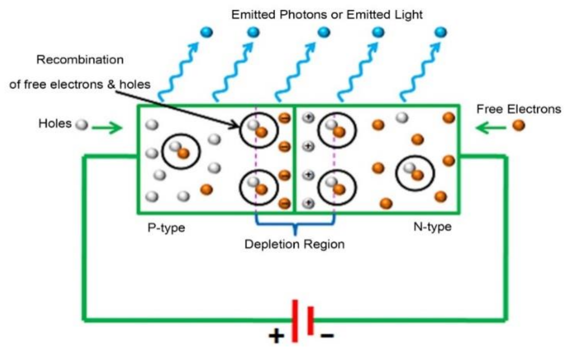


Fig. 3.2(b) LED emitting photons

Practical Activity 1. Identify the Light Emitting Diode terminals.

Material required

Light emitting diode, multimeter

Procedure

Step 1. Consider a LED, manually observe the terminals of light emitting diode. Observe, if the LED has one long and one short terminals. If it is so, that defines long terminals as positive and short terminal as negative as shown in Figure 1.

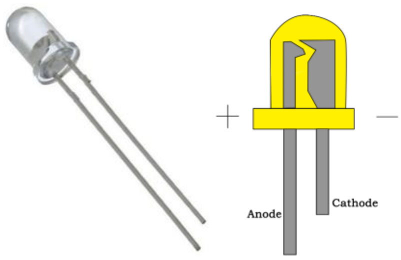


Fig. 1

Step 2. Positive terminal is also referred as anode, negative terminal is also referred as cathode.

Step 3. If terminals are of same length, in that case take a multimeter turn it into a diode mode as shown in Figure 2.

Fig. 2

Step 4. Connect the positive cord and negative cord of the multimeter to the terminals of LED. If LED glow that define, terminal on which red cord is connected is anode, and terminal on which black cord is connected is cathode as shown in Figure 3.

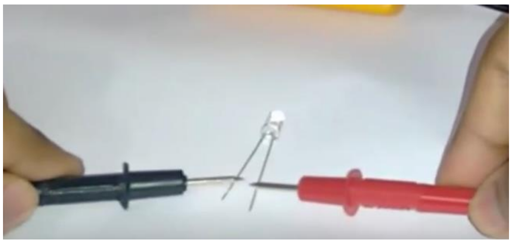


Fig. 3

Step 5. If LED is not glowing, in that case interchange the terminals.

More to know

Spontaneous Emission – Word spontaneous defines "happening in a natural, way". Emission defines "discharge of something like radiation." Thus, spontaneous emission is the sudden discharge of photons from the material surface as shown in Figure 3.3.

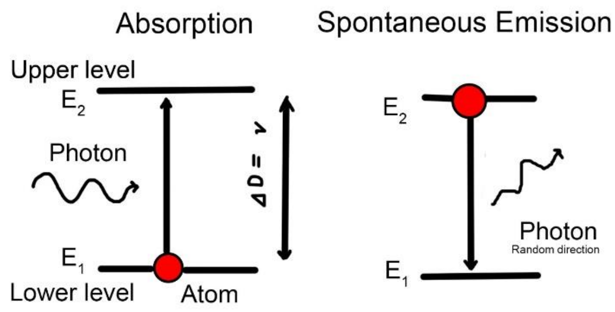


Fig. 3.3 Spontaneous emission of photon

Photons emitted from the junction, where the p-type and n-type regions meet. These photons are neither in same phase nor in same direction. These out-of-phase photons, which are coming out of junction are called as incoherent light. As all the photons are out of phase, it is difficult to focus all the photons in the optical fiber cable. Because of this, only a small percentage of the photons emitted will be get into the optical fiber. Figure 3.3 shows the out-of-phase photons spontaneously emitted from the LED.

More to know

Coherent– The word coherent defines having in same phase.

Incoherent– The word in coherent means not in same phase.

Concept of coherent and incoherent can be better illustrated in Figure 3.4.

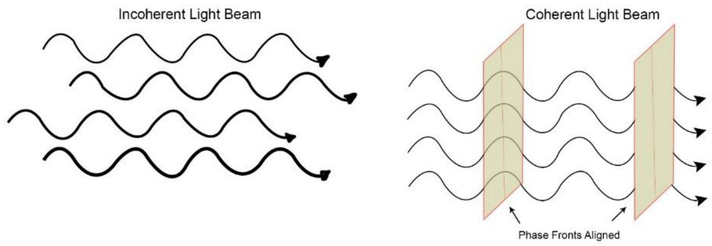


Fig. 3.4 (a) Incoherent light beam (b) Coherent light beam

More to know

Semiconductor – Conductivity of semiconductors materials lies between conductivity of conductors and insulators. Electronic devices are made up of semiconductor material. Silicon and germanium are the basic raw material used to manufacture the integrated circuits (IC) in semiconductor industry. Semiconductors material are of two types i.e. Intrinsic and Extrinsic semiconductor.

Intrinsic Semiconductor – It is a pure form of a semiconductor. The pure word here specifies that this semiconductor does not contain any other impurity atom. For example, pure form of silicon contains only the atoms of silicon; no other impurity atom is present in the silicon. The absence of impurity atom results in less conductivity in semiconducting material. To improve the conductivity of intrinsic semiconductor, impurity atoms are added, which is discussed in the extrinsic semiconductor.

Extrinsic Semiconductor – When impurity atoms are added in intrinsic semiconductor, then it is called as extrinsic semiconductor. The extrinsic semiconductors are also known as impure semiconductor. Extrinsic semiconductors are classified as–

- N-type semiconductor
- P-type semiconductor

For example, if Arsenic (As) is added to pure silicon, then it will form P-type semiconductor, which is extrinsic in nature. Presence of impurity atoms e.g. Arsenic (As) in the pure form of silicon. The process of adding of an impurity atom in a semiconductor material is called as doping. Doping will increase the conductivity of a semiconductor. Since, the atomic number of silicon is 14; electronic configuration of silicon is 2, 8, and 4. Thus, silicon has 4 electrons in the outer most shell. In order to increase the conductivity more and more free electrons haves to be added. As silicon has 4 electrons in its outermost shell, so it is better to add an impurity atom having valence i.e. number of atoms in outermost shell as either 5 (Penta) or 3 (tri). The atoms which have 5 electrons in its outermost shell are known as pentavalent. The atoms which have 3 electrons in its outermost shell are known as trivalent. When trivalent impurity atom is added an extrinsic semiconductor is formed which is known as P-type semiconductor. When pentavalent impurity atom is added an extrinsic semiconductor is formed which is known as N-type semiconductor.

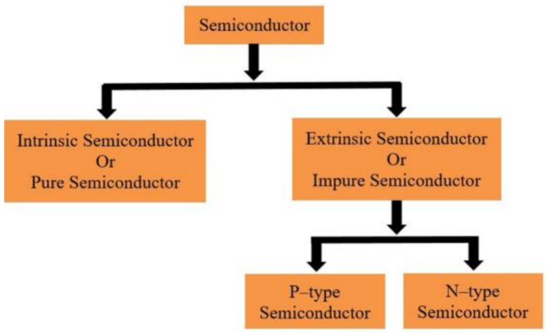


Fig. 3.5 Classification of semiconductor

More to know

Diode – When two semiconductors i.e. P-type and N-type semiconductor are combined to form a new component known as diode. "Di" defines two, thus diode has two terminals electronic component as shown in Figure 3.6 (a) and (b).

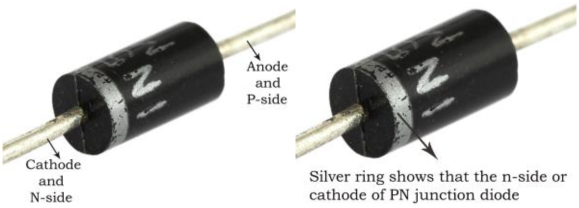


Fig. 3.6 (a) Diode (b) Silver ring in diode

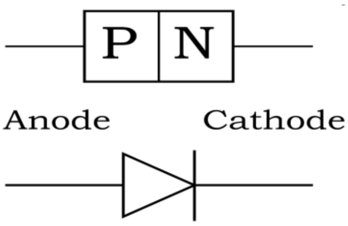


Fig. 3.7 Diode symbol

Diode is use in many applications. Diode passes current only in one direction. Terminal at P-side called as anode and terminal at N-side called as cathode. When anode and cathode terminal of PN-junction diode are connected to external voltage sources, such that the positive end of a battery is connected to anode and negative end of the battery is connected to the cathode diode is said to be forward biased or we can say that diode will acts as a close switch as it will turned turn 'ON' as shown in Figure 3.8. In a forward-biased condition, the diode will pass the current.

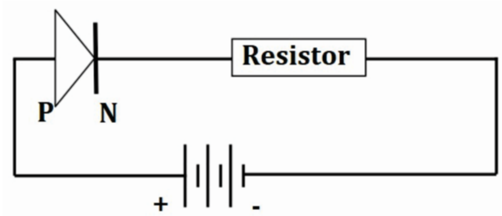


Fig. 3.8 Current will flow in this circuit as diode is in forward bias

When the P-side of diode are connected to the negative terminal of the battery and N-side of the diode is connected to positive terminal of the battery, diode is said to be reverse biased or we can say that diode will acts as an open switch as it will get turned 'OFF' as shown in Figure 3.9. In reverse-biased condition, the diode will not pass the current through.

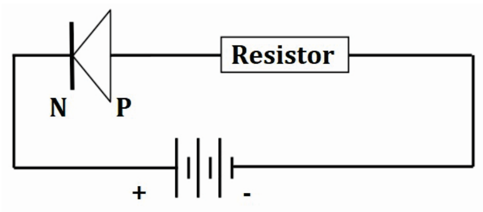


Fig. 3.9 Current will not flow in this circuit as diode is in reverse bias

STRUCTURE OF LED

Structuring of electronic components is very precise. It plays a major role in the performance of electronic components. Based on the amount of light emitted by the LED, structure of LEDs is classified as – S-LED and E-LED

S-LED– S-LED is the surface emitter LED. As the name suggest, in this type of LED, emission of photons is from the surface area. It is confined to the small circular area of LED. The diameter of the circular area is around 20 to 50 micrometer (10^{-6} m). Structural layout of surface emitter LED is shown in Figure 3.10.

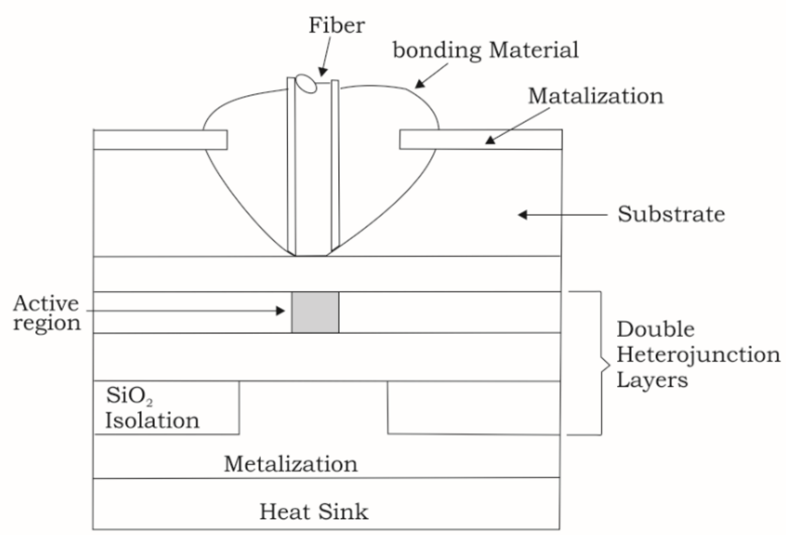


Fig. 3.10 Light emission from surface emitting LED

E-LED – E-LED is the edge emitter LED. As the name suggest, in this type of LED, emission of photons is from the edge of the LED. In this type of LED numbers of layers of semiconducting material are used as shown in Figure 3.11. The area through which light can be emitting out is 8 to 10 micrometer (10^{-6} m) in thickness and up to 150 micrometer (10^{-6} m) in width.

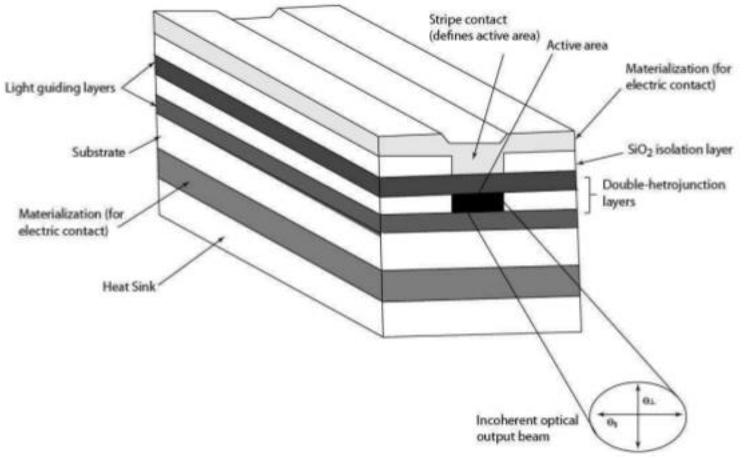


Fig. 3.11 Light emission from edge emitting LED

Advantages of LED

- LEDs are preferred light sources for short distance.
- LEDs are used in optical fiber network because of the following reasons–
- Inexpensive
- Robust
- Long life
- LED can switched on and off at high speeds

Disadvantages of LED

- The maximum light output of an LED is typically very low about 100 microwatts.
- LEDs produce photons of different wavelength, which is undesired in case of optical fiber communication.
- The light produced is neither directional nor coherent. Therefore, it is difficult to couple the LEDs output to the single-mode fiber.
- It is too hard to get the light into the narrow core.

Assignment 1

List out the places where the LED is used at home. Also, discuss about the colours displayed by the LED.

LASER SOURCES

The term LASER stands for "Light Amplification by Stimulated Emission of radiation". Laser is a device that amplifies or increases the intensity of light. It produces directional light beam. Laser not only amplifies or increases the intensity of light but also generates the light. Laser emits light through a process called stimulated emission of radiation. Some lasers generate visible light, but others generate ultraviolet or infrared rays, which are invisible as shown in Figure 3.12.

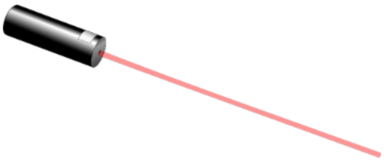


Fig. 3.12 Beam of light emitting out of LASER

Inventor's dairy

Einstein gave the theoretical basis for the development of laser in 1917, when he predicted the possibility of stimulated emission. In 1954, C.H. Townes and his co-workers put Einstein's prediction for practical realization.

More to know

Stimulated emission– Stimulated means encourage development. So in this type of emission electron are used to encourage or excite other electrons to produce light energy as shown in Figure 3.13.

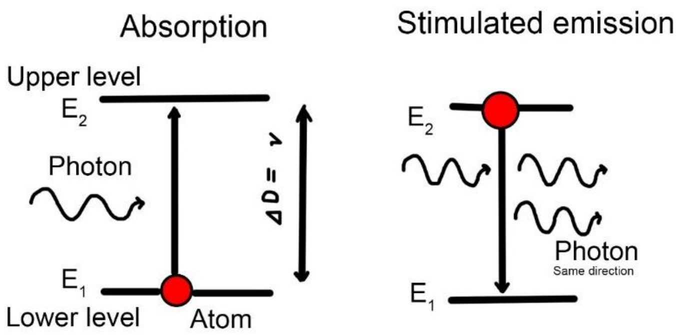


Fig. 3.13 Stimulated emission of photons

Laser light has the following characteristics–

- Monochromatic light which means that single wavelength.
- Coherence which means that phase aligned.
- Good directivity which means that good light focusing or beam does not expand.
- High energy density as high brightness.

The conventional light sources such as electric bulb or tube light does not emit highly directional and coherent light whereas lasers produce highly directional, monochromatic, coherent light beam.

- Lasers are classified into various types based on medium used to emit laser light.
- Semiconductor laser
- Solid-state laser
- Gas laser
- Liquid laser

As we are discussing optical fiber communication. For this reason, we are focusing on lasers which are used in optical fiber communication. Semiconductor laser are widely used in optical fiber communication. They are also known as laser diode. These laser diodes are made up of extrinsic and intrinsic semiconductor as shown in Figure 3.14. These semiconductor devices emit light in the form of laser, when voltage is applied to the P-N junction of compound semiconductor. Semiconductor lasers are smaller and lighter in weight than gas and other type of lasers. Semiconductor laser are widely used for application Blue-ray Disc, DVD, light sources for optical fiber communications.

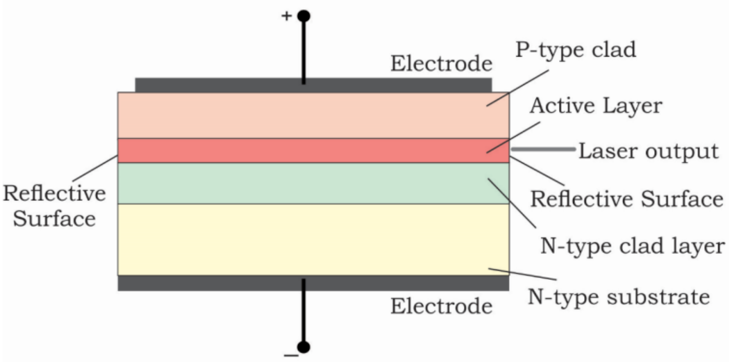


Fig. 3.14 Basic structure of a LASER diode

MECHANISM OF SEMICONDUCTOR LASER LIGHT EMISSION

In simple electric bulb, light produced by converting electricity into thermal energy. But, semiconductor lasers generate light, directly from electric power.

Light bulb→ Electrical energy → Thermal energy → Light

Semiconductor laser → Electrical energy → Light

As we know, that atom has different energy level. Each energy level has their own energies, for example, in first orbit of an atom energy level is E_1, second orbit has an energy level E_2 and so on as shown in Figure 3.15. In general, when electron jumps from a higher energy level to a lower energy level, it emits light or photons. The energy of the emitted photon is equal to the energy difference between the energy levels as shown in 3.15. This emitted energy from each photon is get collected in a space called as cavity in the laser. Energy which is collected in the form of photons is used to produce a high intensity, directional, coherent, monochromatic beam of light.

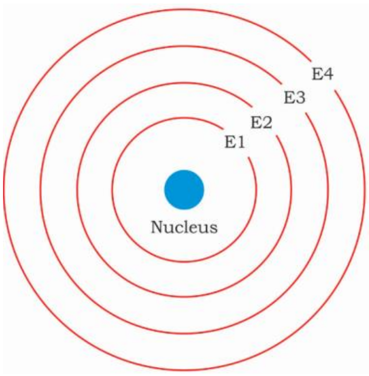


Fig. 3.15 Different energy level of an atom

Plane mirror is use to reflect generated photons are repeatedly with in the cavity of laser. This will enhance the intensity of light. High intense, phase-aligned laser light is emitted by stimulated emission. This process remain continue as external voltage is applied to energize the photons. This will result in continuous laser light emission as shown in Figure as shown in Figure 3.16.

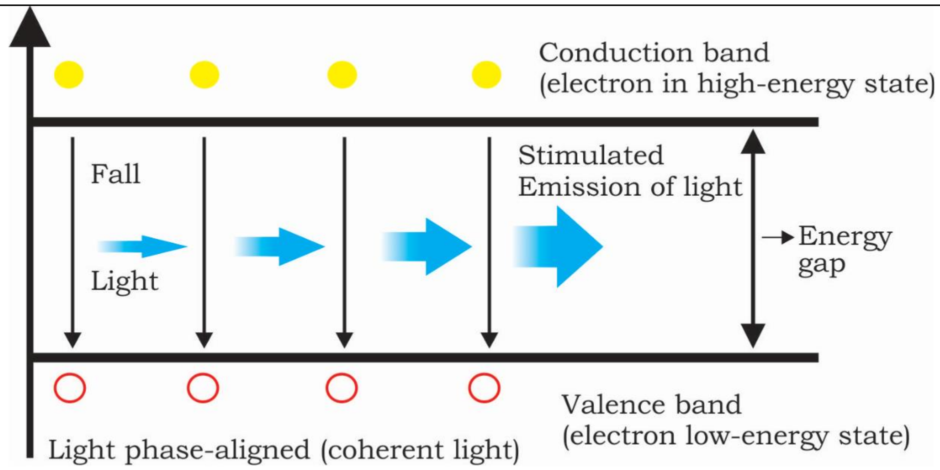


Fig. 3.16 Mechanism of semiconductor LASER light emission

Application of semiconductor laser is based on wavelength of laser light. The colour of laser beam can be change by changing laser active layer material.

Table 3.1 Different colour output of laser for different material

Laser material	Colour	Wavelength	Application
GaInN	400 - 530nm	Blue-violet to Green	Blu-Ray Disc/Projector
AlGaInP	635 - 680nm	Red	DVD/Projector
AlGaAs	780 - 850nm	Infrared	CD/Printer/Optical communications/3D sensor
InGaAs	900 - 980nm	Infrared	3D sensor
InGaAsP	1300/1550nm	Infrared	Optical communications

Light and wavelength

Light is also possessing wave like nature. Therefore, it has a wavelength, frequency and amplitude. Figure 3.17 illustrate the electromagnetic spectrum.

Radio wave → Microwave → Infrared ray → Visible light (Red, Orange, Yellow, Green, Blue, Violet) Ultraviolet ray X-ray

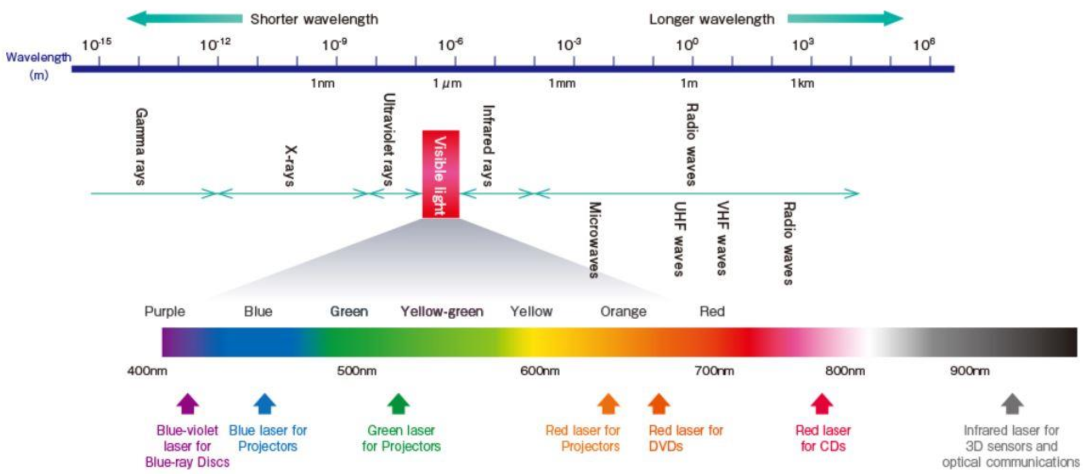


Fig. 3.17 Illustration of Light and wavelength

For optical fiber communication, long-wavelength lasers with a wavelength of 1300 to 1600 nm have low transmission loss inside optical fibers, so they are used as light sources for optical fiber communications.

Practical Activity 2. Determine the wavelength of laser light using diffraction grating.

Material required

Spectrometer, Diffraction grating, He-Ne laser or Semiconductor laser, optical bench and scale arrangement

Procedure

Step 1. Take a LASER as shown in Figure 1, mount it on the optical bench using laser stand.

Fig. 1 LASER source

Step 2. Place the grating stand in front of laser light at certain distance. Fix a diffraction grating on grating stand.

Note: Diffraction grating is an optical device that splits and diffracts light into several beams travelling in different directions.

Fig. 2 Diffraction grating

Step 3. Now, switch ON the Laser. Place the scale arrangement next to the grating stand at distance 'X' as shown in Figure 1. Also, place the diffraction grading in the grading stand.

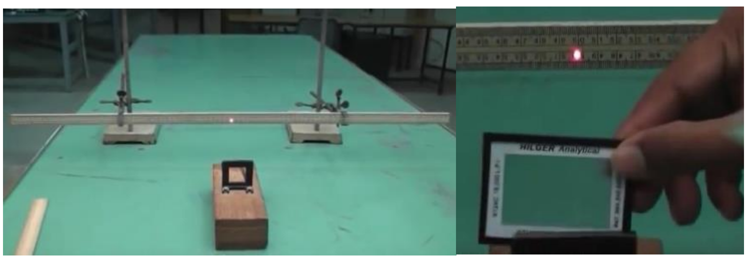


Fig. 3

Step 4. The relative orientation of laser with respect to grating is adjusted such that spectral spots are observed on the scale as shown in Figure 4. Figure 3 also shows the distance 'X' between the diffraction grading and scale. Note down the reading of 'X' in table 1.

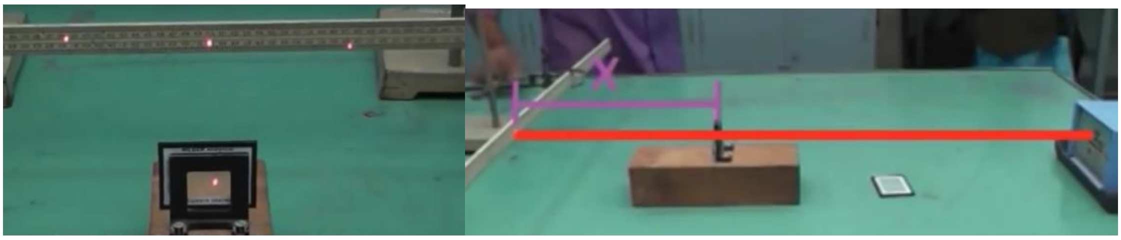


Fig. 4

Step 5. Adjust the distance between scale and grating. So that, at least two spots are clearly seen either side of the central spot. Measure the distance of both first order spot w.r.t central spot as shown in Figure 5. In same way, measure the distance of second order spot w.r.t to central spot.

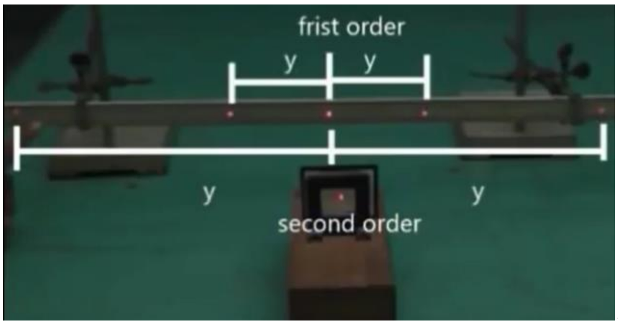


Fig. 5

Step 6. Note down the reading in tabular form as shown in table 1.

Table 1

SN	Order (n)	X (in cm)	Y (in cm)			θ = tan -1 (Y / X)	Sin θ	λ (in m)
			LHS	RHS	Average			
1.	1							
2.	2							
3.	1							
4.	2							

Note– Note down the number of lines per meter reading mention on the grating. It will be 'N'

λ= Sin θ /m.N

'm' is the order of spectrum

'N' number of lines per meter in grating

Wavelength of laser light, λ =

COUPLING OF LIGHT SOURCE TO THE fiber

Coupling is the act of joining two things together. In this case, two things are light source and optical fiber. The coupling efficiency is primarily dependent on the core diameter and numerical aperture (NA) of the fiber. Secondly, coupling depends upon the output of light source, which we are using i.e. light emitting diode or laser diode.

In this section, we will compare the performance characteristics of the LED and laser light source. The performance of a light source can be judged in several areas such as output pattern, wavelength, spectral width, output power. These performance areas determine type of optical fiber, transmission distance, and data rate. However, when it comes to ultra-high-speed, long-distance data transmission the LASERS are suitable.

LED output pattern – LED used in fiber optic light sources are couple as much light as possible into the core of the optical fiber. The LED has a wide output pattern. LED does not couple all its light energy into the core of a multimode optical fiber. LED as a source of light is best suited for single mode optical fiber. LED fiber coupling is shown in the Figure 3.18.

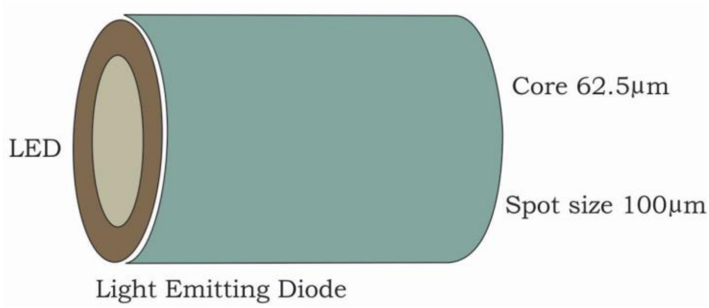


Fig. 3.18 Coupling of light in single mode fiber using LED source

Laser output pattern – Unlike the LED, the laser light source has a narrow output pattern. Laser light sources couple light efficiently into the core of optical fiber cable. Laser light sources are designed for either multi-mode or single-mode applications. LASER output pattern is shown in Figure 3.19.

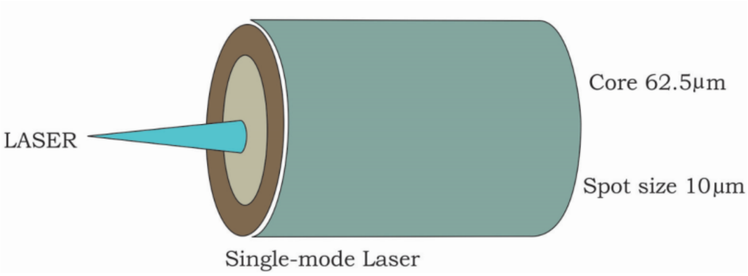


Fig. 3.19 Coupling of light in fiber by LASER

More to know

Difference between LASER light and White light

Light can be understood as consisting of waves traveling through space. Light occurs in different wavelengths, just as waves in ocean vary in length. Wavelength is the distance between peaks on a light wave, as represented in Figure 3.20.

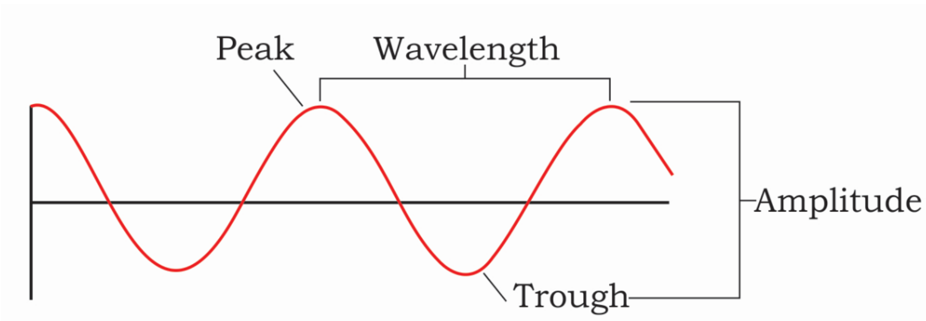


Fig. 3.20 Parameter of Light Waves

The colour of light depends on its wavelength. Violet light has the shortest wavelength of all visible colours, and red light has the longest, as shown in Figure 3.21. White light is a combination of all visible colours or wavelengths.

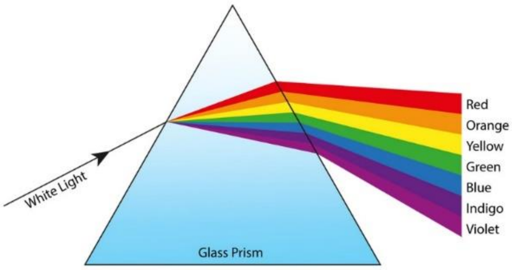


Fig. 3.21 White light through the prism having different wavelength

Laser light as shown in Figure 3.22, unlike ordinary light, is unique in that it usually consists of only a single colour of light. Mono-chromaticity is the laser light property of containing only one colour.

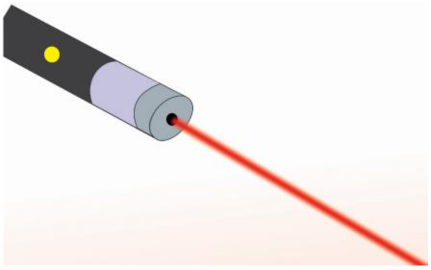


Fig. 3.22 LASER Beam

The light from an ordinary source like a light bulb radiates away from the source in all directions, as shown in Figure 3.23. This spreading or divergence of ordinary light is what makes it so useful for lighting home and workplace.

Fig. 3.23 Incandescent Bulb

Laser light is directional. By comparison, the light emitted by a laser diverges very little, as shown in Figure 3.24.

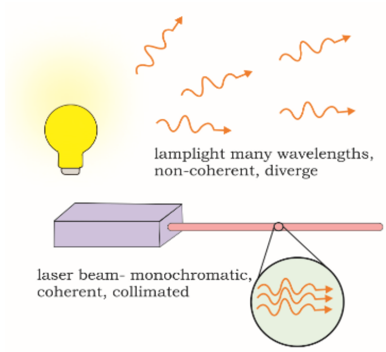


Fig. 3.24 Highly directional beam of LASER

Non-coherent light waves produced by ordinary sources do not form an orderly pattern. They combine in a random fashion like incandescent sources, Light-emitting diodes (LED).

Difference between LED and LASERS

Comparison of LEDs and LASERs on different parameters is shown in table 3.2.

Table 3.2 Comparison of LED and LASER

Specifications	LEDs	LASERs
Output Power	Linearly proportional to drive current	Proportional to current above threshold
Drive Current	Drive Current– 50 to 100 mA	Threshold Current– 5 to 40 mA
Coupled Power	Moderate	High
Speed	Slower than laser 0.5 micro seconds	Faster than average LED
Output Pattern	Wide	Narrower
Bandwidth	Moderate	High
Wavelengths Available	0.66 µm to 1.65 µm	0.78 µm to 1.65 µm
fiber Type	Multimode Only	Single mode, Multimode
Ease of use	Easier	Harder
Lifetime	Longer than laser	Long
Cost	Less costly	Costlier
Applications	Moderate distance, low data rates	Long Distance, High Data rates

PHOTO-DETECTOR

Photo-detector or optical detectors are used to convert variation in optical power into corresponding variation in the electric current. Photo-detector is essential component in the optical fiber communication. For optical fiber communication purpose most suited photo-detector are PIN diode i.e. p-type-Intrinsic-n-type.

More to know

PIN diode is three-layer diode i.e. P-type layer, Intrinsic layer, N-type layer as shown in Figure 3.25. Intrinsic layer is sandwich between p-type and n-type layer. As compare to normal p-n junction diode, this PIN diode has large surface area. When light fall on this area it will generate new charge carriers. This will result in the generation of photocurrent as shown in Figure 3.26. The PIN diode is used in a variety of different applications from low frequencies up to high radio frequencies. The properties introduced by the intrinsic layer make it suitable for a number of applications where ordinary P-N junction diodes are less suitable.

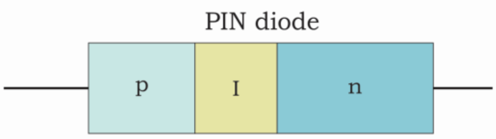


Fig. 3.25 PIN diode

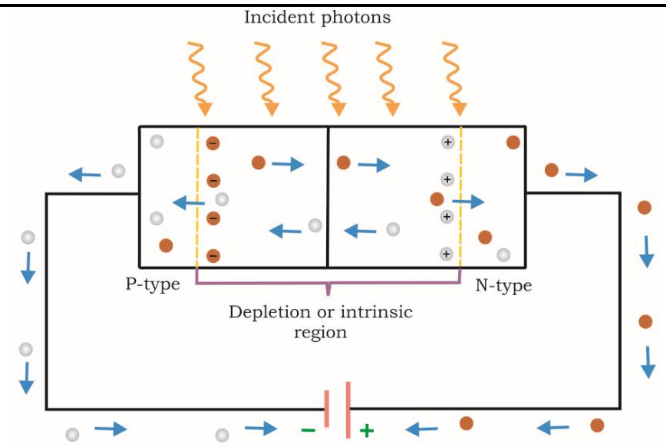


Fig. 3.26 Working of PIN photodiode

Check Your Progress

A. Multiple Choice Questions

1. LEDs emit photons that are out of phase; this is referred to as light ___________ (a) Coherent (b) Incoherent (c) Stimulated (d) Spontaneous
2. Lasers emit photons that are in phase, this is referred to as light _____________ (a) Coherent (b) Incoherent (c) Stimulated (d)Spontaneous
3. The photons emitted from a laser have the same wavelength and are in phase; this is referred to as light. (a) Coherent (b) Incoherent (c) Stimulated (d) Spontaneous
4. LEDs have an output pattern when compared to the output pattern of a laser. (a) Narrow (b) Wide (c) Coherent (d) Stimulated
5. LEDs with visible wavelengths are typically used for ________distance fiber optic communication systems. (a) Long (b) Short (c) Both short and long (d) Sometime long, sometime short
6. Long wavelength 1300 nm LEDs are suited for _______transmission distance, than short wavelength 850 nm LEDs. (a) Long (b) Short (c) Both short and long (d) Sometime long, sometime short
7. The optical output power of a laser ____________ than the optical output power of an LED. (a) Wider (b) Greater (c) Narrower (d) Less

B. Fill in the Blanks

1. The amount of light energy coupled into the core of an optical fiber depends on the _______ and ___ of the optical fiber.
2. LED radiation should not degrade more than __________over its lifetime.
3. Laser light sources have a modulation speed __________than LEDs.
4. LED transmitters are designed to support only ____________modulation.
5. Bandwidth of LED is____________ and bandwidth of LAERS is____________.
6. LEDs are suitable for use with _______________ mode fiber.
7. LASER s is suitable for use with _______________ mode fiber.
8. Edge-emitting LEDs have ______ hetero-junction structure.

C. Short Answers Questions

1. Make comparison between LED and LASER diodes?
2. Explain the working of the LASER diodes?
3. Discuss the principle of LASER diode?
4. What is diode?
5. What are advantages and disadvantages of LED and LASER diodes?
6. What is p-n junction?
7. Explain S-LED and E-LED.
8. Name some of the cpmmonly use LASER.
9. Comparison between LASER light and white light.
10. Differentiate spontaneous and stimulated emission.

Module 2	Tools and equipment and safety precautions

Module Overview

In this module, students will explore essential tools and equipment used in the field of optical fiber technology. Focuses on identifying and understanding various optical fiber tools, including cleavers, splicers, and testers, along with their specific functions and applications. students will delve into optical fiber cable specifications, learning about key characteristics such as core diameter, refractive index profile, and attenuation, which are crucial for selecting the appropriate fiber for different communication systems. By the end of this module, students will gain practical knowledge and insights into the tools and specifications necessary for effective optical fiber installation and maintenance.

Learning Outcomes

After completing this module, you will be able to:

- Describe the various tools used in optical fiber installation and maintenance, including their functions and applications.
- Explain the key specifications of optical fiber cables, such as core diameter, refractive index, and attenuation, enabling them to select appropriate cables for specific applications.

Module Structure

Session 1. Optical fiber tools and equipment

Session 2. Optical fiber cable specification

Session 1. Optical fiber tools and equipment

Tools and equipment play a crucial role in the optical fiber installation. Various tools and equipment used for the installation of optical fiber cable in the network are optical fiber stripper, scissors, cleaver, v-groove, screwdriver kit, crimping tool kit, etc. In this chapter, we will learn basic tools and equipment used in optical fiber installation.

BASIC HAND TOOLS

Basic hand tools are used in our day-to-day life whenever we are dealing with any work of repairing, drilling, cutting. Some of the basic tools are discussed below–

Screwdriver– Screw driver is a hand tool specifically designed to insert and tighten the screws as well to loosen and remove screws from the job. A screwdriver parts are shown in Figure 4.1. Force is applied to the screwdriver to tight it in clockwise direction and to loosen it in anticlockwise direction. A typical simple screwdriver has a handle and a shaft.

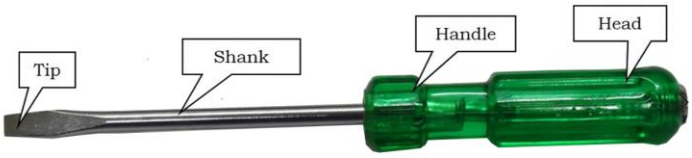


Fig. 4.1 Parts of Screwdriver

Practical Activity 1. Demonstrate use of screwdriver

Material required

Screwdriver, screw of different slots.

Procedure

Step 1. Take a slot head screwdriver, it is the most common screwdriver as shown in Figure 1. Fix it on the slot of traditional screw, apply a gentle pressure and rotate it clockwise direction to tighten the screw as shown in Figure 2. Rotate in anti-clockwise direction to loosen the screw as shown in Figure 3.

Fig. 1 Slotted head screwdriver

Fig. 2 Slotted head screwdriver tightening the screw

Fig. 3 Slotted head screwdriver loosening the screw

Step 2. Take a Phillips head screwdriver as shown in Figure 4. Fix it on the star slot of a screw, apply a gentle pressure and rotate it clockwise direction to tighten the screw as shown in Figure 5. Rotate in anti-clockwise direction to loosen the screw as shown in Figure 6.



Fig. 4 Phillip head screwdriver, Fig. 5 Phillip screwdriver tightening the screw, Fig. 6 Phillip screwdriver loosening the screw

Step 3. Now, to maintain screwdriver technician must practise the following points.

- Use screwdrivers for driving screws only.
- Notice your screwdriver's tip, if is getting bit rounded or chipped, avoid using it. Screwdriver may slip from the screw, which may injured the user.
- To avoid rusting, keep your tools stored in a cool, dry place. Oil the metallic parts to avoid rusting.

Cable Cutting Knife – It has a sharp blade with comfortable, full-sized, handle. Its blade is made of the finest steel as shown in Figure 4.2. The handle has a grip for comfortable handling.

Fig. 4.2 Cable cutting knife

Practical Activity 2. Demonstrate the removal of cable insulation using cutting knife.

Material required

Cable cutting knife, Optical fiber cable.

Procedure

Step 1. Place the cable on a flat surface. Use one hand to hold the cutting knife. Now place a cutting knife, about an inch say 2-3 cm from one end of the cable as shown in Figure 1.

Fig. 1

Step 2. Hold the knife with one hand. Roll the cable with other hand, so the blade scrolls around the insulation sheathing. Apply the correct amount of pressure for the removal of insulation as shown in Figure 2.

Fig. 2

Step 3. Cut the mark around the insulation sheathing. Bend the tip of the cable up and down to break through the cut mark completely as shown in Figure 3. The insulation at the marked line, slide it off from tip of the cable.

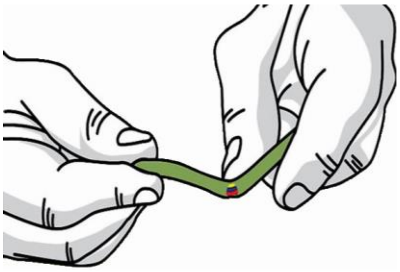


Fig. 3

Plier – Pliers are used for gripping or twisting of wires or cables. There are different parts of the plier like handles, jaws, cutter each with specific operation as shown in Figure 4.3. They are used to grip, splice or cut wires, and strip insulation.

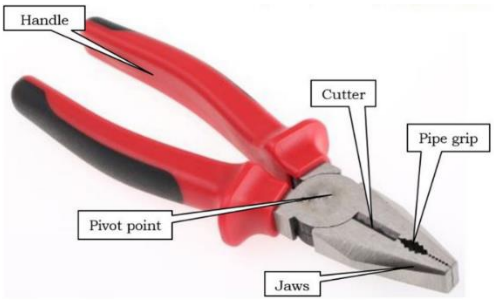


Fig. 4.3 Parts of Plier

Practical Activity 3. Demonstrate the use of combinational plier.

Material required

Combinational plier

Procedure

Step 1. Consider ake a combinational plier. Observe the different shapes i.e. cutter, grip, and jaws.

Step 2. Grip the plier handles in your hand and open them. Perform the cutting of conductor as shown in Figure 1.

Fig. 1

Step 3. Again, grip the plier handles in your hand and open them. Perform the gripping using the jaws of combinational plier as shown in Figure 2.

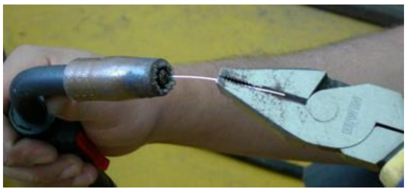


Fig. 2

Electrical measuring tape – This is used for measurement of cable length, during splicing as shown in Figure 4.4.

Fig. 4.4 Electrical measuring tape

Round cable stripper – This tool is used for removing the outer jacket from fiber. Round cutter is compact and lightweight. Figure 4.5 shows round cable stripper.

Fig. 4.5 Tube cutter

Practical Activity 4. Perform stripping of outer jacket from a cable using round cable stripper

Material required

Fiber optic cable, round tube cutter, cable cutter.

Procedure

Step 1. Take a round cutter. Mark the part over the cable, from where we will cut down the outer jacket of cable.

Step 2. Place the optical fiber cable inside the jaws of round cable stripper as shown in Figure 1. Inside the jaw, there is a blade, which will cut the optical fiber outer jacket.

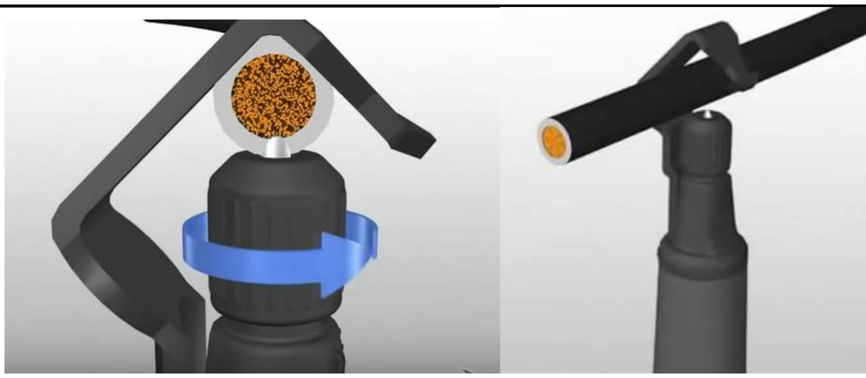


Fig. 1 fiber Cable inside tube cutter

Step 2. Rotate the tube cutter around the fiber cable as shown in the Figure 2.

Fig. 2 Rotation of tube cutter around the cable

Step 3. Now, gently pull the tube cutter to remove the jacket of optical fiber cable as shown in Figure 3. Blade inside the jaws cut the cable along the direction of the pulling.

Fig. 3 Pulling out the jacket from cables

TOOLS AND EQUIPMENT USED IN OPTICAL fiber INSTALLATION

In the workplace of optical fiber installation various hand tools and equipment such as Optical fiber splicing- Fusion splicing, Mechanical splicing, optical fiber cleaver, Optical time domain reflectometer, optical fiber cleaning kit, connector are used which are discuss below.

Optical fiber splicing kit – Splicing is specialised technique of joining the broken ends of the optical fiber (for description of splicing, refer to chapter 9). Some of the commonly used splicing tool are fusion splicing machine, mechanical splicing machine, optical fiber stripper, cleaver, tissue paper, alcohol solution, and protection sleeves as shown in Figure 4.6.

Fig. 4.6 Optical fiber splicing kit

Optical fiber cable stripper – Optical fiber stripper is a tool which is use to remove the different layers of optical fiber cable. It consist of three large, middle and small slot as shown in Figure 4.7. Large slot is use remove jacket of optical fiber cable. Middle slot is use to remove buffer.

Fig. 4.7 Optical fiber stripper

Practical Activity 5. Demonstrte the use of optical fiber stripper.

Material required

Optical fiber stripper, optical fiber cable

Procedure

Step 1. Consider an optical fiber cable. Using ruler, mark the length of 40mm on the optical fiber cable as shown in Figure 1.

Fig. 1

Step 2. Take the optical fiber cable stripper, using large slot of optical stripper, strip 40mm of jacket section as shown in Figure 2.

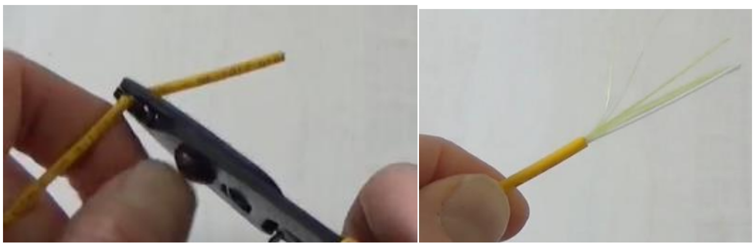


Fig. 2

Step 3. Mark the point of 22mm length on buffer coating as shown in Figure 3.

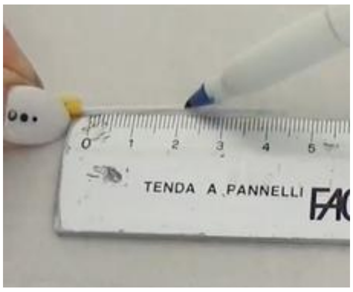


Fig. 3

Step 4. Strip 18 mm of buffer coating, remove the buffer coating with the medium slot of optical fiber stripper as shown in Figure 4.

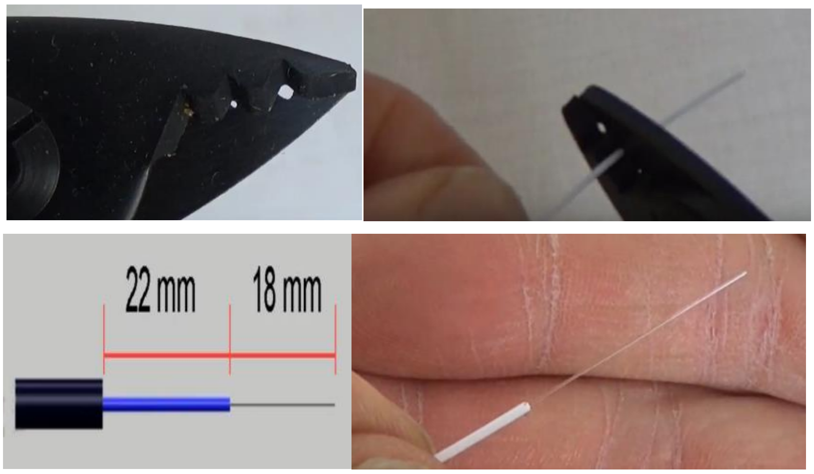


Fig. 4

Step 5. Remove the cladding with little slot of optical fiber stripper as shown in Figure 5.

Fig. 5

Step 6. Clean the fiber using tissue paper with isopropyl alcohol as shown in Figure 6.

Fig. 6

Tools for optical fiber cable splicing

a. Optical fiber fusion splicing machine – It is small, lightweight machine with an LCD screen is used for the fusion splicing as shown in Figure 4.8. In the LCD screen, technician can see and monitor the splicing operation, which is going inside the splicing machine.

Fig. 4.8 Machine for Fusion splicing

b. Optical fiber mechanical splicing machine – Mechanical splicing is one more way to join the two optical fibers as shown in Figure 4.9. It is mostly used in the restoration of optical fiber cable. Joint made through mechanical splicing is not as good as fusion splicing. The advantage of using mechanical splicing is that, it is very portable, as it does not need any bulky machine for their operation.

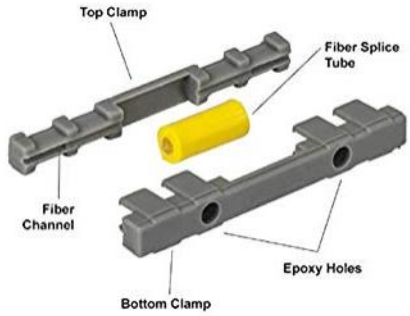


Fig. 4.9 Mechanical splice machine

Practical Activity 6. Demonstrate to prepare optical fiber cable for splicing.

Material required

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

Procedure

Step 1. Take an optical fiber cable, remove the fiber optic cable's protective jackets and buffers to allow access to the optical fiber. 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 fibers.

Fiber optic cleaving tool

fiber cleaving is used to cut the fiber ends perfectly perpendicular to the axis before joining. Cleaving is different from normal cutting of cable using steel blade/knife. When optical fibers are spliced, the fiber ends i.e. core need to be prepared such that they have clean surfaces. Hence, fiber to be cut is kept horizontally and the diamond blade is kept vertically. Two types of cleaving tools are used for fiber cutting

Scribe cleaver
Precision cleaver

Scribe clever – It is used to cleave the fiber manually. It is a traditional cleaving method, typically used to remove extra fiber from the end of the fiber, uses a simple hand tool called a scribe. Scribe cleavers are usually shaped like ballpoint pens with diamond tipped blade as shown in Figure 4.10. The scribe has a hard, sharp tip, generally diamond that is used to scratch the fiber manually.

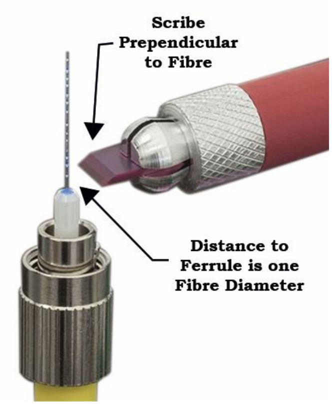


Fig. 4.10 Scribe Cleaving

Precision cleaver – Precision cleavers are the most commonly used cleavers in the industry as shown in Figure 4.11. They use a diamond or tungsten blade to provide cut in the fiber. By pressing a lever of precision cleaver, cleaving of optical fiber cable ends can be done in few seconds.

Fig. 4.11 Precision Cleaver

Protection sleeves – Fiber optic protection sleeve is used during the process of optical fiber splicing as shown in Figure 4.12. The sleeve acts like a strong coat for the fiber splices to prevent unpredictable fractures.

Fig. 4.12 Protection sleeve

Practical Activity 8. Demonstrate to use protection sleeve in optical fiber cable splicing.

Material required

Protection sleeves, optical fiber cable, optical fiber stripper, isopropyl alcohol, tissue paper

Procedure

Step 1. Consider an optical fiber cable, stripper it end using fiber stripper.

Step 2. Poured the tissue paper in the isopropyl solution, clean the fiber using tissue paper.

Step 3. Now, insert the protection sleeve through the stripped end of optical fiber cable as shown in Figure.

Fig. 1

Step 4. Splice the joint using fusion arc splice machine. Once the splicing is completed. Place the protection sleeve over the joint, heat the protection sleeve to fix it over the splice joint.

CLEANING TOOLS

Cleaning Swab – The cleaning swabs are high absorbency swab removes dust and other contaminants as shown in Figure 4.13. They work well as solvent applicator like alcohol.

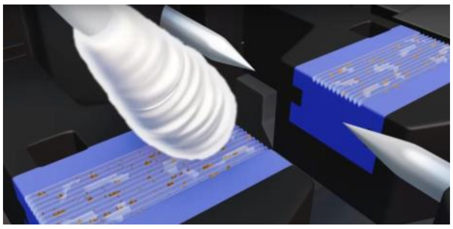


Fig. 4.13 Cleaning Swab

Tissue paper – It is light weight paper used for cleaning the fiber after stripping it. It is made by recycling the paper pulp as shown in Figure 4.14. Dry tissue paper is taken with few drops of isopropyl alcohol above it and then it is used to clean the fiber. Use of tissue paper is shown in the step 7 of Practical Activity 5.

Fig. 4.14 Tissue paper

Alcohol – This fast-acting cleaner Alcohol can be used with dry fiber wipes or tissues to remove jelly above the fiber core. It is used with the tissue paper to clean the bare fiber as shown in Figure 4.15.

Fig. 4.15 Isopropyl alcohol

Gloves– Gloves are used for safety during splicing as shown in Figure 4.16.

Fig. 4.16 Hand Gloves

TESTING TOOLS

Optical Time Domain Reflectometer (OTDR) – OTDR checks the reflected light from the fiber under test along time as shown in Figure 4.17. OTDRs are useful tools for locating fiber faults and characterizing the loss in installed fiber connections.

Fig. 4.17 Optical time domain reflectometer

Practical activity 9. Demonstrate the 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.

Step 2. Observe the ports in OTDR such as 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 3. Observe the functional keys such as shortcut keys, numeric keypad, rotary dial, arrow key, power switch, LCD display, as shown in Figure 2.

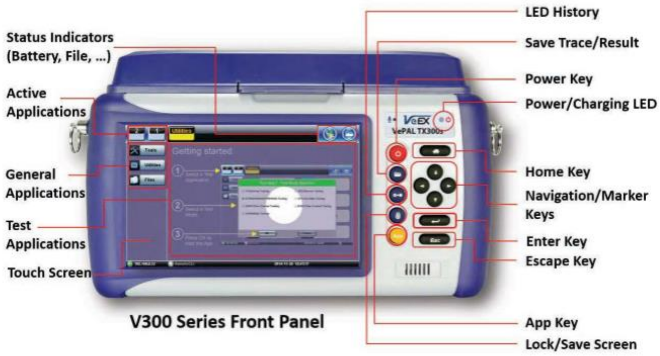


Fig.2 Functional key interfacing of OTDR

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 5. Note down the functions of all keys and ports.

Optical power meter – Optical power meter is a measuring equipment, which measure the power value of light, which is transferring via optical fiber cable. Various functional keys on optical power meter is shown in Figure 4.18.

Fig. 4.18 Optical power meter

Practical Activity 10. Demonstrate the use of functional keys in optical power meter.

Material required

Optical power meter, notepad, pen

Procedure

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

Fig. 1 Optical power meter

Step 2. Observe the functional keys in optical power meter such as power button, initialising key, light button, decibel key, and wavelength control key as shown in Figure 2.

Fig. 2 Functional keys of optical power meter

Step 3. Observe the test port of optical power meter as shown in Figure 3.

Fig. 3 Port in optical power meter

Practical Activity 11. Demonstrate the use of optical power meter operation

Material required

Optical power meter, optical fiber cable with connector, light source.

Procedure

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

Fig. 1 Optical power meter

Step 2. Take an optical fiber cable, connect it to optical power meter port as shown in Figure 2.

Fig. 2 Optical fiber cable connected in optical power meter

Step 3. Take a light source, connect the other end of the optical fiber cable 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 optical fiber cable.

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 light source

Optical light source is a device use to produce a light ray, which will be coupled to optical fiber cable. It is use to test the optical fiber cable. Figure 4.19 shows optical fiber light source.

Fig. 4.19 Optical light source

Practical Activity 12. Demonstrate the use of functional keys in optical light source.

Material required

Optical light source, notepad, pen

Procedure

Step 1. Consider an optical light source as shown in Figure 1.

Fig. 1 Optical light source

Step 2. Observe the functionalities of different keys in optical light source such as power key, wavelength key, and mode key as shown in Figure 2.

Fig. 2

Optical fiber handheld microscope

Optical fiber handheld microscope is a device, which is used for inspection of optical fiber cable. It help technician to identify the dust and impurities present in the optical fiber cable. Figure shows the optical fiber handheld microscope.

Fig. 4.20

Practical Activity 13. Demonstrate the parts and functionalities in optical fiber handheld microscope.

Material required

Optical handheld microscope, notepad, pen

Procedure

Step 1. Consider an optical fiber handheld microscope as shown in Figure 1.

Fig. 1

Step 2. Observe the parts of optical fiber handheld microscope such as adapter ring, battery compartment, focus adjustment, ON/OFF switch, eyepiece as shown in Figure 2.

Fig. 2

Note down the functionalities of different parts.

TERMINATION KIT

Optical fiber connectors – Optical fiber connectors are those devices, which are used to connect or disconnect the optical fiber cables together to extend its length or to repair it if broken accidentally.

Components of an optical fiber connector

The main components of an optical re-connector are a ferrule, connector body, coupling device, boot, cap.

Ferrule – Ferrule acts as a fiber alignment mechanism and holds the glass fiber. It has a hollow portion that forms a tight grip on the fiber.

Connector Body – Body holds the ferrule, attaches to the jacket, and strengthens members of the fiber cable itself. Connector body also known as the connector housing.

Coupling Device – Coupling device is a part of the connector body that keeps the connector in place when attached to another device like as bulkhead coupler and optical transceiver.

Boot – It is use to protect the optical fiber cable from an external damage. It also provides flexibility to optical fiber cable.

Cap – It protect the optical fiber cable from dust particle.

Fig. 4.21 Connector parts (a) Connector housing (b) Ferrule and connector sub assembly (c) Crimp (d) Boot (e) Cap

Practical Activity 14. Demonstrate the preparing of optical fiber connector.

Material required

Optical fiber cable, cleaver, tissue paper, isopropyl alcohol, fiber stripper, pen, scale, parts of connector

Procedure

Step 1. Repeat the steps from 1 to 7, which we have discussed in practical activity 5.

Step 2. Insert the fiber into the cleaver as shown in Figure 8.

Fig. 8

Step 3. Cut down the fiber at the length of 13mm as shown in Figure 9.

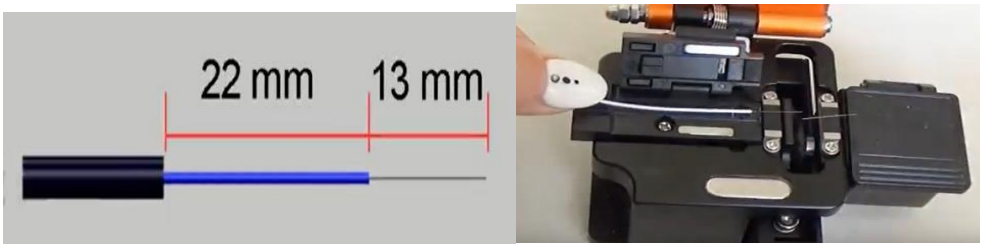


Fig. 9

Step 4. Insert the fiber cable into the fiber guide of the connector as shown in Figure 10.

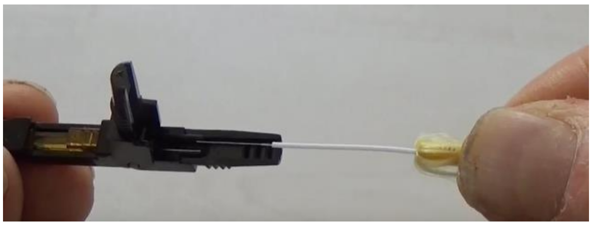
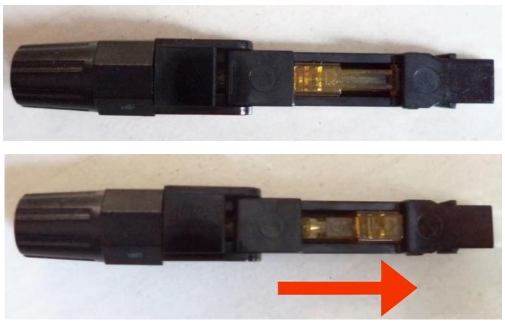
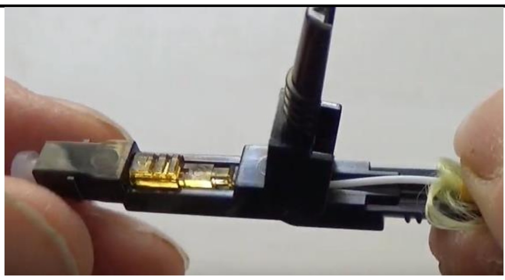


Fig. 10

Step 5. Push the connector holder forward to end and fix the fiber as shown in Figure 11.



(a)



(b)

Fig. 11

Step 6. Using scissor cut the aramid of 1 cm length as shown in Figure 12.

Fig. 12

Step 7. Close the cover of the connector as shown in Figure 13.

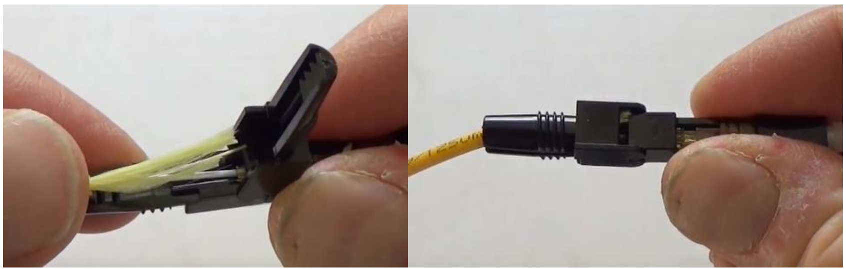


Fig. 13

Step 8. Insert the screw cap as shown in Figure 14.

Fig. 14

Step 9. Insert the connector shell as shown in Figure 15.

Fig. 15

Step 10. Now optical fiber cable with connector at an end is ready to use as shown in Figure 16.

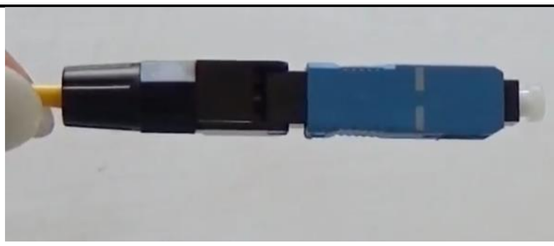
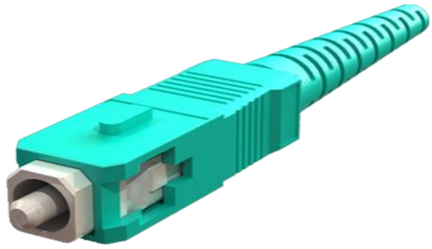


Fig. 16

Types of fiber Connectors

Some common types of optical fiber connectors are described in brief with its picture.

Bi-conic connector – It is designed with narrow end to have low insertion loss. Narrow end also enables the protection sleeve to be located on the connector properly as shown in Figure 4.22.	 Fig. 4.22 Bi-conic connectors
D4 connectors– D4 connector is made up of stainless steel. They are more durable as they have metallic ferrule as shown in Figure 4.23.	 Fig. 4.23 D4 connector
Enterprise Systems Connection (ESCON) connectors – ESCON connectors are made up of plastic body. They are commonly used in connect of computer and their peripherals as shown in Figure 4.24.	 Fig. 4.24 Connection connector
FC connector – It is used for single-mode fibers and high-speed communication links. FC connector is a used to transfer video signal over fiber transmission equipment as shown in Figure 4.25.	 Fig. 4.25 FC connector
FDDI connector– It is a duplex connector, which makes use of a fixed case as shown in Figure 4.26. FDDI use in local area network. The FDDI connector connects network equipment.	 Fig. 4.26 FDDI connector

LC connector – The LC connector, which have small form factor, which is designed to join LC fibers where a connection or disconnection is required.	 Fig. 4.27 LC connector
SC connector– It is used in simplex mode and is best suited for high-density applications as shown in Figure 4.28. SC connectors use a ceramic ferrule to deliver accurate alignment of the single mode fiber.	 Fig. 4.28 SC connector

Practical Activity 15. Demonstrate to prepare SC optical fiber connector.

Material required

SC fiber connector, optical fiber cable , optical stripper

Procedure

Step 1. Take an optical fiber cable, strip its coating using optical stripper.

Step 2. Now, insert the bare fiber into the centre hole of ferrule as shown in Figure 1.

Fig.1

Step 3. Ferrule is then assembled in the SC sub-assembly body, which has mechanism to hold cable and fiber in place.

Step 4. Connector sub-assembly is then assemble together with the connector housing. It helps to hold the connector in place.

Step 5. Take a crimp eyelet, crimp it over the optical fiber cable. This will provide the strength to the cable.

Step 6. Stress relief connector body covers joint between connector body and optical fiber cable and protect SC connector from mechanical damage.

Practical Activity 16. List the parameters and use of different optical fiber connector.

Material required

Different connector, notepad, pen

Procedure

Step 1. Consider the different connector. By observing these connectors, prepare a table mentioning the name of each connecter, its parameters and use.

Connector	Parameter	Use

SC connector	• They are rectangular in shape. • Ferrule has push pull locking mechanism. • They have 2.5mm diameter ferrule.	Most widely used connector in LAN/WAN
LC connector	• They are rectangular in shape. However, half in size that of SC connector. • Ferrule has push pull locking mechanism. • They have 1.25mm diameter ferrule.	Fastest growing connector, they are generally used in single mode fiber
ST connector	• They are cylindrical in shape. • Ferrule with twist locking mechanism. • They have 2.5mm diameter ferrule.	Mainly used with multimode fibers
FC connector	• They are cylindrical in shape. • They have 2.5mm diameter ferrule.	Mainly used with single mode fiber

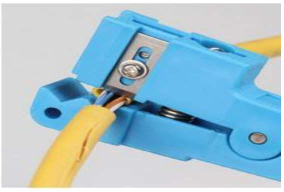
2. Analyse the table and observe the basic difference between different connector.

Assignment 1

Pictorial representation of connector	**Identify the name of connector in the picture**
 Fig. 1	....
 Fig. 2	....
 Fig. 3	....

 Fig. 4	....
 Fig. 5	....
 Fig. 6	....
 Fig. 7	....

Assignment 2. Identify and name the tools by observing the picture of tool.

Pictorial representation	Identify the name of tool which is in the picture
 Fig. 1	....
 Fig. 2	....
 Fig. 3	....
 Fig. 4	....

Check Your Progress

A. Multiple Choice Questions

1. Which of the following is not the part of a screwdriver? (a) Head (b) Shaft (c) Tip (d) V groove
2. Which of the following is not the part of a plier? (a) Jaws (b) Pivot point (c) Cutter (d) All of the above
3. Which of the following cutting tool is rotated around the optical fiber several times to create a cut in the buffer tube? (a) Plier (b) Nose plier (c) Tube cutter (d) Cleaver
4. Which of the following tool it enables the user to perform the combine operation i.e. cutting and stripping? (a) Optical fiber stripper (b) Nose plier (c) Cleaver (d) Scissor

5. Which of the following is the most commonly used alignment mechanism for mechanical fiber splices? (a) Cleaning swab (b) V-groove (c) Matching gel (d) Clamp spring
6. Identify the following picture and choose the appropriate name for the equipment from the given option. (a) Scriber cleaver (b) Precise cleaver (c) Optical power meter (d) Optical Time Domain Reflectometer

Fig. 1

B. Fill in the blanks

1. In order to tighten the screw, force applied to the screwdriver is in __________ direction.

In order to loosen the screw, force applied to the screwdriver is in __________ direction.

Cable can be placed in a Figure of __________ This prevents the twisting of fiber cables.

Ferrules are typically made of __________, __________ or quality plastic.

Tubing cutter is __________, __________ and more convenient way of cutting cable.

Before installation of the cable, check the __________ and __________ of the cable.

For temporary joint of optical fiber cable __________ is used.

For cleaving the optical fiber __________ material is used.

Typical lengths of protection sleeve are __________ and __________ in diameter.

Coupling device is a part of the connector body that keeps the __________ in place when attached to another device.

C. Short Answer Questions

1. Define the following terms (a) Precise cleaving (b) Cable pulling (c) Cable placement (d) Cleaning swab
2. Define the following connector– (a) Bi-conic (b) D4 (c) ESCON (d) fiber Connector (FC) (e) LC (f) Subscriber Connector (SC) (g) Straight Tip (ST)
3. Name the tools used for fiber splicing.
4. Write down the safety and care to handle various tools and equipment.
5. Write down the tips to use a screwdriver.

Session 2: Optical Fiber Cables Specifications

Suppose you are studying in class 10th. For examination, you have prepared all the subjects, mention in the syllabus. However, at the day of examination you got a paper in which most of the topics are out of syllabus. These topics will make a difficulty for you to write in the examination, as you have prepared for the specific topics, which are there in the syllabus. Likewise, in case of cable installation, specification of cable plays a major role in the installation. As syllabus are specifically designed for class 10th in the same way cable are specifically designed and manufactured as per the field in which it is going to be use. If these designed, cable is used in the field other than the specified by the manufacturer. Then in that case cable will not going to stand efficiently. In this chapter, we are going to discuss guidelines for cable specification, cable installation. We will also discuss environmental specification in respect of optical fiber cable.

OPTICAL fiber CABLE SPECIFICATIONS

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 we 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, fiber optic cable is the medium, which provide fastest means of transferring data or information with a speed of light. Before performing the installation of fiber cable, one should know about the specification of optical fiber cable. These specifications are classified as cable specification and environmental specification

Cable specification

Cable specification is like the profile or bio data 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 going to be use. Some of the cable specifications are discussed below–

Bend radius

Tensile strength

Diameter

Impact resistance

Crush resistance

1. **Bend radius–** Bend radius defines the bend in the cable. It is the minimum radius a cable can bend without damage as shown in Figure 5.1. 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.

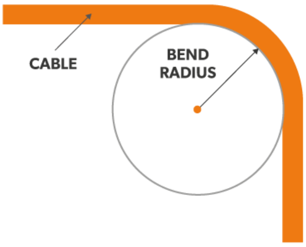


Fig. 5.1 Bend radius

Example – If a cable of 5mm in diameter is running outside a building under a tensile load, what can be minimum bend radius?

Solution – Remember that the minimum bend radius for cables running outside a building is 20 times the cable diameter, if the cable is under a tensile load.

5 mm x 20 = 100 mm

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

Tensile strength – When fiber cable is installing there is need to pull the cable for proper underground laying of optical fiber cable. At that time, optical fiber cable 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. By understanding the role of tensile strength, we can define tensile strength as "the maximum tension which a cable can bear, without getting damage".

More to know

To understand optical fiber tensile strength. Strength, toughness, and elasticity are all mechanical properties. However, what do these words really mean?

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. However, term which describes the kind of strength is tensile strength. Tensile strength is important for a material that is going to be stretched due to tension, like rope.

Table 5.1 Strength in optical fiber cable

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

Diameter of cable – It defines the thickness of cable. In other word, it is the cross section of cable. Diameter of fiber optic cable is so small that it cannot be measured without using appropriate measure instrument.

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 without getting damage.

Crush resistance – It defines the compression strength of cable. It includes deformation, fracture, collapse of optical fiber cable.

Practical Activity 1. Observe macro bending loss in optical fiber cable using power meter.

Material required

Optical fiber cable, Power meter, light source.

Procedure

Step 1. Take an optical fiber cable, pass the light through fiber from one end.

Step 2. Measure the light intensity at other end using optical power meter. Note down the reading.

Step 3. Firstly, bend the optical fiber cable. Bend radius will be fix to 15 times of fiber cable diameter as shown in Figure 1. After this setup, repeat step 1 and 2.

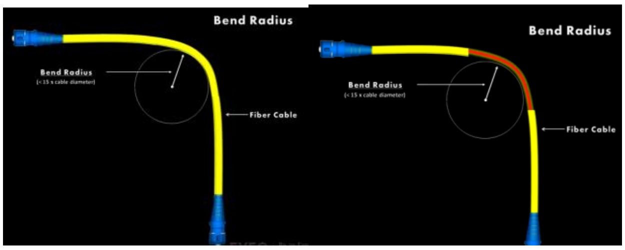


Fig. 1

Step 4. Now, again bend the fiber cable. Bend radius will be fix to 5 times of fiber cable diameter as shown in Figure 2.

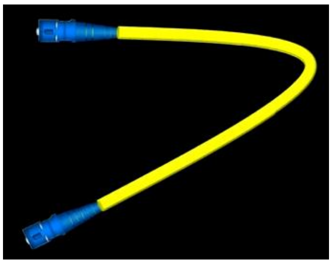


Fig. 2

Step 5. Measure the power at output of the optical fiber cable using power meter. Compare the reading taken at different bend radius. You will observe that power will get reduce as we reduce the bend radius of optical fiber cable as shown in Figure 3.

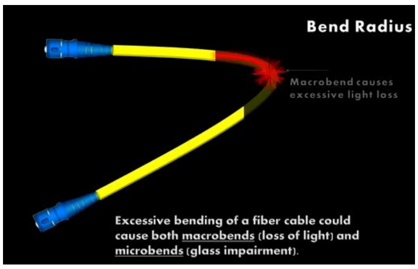


Fig. 3

Step 6. Now, it is observe that as we bend the optical fiber cable, the light get lost in macro bending. To reduce these losses, technician must follow bend radius standard.

Environmental specification – Environmental factor includes soil, water, climate, natural vegetation and land forms. Environmental specifications are those that must be meet in order to ensure successful operation of the cable in its environment. General environmental specifications are as follows–

Temperature range of operation

Flame resistance

UV resistance

Resistance to damage from species

Resistance to damage from water

Crush load

High Flexibility

Resistance to solvents, petrochemicals, and other chemicals

Airtight sealed fiber

Radiation resistance

Fig. 5.2 Optical fiber cable laying in different environmental condition (a) in snow (b) in desert (c) in water (d) in forest (e) in mountain (f) in railway track

1. **(a) Temperature Range of Operation –** In different area where fiber cable is going to be installed have different temperature and climatic condition. To ensure the proper internal working of optical fiber cable in these climatic conditions, manufacturer provides a range of operating temperature of fiber cable. Exceeding these limits of operating temperature may disturb the internal performance of the cable. Installer should go through the data-sheet, which is prepared by cable manufacturer.

Typical ranges of operation are given in table below for various types of applications.

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 – Flame resistance specifies that the cables must be constructed of flame-resistant materials. Many commonly used materials are either flame resistant 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 to protect cable from ultraviolet radiation protected. Otherwise, the cable jacket will get cracked 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 optical fiber cable. Animal may bite the optical fiber cable. Optical fiber cable can be protected by modifying the construction. Now a days, advance optical fiber cables have amour in there outermost layer, which will protect the cable, form these damages.

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

(f) Crush Load – Crush is the compressive force, which acts on the cable. This force is applied perpendicular to the cable. Crush loads can be divided, based on 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 we know that, flexibility is the bending without breaking similarly, high flexibility show high quality of bending. In some places, there is a need of repetitive bending of fiber optic cables. For example, in military field, elevators. Flexibility requirements must be met by both cable materials and by fibers.

(h) Resistance to Solvents, Petrochemicals, and other Chemicals – In some situations, you need the fiber optic cables be resistant to worse from exposure to certain chemicals. Such as cables are occasionally exposed are gasoline, aircraft fuel, fuel oil, greases, and crude oil.

(i) Airtight Sealed fiber – In some applications, optical fiber cable is kept in very high water pressures or high temperature, fiber must be airtight in order to retain its mechanical strength. In these conditions, fiber must be airtight. Airtight sealing is required because contact with moisture results in significant reduction in the strength of the fiber and absorption of hydrogen from water results in a significant increase in attenuation.

(j) Radiation Resistance– When optical fiber cable is subjected to ionizing radiation such as in the core of a nuclear power plant, outer space, or an x-ray chamber. In such conditions cable material and fiber must be radiation resistant, in order to retain acceptable mechanical properties. Since, these properties tend to be degraded by exposure to ionizing radiation.

CHECK YOUR PROGRESS

A. Multiple Choice Questions

1. Which of the following is not the cable specification? (a) Tensile strength (b) Impact resistance (c) Diameter (d) Temperature range of operation
2. Which of the following is not the environmental specification? (a) Flame resistance (b) UV resistance (c) Resistance to damage from species (d) Bend radius
3. Bend radius defines .... (a) Attenuation in cable (b) Bending in the cable (c) Transfer of light (d) UV radiation detection
4. Range of temperature for military operation is...... (a) -55 to +85 (b) -30 to+70 (c) -20 to +60 (d) -10 to +80
5. The force that is applied perpendicular to the cable. (a) Crush load (b) Shear load(c) Flexibility (d) Radiation Resistance
6. Polyethylene is use to protect the cable from ......(a) Fire (b) Tensile load (c) Water (d) UV radiation
7. Which of the following define compression strength of cable? (a) Crush resistance (b) Impact resistance (c) Tensile strength (d) Bending radius
8. If a cable 10mm in diameter is running outside of a building under a tensile load, what is the minimum bend radius? (a) 400mm (b) 300mm (c) 200mm (d) 100mm
9. Which of the following defines the thickness of cable? (a) Tensile strength (b) Crush load (c) Impact load (d) Diameter of cable
10. Which of the following are the type of short term and long-term load? (a) Impact load (b) Crush load (c) Tensile strength (d) Shear load

B. Fill in the blanks

1. The maximum tension which a cable can bear, without getting damaged is called as ....
2. Flexibility is the quality of .... easily without breaking
3. Action of one object coming forcibly into contact with cables is defined as .... on cable.
4. To prevent the optical fiber cable from moisture it should be ....
5. For ....operating range of optical fiber cable is -62 to +125.
6. Jacket of optical fiber cable can be damage because of .... ray.
7. Two specifications must be considered when specifying optical cable. They are .... and ....

2. C. Match the column

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

D. Short Answer Questions

1. What do you mean by the term specification in respect of optical fiber cable?
2. What are the types of cable specification?
3. Define the terms in respect of optical fiber cable– (a) Crush load (b) Impact (c) resistance (d) Flexibility (e) UV stability (f) Bend radius (g) Tensile strength

Module 3	Installation of optical fiber cable (OFC)

Module Overview

In this module focuses on the critical aspects of optical fiber cable installation, starting with Pre-Installation Testing of Optical Fiber Cables, where students learn to verify cable integrity and performance before installation to ensure optimal functionality. Following this, Splicing techniques are introduced, covering both fusion and mechanical splicing methods, enabling students to join optical fibers efficiently while minimizing signal loss. In Indoor Optical Fiber Installation, learners gain practical skills in deploying fiber optic cables within buildings, including proper handling, routing, and securing techniques to maintain cable performance and compliance with safety standards. Finally, the module concludes with Link Performance Analysis, where students are taught how to measure and analyze the performance of installed optical fiber links using various testing equipment and methods. This comprehensive approach ensures that students acquire the necessary skills and knowledge for effective optical fiber installation and maintenance in real-world scenarios.

Learning Outcomes

After completing this module, you will be able to:

- Learning Outcome: Students will be able to conduct pre-installation tests on optical fiber cables to assess their integrity and performance, ensuring that the cables are suitable for installation.
- Learning Outcome: Students will learn to perform both fusion and mechanical splicing techniques, enabling them to join optical fibers effectively while minimizing signal loss.
- Learning Outcome: Students will acquire practical skills for the safe and efficient installation of optical fiber cables indoors, including proper handling and routing techniques.
- Learning Outcome: Students will be able to perform link performance analysis using appropriate testing equipment to measure and evaluate the performance of installed optical fiber links.

Module Structure

Session 1: Pre-Installation Testing Of Optical Fiber Cables
Session 2: Splicing
Session 3: Indoor optical fiber installation
Session 4: Link performance analysis

Session 1: Pre-Installation Testing Of Optical Fiber Cables

Before installing optical fiber cable, they are to be tested number of times. Firstly, at the time of manufacturing they are tested by manufacturer. Secondly, they are tested at installation site. This ensures that there has been no damage done to the cables during shipping and handling. For every optical fiber cable which is to be installed it needs to be tested for continuity. If optical fiber cable is very long with intermediate splices, then the individual splice points can only be verified using the optical time domain reflectometer (OTDR) test. This OTDR test is the only way to make sure that each splice is good. It is useful for testing the integrity of optical fiber cables. It can verify splice loss, measure length and find faults. The OTDR is also commonly used to create a "picture" of optical fiber cable, when it is installed. This chapter includes basic testing procedures for verifying optical fiber cabling before installation and operation of optical fiber test equipment.

TESTING OF OPTICAL fiber CABLE

Before installing your optical fiber network, technician must ensure that data will be transmitted properly in form of light through the optical fiber cables. Continuity test is being perform for optical fiber cable and connectors. This continuity test can be performed using two-test equipment i.e. Visual Fault Locator and Inspection Microscope.

1. Optical fiber visual fault locator

Visual Fault Locator (VFL) is a visible light source that injects visible light energy into a fiber. By injecting the light from a visible source, one can visually trace the fiber from transmitter to receiver to ensure correct orientation and check continuity. Sharp bends, breaks, faulty connectors and other faults may result in leakage of light, these leaks can be visually spot by the technician. There are some other names for visual fault locator, such as fiber Tracer, Visual Fault Finder, Visual Fault Indicator, Visual Fault Identifier, Visual Fault Detector, Visual Fault Light, Visual Fault Locator Pen. VFL looks like a pen as shown in the Figure 6.1.

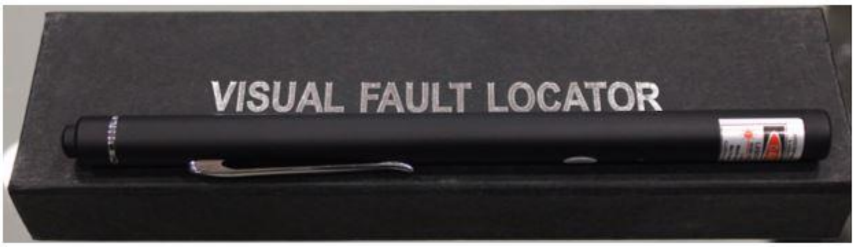


Fig. 6.1 Optical fiber Visual Fault locator

Table 6.1 Visual fault locator specification sheet

fiber Test Types	Multimode or single mode
Light source	laser diode
Operation environment	-10°C to +50°C
Storage environment	-20°C to +80°C
Power supply	Two 1.5V AA Alkaline batteries

Connector	2.5mm universal
Battery life	> 80 hours
Range distance in km	5-10 Km

Practical Activity 1. Demonstrate to use the Visual Fault Locator.

Material Required

Visual Fault Locator, batteries, fiber 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 3. Then insert the batteries inside it 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 it indicates ON and by 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 VFL

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.

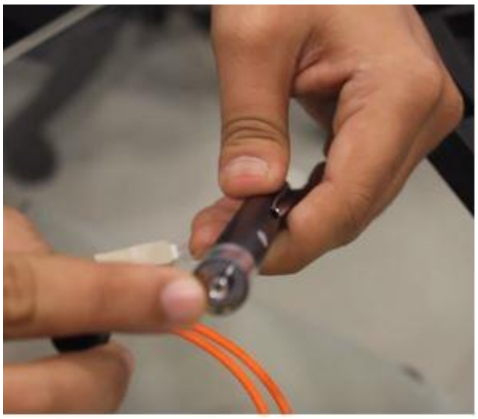


Fig. 6 Checking of the passage of light emission by visual fault indicator

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

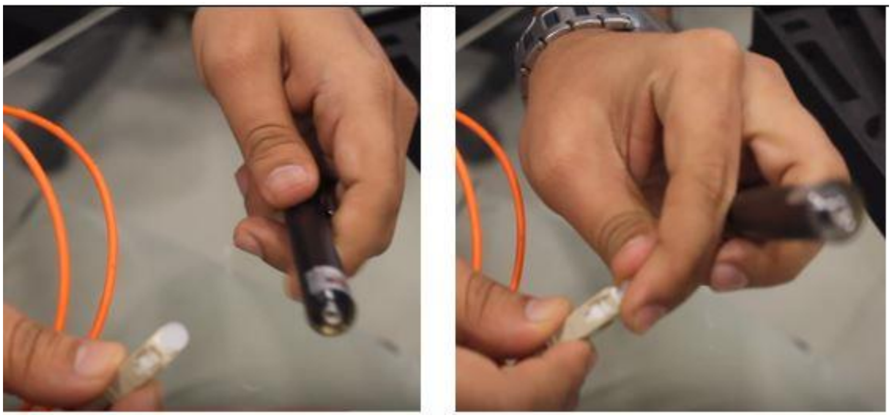


Fig. 7 Connection of the connector to visual fault device

Step 8. Now, pass the light emitted by the visual locator inside the fiber as shown in Figure 8 and press ON button. This allows the light beam to pass through the fiber.

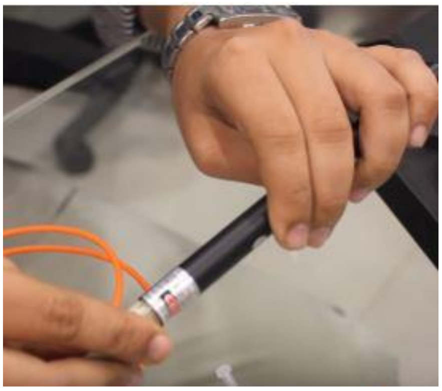


Fig. 8 Mating of the light passage inside the connector of visual fault indicator

Step 9. Observe the other end of the fiber, whether light is coming out of it or not. If it is coming out that defines optical fiber cable working properly as shown in Figure 9.

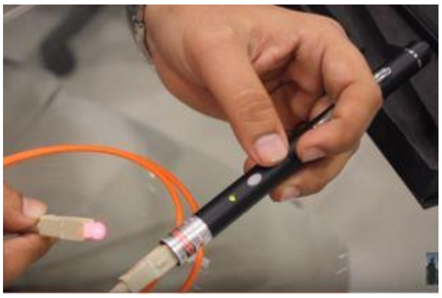


Fig. 9 Checking of the light passage through the fiber

2. Optical fiber inspection microscope

Inspection microscope is a device that enlarges objects that are too small to see with the naked eye as shown in Figure 6.2. Cleaved fiber ends ready for splicing and connector require visual inspection to find possible defects. This inspection is perform using an optical fiber inspection microscope. The optical fiber inspection microscope will focus the sections of cleaved fiber, which are not visible through naked eyes.

Fig. 6.2 Optical fiber inspection microscope

Practical Activity 2. Demonstration of optical fiber inspection microscope.

Material Required

Inspection microscope, optical fiber cable

Procedure

Step 1. Consider an optical fiber cable. Place the optical fiber cable at the adapter of microscope as shown in Figure 1.

Step 2. Input the fiber cable to be tested, into the Light source entrance of inspection microscope

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

Step 3. See from the eyepiece and press on the 'ON' button. Now, pass the light into the optical fiber cable which is to be tested.

Fig. 2 Seeing from the eyepiece to the microscope

Step 4. Adjust the focus control. Just to find the clearest viewing.

Fig. 3 Adjusting the focus control of the microscope

Optical fiber visual connector is also use to inspect the connector. Any contamination in the fiber connection can cause failure of the components or system. Even microscopic dust particles can cause a variety of problems for optical fiber connector. Particles can partially or completely blocks the core of optical fiber connector. This blockage generates strong back reflection. Dust particles trapped between two fiber faces can scratch the glass surfaces. To inspect the optical fiber cable for these problems following activity is illustrated.

Practical Activity 3. Demonstrate the cleaning procedure in optical fiber connector.

Material required

Fiber optic cable with connector, connector cap, cleaning device.

Procedure

Step 1. Consider an optical fiber with connector at the terminal of cable as shown in Figure 1.

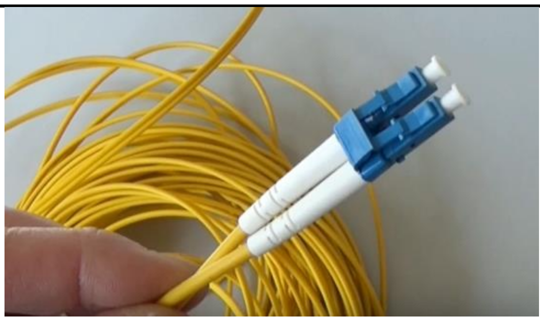


Fig. 1 Optical fiber cable with connector

Step 2. Remove the cap of connector. Inspect the fiber using microscope as shown in Figure 2.

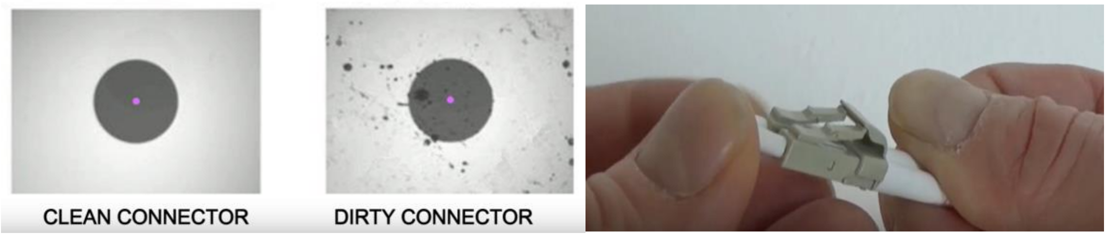


Fig. 2 (a) Microscopic view of optical fiber (b) Removing the cap of connector

Step 3. Take a cleaning device, insert it into the fiber connector as shown in Figure 3.

Fig. 3 (a) Cleaning device (b) Cleaning the optical fiber using cleaning device

Step 4. Again, check for the dust particle in the fiber. After inspecting, the fiber put the cap on the connector.

Assignment 1

Take an optical fiber cable with the connector fitted to its ends. Find out, whether fiber cable and connector are fit for transmission by passing light into the cable. Use VFL, fiber microscope for inspection. Note down the observations and inspect the cable for any breakage.

Practical Activity 4. Demonstrate to test optical fiber without fiber optic connector.

Material required

Bare fiber optic cable, stripper, OTDR, protective covering

Procedure

Step 1. Take a cable, inspect the cable and record any visible sign of defects.

Step 2. Strip at least 2ft. of cable end, clean the stripped fibers.

Fig. 1

Step 3. Connect the fiber using a bare fiber adapter to an OTDR through a patch cord.

Fig. 2

Step 4. Start the OTDR and select the correct wavelength and refractive index for the test. Print and record the OTDR trace on disk.

Fig. 3

Step 5. Compare the test result to the manufacturer specification

Step 6. Remove bare fiber adapter and cut off excess fiber from the cable end.

Step 7. Install heat shrink protective covering to the cable end to prevent the entry of moisture or contaminants.

OPTICAL RETURN LOSS TEST

In optical fiber transmission, when we transmit the light into the fiber, some part of light is return back due to reflection. Testing is performed to analyse the light in the fiber. Such test is optical return loss test or ORL test. Figure 4.16 shows the setup for optical fiber return loss. In this setup, power meter device uses to measure amount of light, which is returning in fiber.

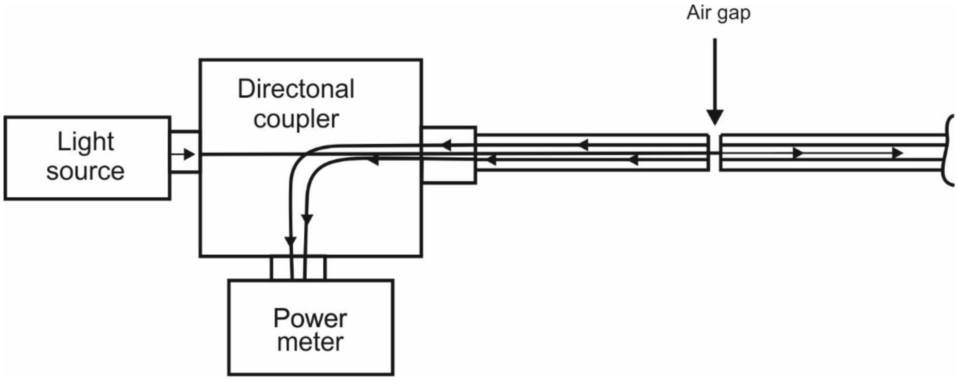


Fig. 6.3 Optical Return Test

National and international standards bodies have standardized test procedure for optical fiber cable. There are different techniques for measuring return loss in optical fiber, which are as follows.

1. Optical time domain reflectometry (OTDR)
2. Optical low coherence reflectometry (OLCR)
3. Optical frequency domain reflectometry (OFDR).

INSERTION LOSS TESTS

As the name suggest, it is the loss occur when light is about to enter the optical fiber cable. It is the initial loss in optical communication. It describes the difference between amount of light sent into optical fiber cable, and the amount of light that successfully coupled into the optical fiber cable.

Practical Activity 5. Demonstrate to test insertion loss in optical fiber.

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. Then connect one end of reference cord with connector attach to it, through the optical power meter and another end of the cord to the optical light source as shown in Figure 1.

Fig. 1

Step 2. Choose the wavelength of 1310nm in light source. Press the “REF” button in optical power meter to set the reference dB level as shown in Figure 2. At the same time note down the reading on power meter display.

Note: There will be 0 dB in power meter display indicating no loss.

Fig. 2

Step 3. Now, remove the reference cord end, which was connected to the light source. Take a test cable with connectors attached to its both ends. Connect one of the test cable end to the light source and mate other end of the test cable via connector adapter to the reference cord end as shown in Figure 3.

Fig. 3

Step 4. Now repeat step 2, and note down the reading of optical power meter as shown in Figure 4.

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

Fig. 4

CHECK YOUR PROGRESS

A. Multiple Choice Questions

1. Which of the following define test equipment (a) Testing a device (b) Measuring a device (c) Testing fiber (d) Measuring fiber
2. Optical test equipment are the devices used to check (a) Light propagation (b) Losses (c) Splice (d) Reflection
3. Optical Power can be measured by using (a) Optical Power meter (b) OTDR (c) Test fiber box (d) Optical Coupler
4. OTDR stands for (a) Optic time depart reflector (b) Optical time domain reflector (c) Optical time domain reflectometer (d) Optical time depart reflector
5. OTDR screen has X-axis and Y-axis. (a) The X-axis measures distance and Y-axis measures attenuation. (b) The X-axis measures attenuation and Y-axis measures distance (c) The X-axis measures time and Y-axis measures attenuation (d) The X-axis measures distance and Y-axis measures time
6. Optical power meter can be operated in the wavelength of (a) 450nm (b) 1300nm (c) 1490nm (d) 1550nm
7. The slope of the fiber trace shows (a) The attenuation coefficient of the fiber and is calibrated in db/km (b) The attenuation of the fiber and is calibrated in db/km (c) The attenuation coefficient of the fiber and is calibrated in db (d) The reflection coefficient of the fiber and is calibrated in db/km
8. LASER which produces (a) Focused beam of light (b) Unfocused beam of light (c) Focused beam of electrons (d) Unfocused beam of electrons
9. Fresnel reflections cause a vital OTDR specification referred to as (a) Dead zones (b) Live zone (c) Test zone (d) Neutral zone

B. True or False

1. Mini OTDRs are not portable and designed for field testing.
2. PC-based OTDRs can be connected to the personal computer.
3. OTDR Test set up are generally used for testing the signal with a launch cable and hence use a receive cable.

4. Optical power meter consists of two ports. One port can be joined to reflectometer to measure power and other slot is connected to light source
5. The slope of the fiber trace shows the attenuation coefficient of the fiber and is calibrated in dB.
6. OCWR stands for Optical Continuous Wave Reflectometer
7. OTDR equipment is not able to sustain extreme environmental conditions like temperature, humidity etc.

C. Short Answer Questions

1. What do mean by test equipment
2. What is OTDR
3. What is power meter
4. What do you mean by dead zone?
5. What do OTDR test?
6. When do I need to use a launch cord (cable) with my OTDR?
7. Difference between OTDR and power meter
8. Draw and explain block diagram of OTDR
9. What does OTDR measures
10. How faults in cable is detected
11. What is backscattering
12. Which solution is used to clean the connector
13. Name the types of OTDR available in the market

Session 2: Splicing

Optical fiber is used as transmission medium for data communication. In general, for any communication, there is requirement of transmission medium, transmitter, receiver. For long distance communication, there is requirement of joining the fiber cables. fiber joining is analogous to the joining of electrical wire. In general, to join the wire either of electric or telephone line, the broken edges are twisted together or we either solder the broken edges of wire to join the wires together. But, in case of OFC, two fiber cables are joined together by a method, known as splicing. Hence, splicing is the method in which broken fiber ends are joined permanently. Splicing is nothing but a sort of noble name of "soldering". In this chapter, we will learn the method of splicing.

NEED OF SPLICING

fiber cables are widely use in communication network. They acts as veins of communication system. Since, optical fiber cable is made up of glass and if these cables are broken or damaged as shown in Figure 7.2, requires repairing. Specialized technique needs to be perform to join the damaged optical cable because the cable of optical fiber is composed of glass. This technique of joining the fiber optics cable is called as splicing. Basic steps for splicing is shown in Figure 7.1.

Stripping → Cleaning → Cleaving → Splicing → Protection

Fig. 7.1 Steps of performing splicing

Fig. 7.2 Damaged optical fiber cable

FACTORS EFFECTING THE OPTICAL fiber CABLE

In the telecommunication network, optical fiber cables are mostly installed underground. Several factors can destroy buried optical fiber cable. To repair these damaged optical fiber cables splicing has to be perform. Firstly, we will look some of the factors affecting the optical fiber cable are water, rodents, lightning, infrastructural construction, ice crush.

Water – Water is very harmful for optical fiber cable. Water slowly reduces strength of coating on optical fiber cable. Water may be enter into the optical fiber through splice joints. This may damage the quality of optical fiber cable as shown in Figure 7.3.

Fig. 7.3 Damage of the splice enclosure due to water

Rodents – Rodents are often responsible for extensive damage to fiber optic cable. Even metal armoured cable can cut by them as shown in Figure 7.4.

Fig. 7.4 Damage of the fiber cable due to rodents

Lightning – When lightning strikes the ground, it will look for least resistive path. Due to moisture in soil these high amount of charges bypass the optical fiber cable and get sink into the ground. This action will give major damage to the outer coating of fiber cable as shown in Figure 7.5.

Fig. 7.5 Damage of the fiber cable due to Lightening

Infrastructural Construction – Infrastructural construction is the biggest cause of damage to buried cable. As we know, fiber cables are installed beneath the earth surface. Therefore, at the time of digging, caution has to be taken at site as shown in Figure 7.6.

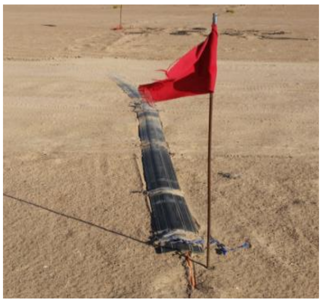


Fig. 7.6 Damage of the fiber cable due to construction

Ice Crush – In cold place, water that enters a splice joint get freeze, this will damage the internal structure of optical fiber cable as shown in Figure 7.7.

Fig. 7.7 Damage of the fiber cable due to Ice crush

TYPES OF SPLICING

Splicing can be perform in two ways, which are as follows –

1. Fusion splicing

   Mechanical splicing

If splicing is done mechanically, it is called mechanical splicing. However, if splicing is done electrically it is called fusion splicing. Fusion splicing is done by heating the ends of the fiber using electric arc. It is useful to join the fiber 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.

Practical Activity 1. Demonstrate the opertion of precision cleaver

Material required

Optical fiber cable, Precision cleaver

Procedure

Step 1. Consider an optical fiber cable , at one of its end strip of its outer layer using optical fiber stripper.

Step 2. Clean its other jelly using tissue paper with few drops of alcohol on it.

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

Fig. 1 Precision cleaver

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

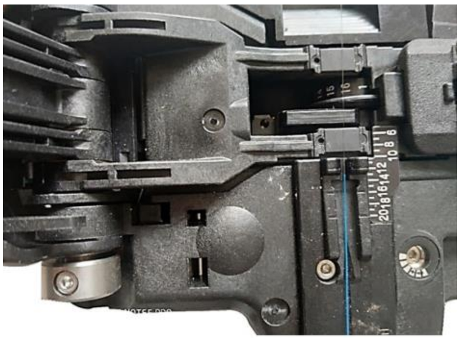


Fig. 2 Slot inside the precision cleaver

Step 4. Adjust the blade of the precision cleaver to cut the stripped fiber cable.

Step 5. Close the cap of precision cleaver, as we close the cap of precision cleaver it will cut the stripped optical fiber vertically in perpendicular direction as shown in Figure 3.

Fig. 3 Closing the cap of cleaver

Step 6. Again, open the cap of precision cleaver, check the end terminal of stripped fiber, it will be cut in precise way.

Step 7. Similarly repeat the same procedure for the other end of the fiber cable to perform its cleaving.

Assignment 1

Suppose you have an optical fiber cable of 1m in length, which is broken. Now in order to join it you need to perform the stripping of optical fiber cable and then perform precise cleaving.

Write the advantage of precise cleaving over cutting the fiber ends using blades of the knife.

Practical Activity 2. Demonstrate the parts of fusion splice machine

Material required

Fusion splice machine, notepad, pen

Procedure

Step 1. Place a fusion splice machine on a solid surface. Visually inspect the parts fusion splice machine and its screen to view splicing operation as shown in Figure 1.

Fig. 1 Parts of fusion splice machine

Step 2. Open the cap of fusion splice machine and analyse the inside electrodes used for electric arc to join the fiber as shown in Figure 2.

Fig. 2 Internal interfacing of fusion splice machine

Step 3. Analyse the left and right clamps used for fixing both the ends of the cleaved fiber, which is to be spliced as shown in Figure 3.

Fig. 3 Clamps inside the fusion splice machine

Step 4. Open the wind protector cap, analyse the slot made for fixing the protection sleeves above the fiber as shown in Figure 4.

Fig. 4 Wind protector cap

Step 5. Observe and note down the different parts of splice machine.

Practical Activity 3. Demonstrate to perform fusion splicing using electric arc.

Materials required

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

Procedure

Step 1. Consider the damaged optical fiber cable, which need to be splice as shown in Figure 1.

Fig. 1 Damaged optical fiber cable

Note – When we take optical fiber cable, read the specification printed on the outer coating of fiber cable. Whether it is single mode or multi-mode. Based on it, splice machine setting needs to be customize.

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

Fig. 2 Breaking damaged fiber using plier

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

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

Step 4. Now, take one broken parts of fiber cable out of two parts, take a round cutter and put the fiber 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 fiber end to remove it as shown in Figure 4.

Fig. 4 Working of Round Cutter on the fiber

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

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

Step 6. Take any one fiber. This fiber is now used for splicing.

Note: As we are learning the fusion splicing for that we are considering only one fiber out of multiple. But, in actual practice all fiber needs to be spliced in the same way.

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

Fig. 6 Placing protection sleeve inside the fiber

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

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

Step 9. Now, cut the edge of cladding using precision cleaver. fiber in the machine is kept horizontally and the machine blade cuts the fiber ends vertically.

Precaution– Don't place your finger inside the cutter

Step 10. Take other fiber repeat the same steps to prepare the fiber.

Step 11. Now, take fusion splice machine, open its cover place the both the fibers in fusion splice machine as shown in Figure 8.

(a)

(b)

(c)

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

Step 12. The machine has two steps of operation. Firstly, it aligns the cores of the two fibers to be joined and then the two electrodes inside it performs fusion of the fiber as shown in Figure 9.

Step 13. Now open the wind protector place the spliced fiber 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. Hence in this way protection sleeve is fix on the spliced fiber joint as shown in Figure 10.

Fig. 10 Display unit shows the splicing operation going inside the fusion splice machine

Assignment 3

After performing the assignment 2 of this chapter, perform the fusion splicing of the cleaved fiber ends. Also, place the protection sleeve above it and fix it on the joined fiber ends. Note the time required to join the fiber ends and check its performance for any loss of light by passing the light into the spliced optical fiber cable.

Practical Activity 4. Demonstrate the mechanical splicing in optical fiber cable.

Materials required

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

Procedure

Step 1. Perform the same, which is being done for the fusion splicing in practical activity 3, follow the steps from 1 to 7 for doing mechanical splicing. Only difference is that protection sleeve and method of heating the end of the fiber is not applied.

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

Step 2. Take a stripped optical fiber 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 fiber 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 fiber end to the other.

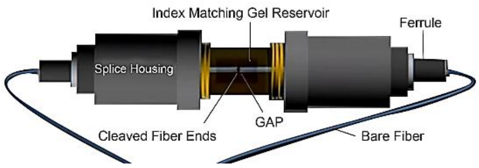


Fig. 1 Mechanical splicing housing

Fig. 2 Mechanical connector

LOSSES IN SPLICING

When joining optical fibers, the opposed cores must be properly aligned. Optical fiber splice loss occurs mostly due to following–

Poor concentricity – Poor concentricity of joined optical fibers causes a splice loss. For example, if the light source wavelength is 1310nm, misalignment by 1 μm results in approximately 0.2 dB of loss as shown in Figure 7.8.

Fig. 7.8 Splice loss due to poor connectivity

Bending of optical cable – Due to excessive bending of optical fiber cable, light inside the optical fiber cable may be diverted, which will make a loss of light. Avoid the increasing bending angle of optical fiber cable as shown in Figure 7.9.

Fig. 7.9 Splice loss due to Axial run-out

Gap– An end gap between optical fibers causes a splice loss as shown in Figure 7.10.

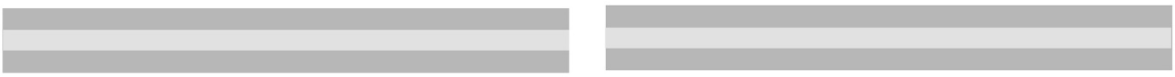
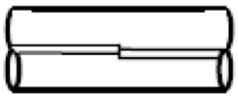


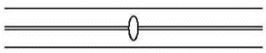
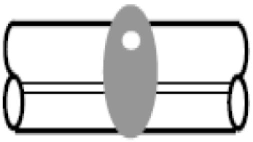
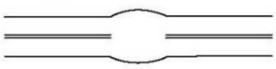
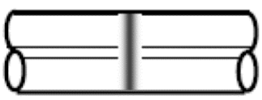
Fig. 7.10 Splice loss due to Gap

Reflection – At the terminal of optical fiber cable, due to change in refractive index there is a loss of light. This loss is in the form of reflection.

Splice Problem Troubleshooting

Here are some common problems and likely causes.

Symptom	Cause	Remedy
Core axial offset  Fig. 7.11	Dust on the V-groove of fusion splice machine or fiber clamp	Clean V-groove and fiber clamp
Core angle  Fig. 7.12	a. Dust on the V-groove of fusion splice machine or fiber clamp. b. Bad fiber end face-quality	a. Clean V-groove of fusion splice machine and fiber clamp b. Check if fiber cleaving is done properly.
Core step  Fig. 7.13	Dust on the V-groove of fusion splice machine or fiber clamp	Clean V-groove of fusion splice machine and fiber clamp

Core curve  Fig. 7.14	1. Bad fiber-end face quality 2. Pre-fuse power is too low or pre-fuse time is too-short	1. Check if fiber cleaving is done properly. 2. Increase pre-fuse power and pre-fuse time
Bubbles–  Fig. 7.15	1. Bad fiber-end and face quality 2. Pre-fuse power is too low or pre-fuse time is too-short	1. Check if fiber cleaving is done properly. 2.Increase pre-fuse power and pre-fuse time
Combustion  Fig. 7.16	1. Bad fiber-end and face quality 2. Presence of the dust is still there after cleaning fiber or cleaning arc.	1. Check if fiber cleaving is done properly. 2. Cleaning the fiber ends thoroughly or increasing the cleaning arc time
Separation  Fig. 7.17	If electrodes are contaminated. Electrodes and the fusion current are very high.	Increase pre-fuse power and pre-fuse time
Fat  Fig. 7.18	Auto feed too fast, incorrect current	Increase pre-fuse power and pre-fuse time
Thin  Fig. 7.19	This type of problem is present when current is high and 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. 7.20	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 fibers is known as a (a) fiber splicing (b) fiber connector (b) fiber attenuator (d) fiber dispersion
2. Which of the following is a major part of fusion splicing (a) Electric Arc (b) Heating (c) Fusion (d) All of the above
3. Which of the following defines the term cleaving (a) Cutting the fiber edges (b) Polishing the fiber ends (c) Cleaning the fiber (d) All of above
4. The loss of light in fusion splicing compared to mechanical splicing is (a) Equal (b) Greater (c) Less (d) None of above
5. Mechanical splicing is also known as (a) V-Groove splice (b) Elastic tube splice (c) Rotary splice (d) Both a and b
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 we 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 are 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 fiber is larger than the cladding of the receiving fiber (b) The cladding diameter of the transmitting fiber is smaller than the cladding of the receiving fiber (c) The cladding diameters of the fibers do not match (d) The cladding diameters of both fibers are slightly larger than normal
10. Which of the following loss, if there is a mismatch between the cores of two fibers. (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) None of the above

B. Fill in the blanks

1. Mechanical fusion provides the loss of ____________ dB.
2. Fusion splicing provides loss of ____________ dB
3. fiber end must be cut ____________ to the end of the fibers.
4. The fusion one provides a lower level of ______ and a higher degree of ________ than mechanical splicing
5. OTDR full form is _________
6. fiber cleaning is done by____________ method.

7. Splicing operation can be monitor using __________part of fusion splicing machine.
8. Cleaning of stripped fiber can be perform using.

C. Short Answer Questions

1. What is splicing?
2. What is cleaving?
3. How to clean fiber during splicing?
4. Name the tool used for cleaving.
5. Why diamond is used as cutting agent in the tools used for cleaving?
6. What are the basic methods used for splicing?
7. Compare different splicing techniques
8. What are the advantages of placing optical matching cement?
9. Write steps involved in splicing technique?

D. Answer the following in short

1. How to repair a broken fiber?
2. What is mechanical splicing?
3. Which solution is used for cleaning fiber?
4. Differentiate between splicing a fiber and joining two copper wires?
5. Which is the best method employed for splicing?
6. List out the applications of splicing.
7. How to test the splicing procedure.
8. What are the characteristics of good splicing.

Session 3: Indoor Optical Fiber Installation

Cable installation means laying the cable between the transmitter and the receiver. This cable acts as a medium to transfer the data or information in case of wired communication as discussed in chapter 1. Proper planning is done, area is surveyed, and instruction are made for do's and don'ts. Cables can be installed indoor or outdoor using various installation methods. The installation process will depend on the type of cable being used and nature of the installation. Installation of both copper wire and optical fiber cables are similar. Optical fiber cables require careful handling. As optical fibers are made up of glass, hence carefully it has to be installed.

INDOOR OPTICAL fiber INSTALLATION

In the installation of optical fiber cable following steps are perform.

1. Site visit
2. Route inspection
3. fiber optic cable laying
4. Splicing and termination of optical fiber cable
5. Name plates and tagging

6. Post installation testing

1. Site Visit

Before installation of optical fiber cable, site visit needs to be done. Site visit will determine approximate idea of the area where cable has to be laid as shown in Figure 9.1. The visit gives the necessary information about the ground reality of the site. By doing effective site visit one could make the best plan of installation. Site visit will make us understand actual equipment locations, routing for cable, and proper elevations. As services such as digging, trenching have to be perform, site visit is helpful for executing these services. For example, site can be rocky, sandy, hilly as shown in Figure 9.2.

Fig. 9.1 Site visit for installation of optical fiber cable

Fig. 9.2 Some site condition (a) Hilly area (b) Sandy area (c) Rocky area (d) Residential area

2. Route Inspection

Route inspection is the actual survey of the route. Route is representing the path, which is to be followed by the optical fiber cable. This will help in determining the location for cable routing, termination points, joint prior to the commencement of any work. Route plan has to be prepare after doing route inspection. Following are the steps to perform route inspection.

- Optical fiber cable route plan.

- Verify the plan through a route walk.
- Route inspection report

Obtain an optical fiber route plan – Obtain a layout, describing the proposed optical fiber cable route. This layout will helps to identify physical locations, departments involved such as electricity, water, and municipality. Permission required for carrying out the entire activity, physical obstacles & health hazards along the route.

Fig. 9.3 (a) Team carrying layout of OFC installation (b) Team observing obstacles in way of OFC installation

Verify the plan through a route walk– Preliminary survey have to be carried out for finalizing the drawing for route of optical fiber cable. While performing the route walk, planning team should consider the following points.

Planning team must carry drawing of optical fiber route.

Fig. 9.4 Team carrying out the drawing of optical fiber cable route

- List of tools require for performing the installation of optical fiber cable. Technical data-sheet of the cable, installation guidelines, safety measures to be incorporated, total budget or cost involved.
- In order to protect the cable from corrosion, determine the composition of different soil type.

Fig. 9.5 Soil test performing by the technician

- Avoid laying of optical fiber cable close to a water and LPG gas pipe.

Fig. 9.6 (a) Leakage in water pipe may damage optical cable (b) Leakage in LPG gas pipe may damage the optical cable

- Avoid laying of optical fiber cable adjacent to cultivated field.

Fig. 9.7 Cultivation may damage the nearby optical fiber cable

- Avoid the areas near chemical industry as they dispose toxic chemical , which will damage the optical cable.

Fig. 9.8 Industry nearby to the road may damage the optical fiber cable

- Avoid the areas, which require large rock cutting. It will make difficult to dig such areas. It will also not appropriate as per the workplace safety.

Fig. 9.9 Digging in rock

- Carefully decide the route of the cable in order to avoid built up areas including those areas where building are likely to come up in future.
- Verify the plan for accessibility and availability as per design.
- Verify construction methods, special tools, splice locations.
- Check for material storage areas and ventilation.

Fig. 9.10 (a) Ware house for optical fiber cable (b) Reels of optical fiber cable stored in warehouse

- Then after make a sketch as per the route walk. This sketch is called as route walk sketch.

Fig. 9.11 Sketch of installation area after route walk

Route inspection report – Planning team should submit the route inspection report. This report defines most suitable routes for all the fiber optic links. The employer will give the preliminary approval for the route. After approval of the route, planning team will submit the final report for approval before implementation. The final survey report shall include following–

- A drawing of the proposed route indicating all details of the route including relevant details of soil, underground pipe line, power and communication cables routes, other important landmarks.
- The distance of optical fiber cable route from the centre of the road shall be indicated on the route maps as well as documented in tables.
- Location and number of permanent and temporary manholes.
- Location of all turns, bends and major landmarks.

- Type, quantity and location of all the joint boxes. Care must be taken to minimise the number of splicing and joint boxes.

3. Optical fiber laying

- Perform the trenching in accordance with the route inspection.

Fig. 9.12 Trenching along the road for optical fiber installation

- Optical fiber cable installation should be carried out using cable roller and due care shall be taken to avoid damaging of outer sheathing of the cable.

Fig. 9.13 Cable drum trailer

Fig. 9.14 Cable drum handling

Fig. 9.15 Cable pulling grip

Fig. 9.16 Cable roller

- Cable reels should be properly aligned, while pulling the cable for installation.

Fig. 9.17 Aligning optical fiber cable drum

- Ensure that cable pulling tension does not cross the maximum pulling tension recommended by cable manufacturer.

Fig. 9.18 Person pulling the optical fiber cable for cable laying

- Lubricant should be applied to the cable sheath to minimise the pulling tension.

Fig. 9.19 Lubricating the cable for reducing the friction

- Cable should be carefully inspected for sheath defects. If defect are detected, pulling should be stopped immediately, cable section should be repaired or replaced as per the damage.

Fig. 9.20 Damage in the cable sheath

- Care should be taken not to violate the minimum bending radius value specified by the manufacturer.

Fig. 9.21 Bending of cable

- Cable end should be covered with an end cap to avoid moisture.

Fig. 9.22 End cap in the cable

- After laying of optical fiber cable, make sure that the tension of cable must be less then specified tension by the manufacturer.

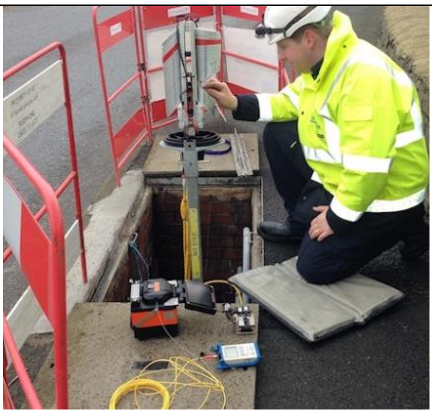


Fig. 9.23 Technician testing OFC using tension measuring device

- Extra length of cable should be left at the beginning and at the end of the cable run.

Fig. 9.24 Extra cable

- If there is a need of manhole for splicing, make sure that manhole must be properly covered and have space for work.

Fig. 9.25 Manhole for optical fiber maintenance

Fig. 9.26

4. Splicing and termination of optical fiber cable

If there is need of splicing, perform the splicing as discussed in previous chapter.

Fig. 9.27 Repairing optical fiber cable using splice machine

- During splicing, ensured that the physical durability and the optical characteristics of the fiber are not affected.
- Average splice loss for any OFC network shall not be more than 0.1dB.
- Each splice joint should be properly covered to protect them from dust.

Fig. 9.28 Protecting cover on splice joint

- Fiber distribution panel must be accessible for ease of maintenance and troubleshooting.
- The fiber distribution panels at terminal sites shall be securely mounted.

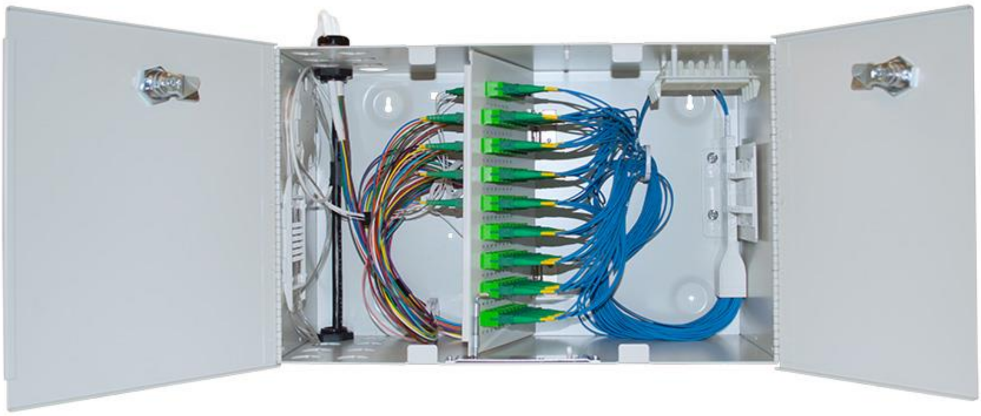


Fig. 9.29 Optical fiber distribution panel

fibers shall be numbered and fiber cable destination shall be indicated on the fiber distribution panel.

Fig. 9.30 Serial number tag on optical fiber cable

The splice loss for each splice, attenuation loss for each fiber link and the OFC route should be shown in the documentation.

5. Name plates and tagging

All optical fiber cable, splice joint and manholes must be mark with number tag and nameplate.

Fig. 9.31 Tags on optical fiber cable

Nameplate must consist of stainless steel plate.

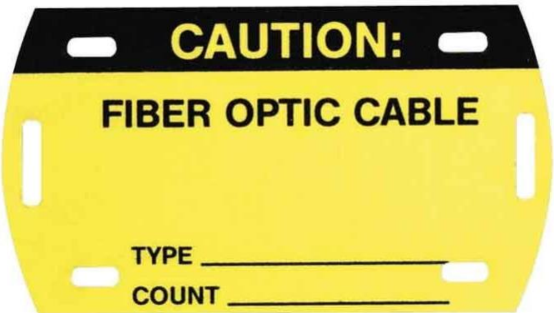


Fig. 9.32 Format of cable identification tag

6. Post installation testing

After completion of installation and splicing of optical fiber cable, all the fiber links from both the ends are tested. This test is perform using optical power meter, OTDR and light source to ensure that all the fibers of the installed optical fiber cables in are in good condition. Power loss test conduct at wavelength of 1310 nm and 1550 nm. In addition, result submitted to the controlling team for review and approval.

- This test is essential to ensure that the installation activities like drum transportation, cable laying and pulling did not cause any damage to optical fiber cable. Then after test results are included in documentation for future reference.

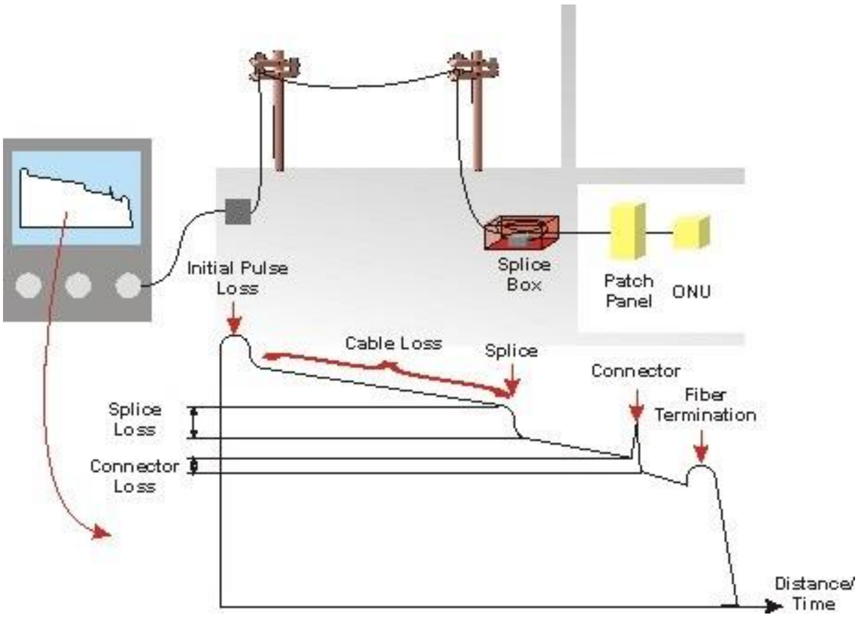


Fig. 9.33 (a) Optical time domain reflectometer (OTDR) (b) Graphical representation of different losses in optical fiber cable

CHECK YOUR PROGRESS

A. Multiple Choice Questions

1. Identify the basic requires for optical fiber cable installation. (a) Skilled labors (b) Equipment (c) Technicians (d) All of above
2. Optical cables are made up of (a) Copper (b) fibers (c) Twisted Wires (d) Shielded wires
3. In which area optical fiber cable can be installed (a) Indoors (b) Outdoors (c) Both a and b (d) Only a

4. To install the cable underground first thing it require is– (a) Route plan (b) Permission from various governing bodies (c) Site visit (d) None of the above
5. Which of the following are the steps for the route inspection. (a) Obtain an OFC route plan. (b) Verify the plan through a Route Walk (c) Take corrective actions (d) All of the above
6. Which of the following steps are required to inspect the installation site. (a) Approximate idea of the area where cable has to be laid (b) How much overall area to be covered (c) What all obstacles have to be faced like somewhere building or trees are encountered. (d) All of the above
7. Moisture in the environment can result in (a) fiber breakage (b) Increased fiber strength (c) Attenuation rate is decreased (d) All of the above
8. Cable placement means (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 without pulling

B. Fill in the blanks

1. When pulling the cable ________ part of the cable must not get damaged.
2. Frictional force can be reduce using ________ at the time of cable laying.
3. Extra cable length is left at the beginning and at the ________ of cable run, must be cut using cutter.
4. Nameplates and tags consist of ________ material.
5. Average splice loss for any optical network shall not be more than ________ dB.

C. True or False

1. Cable installation cannot be done with the coaxial cables.
2. Before installation of the cable it is required to have proper planning where installation can take place
3. There are two unique kinds of fiber optic broadband, FTTC and FTTH.
4. Safety glasses or goggles must be worn while performing drilling or similar operation
5. When working in extremely hot conditions, you need to follow safe work practices to combat working in extreme temperatures.
6. Safety helmets cannot be worn by all workers at all times in all designated areas.
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. Safety gloves of appropriate protective material are to be worn when handling sharp or hot materials, chemicals or dangerous liquids.
9. Trenching uses machinery to either create a large cut all the way through the pave or a slender cut within the high of the pave to put the fiber cable

D. Short Answers Questions

1. What is route inspection?
2. What are benefits of Route Inspection
3. Briefly explain the three steps of route inspection.
4. List out precautions to be taken to install fiber
5. How to do site visit to install the cables
6. What is the benefits of route plan
7. How cables are installed underground

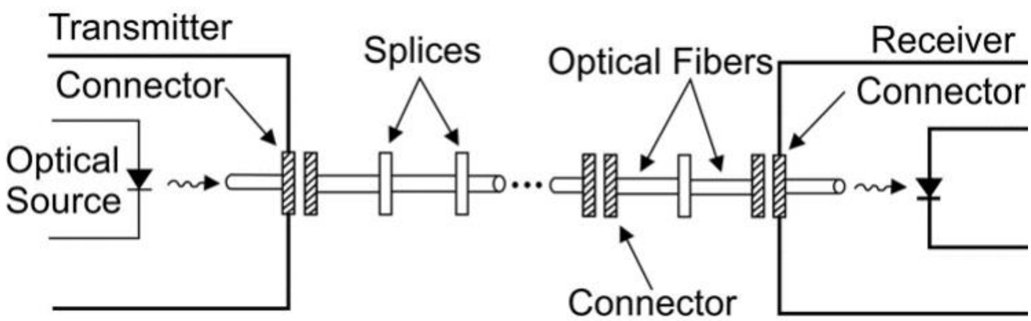
8. How the future networking is dependent on optical fiber cabling and why?
9. What is the requirement of site visit?
10. Why route inspection is necessary? Write the steps to follow route inspection
11. Write the safety precautions to be followed to perform route inspection?
12. How to install the cables near railway lines?
13. How to install the cables near existing pipelines?
14. Why safety at the site of job is important?
15. In case of extreme temperature what precautions has to be taken at job at site.
16. Write at-least 6 steps to execute job at site safely
17. What happens if there is sudden rainfall at the site occurs?
18. In case of emergency, which number should be dialled to call ambulance?
19. List the method to resolve the problem with job technician in case any tool/machinery fault in between job

Session 4: Link Performance Analysis

The precious chapters have presented the fundamental characteristics of the individual building blocks of an optical fiber transmission link. These include the optical source as transmitter, optical fiber transmission medium, connectors used to join individual fiber cables to each other. In this chapter, we will examine how these individual parts can be put together to form a complete optical fiber transmission link. After examine at components level, next we will relate it to system level. For a given set of components and a given set of system requirements, we then carry out a power budget analysis to determine whether the optical fiber link meets the attenuation requirements.

OPTICAL fiber LINK ANALYSIS

A link is a way through which signal travel between two points. Optical fiber cable is physical link between the two points. Path is the way through which signal travel; optical fiber cable is one such path. A simple intercom consists of the sending station, which converts voice into electrical signals, the wire over which the signals are transmitted and the receiving station, which converts the electrical signal back into voice, is an example of point-to-point link.



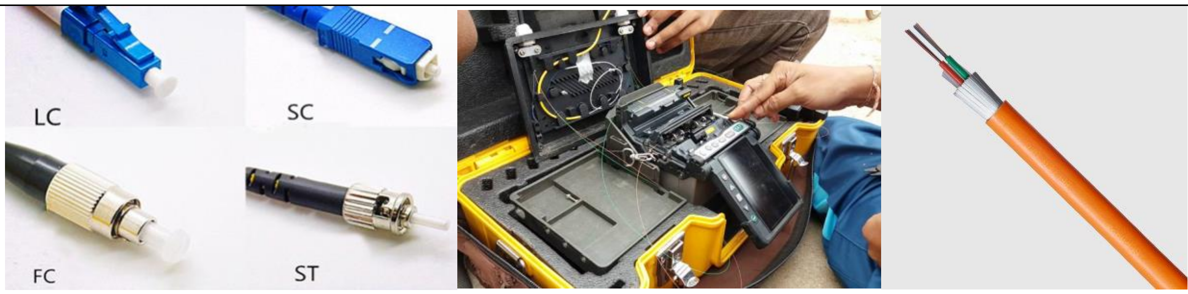


Fig. 10.1 Optical power loss model for a point-to-point link. Loss occur at (a) Connector loss (b) Splice loss (c) Optical fiber loss

Hence, analysis are usually carried out to ensure that the desired system performance. This analysis is done by link power budget analysis.

In link power budget analysis, one first determines the power margin between the optical transmitter and receiver as shown in Figure 10.1. This margin can then be allocated to connector, splice, and fiber losses, and any additional margins required for expected component degradation or temperature effects. If the choice of components did not allow the desired transmission distance to be achieved, the components might have to be changed or repeaters might have to be incorporated into the link. We shall now examine this analysis in more detail.

Link Power Budget

Losses occur at many points in an optical fiber system. We have to ensure that the light source launches enough power into the fiber to provide enough power at the receiver. The link loss budget is derived from the sequential loss contributions of each element in the link.

Transmitter output - Receiver input = Losses + Margin (All calculations are done in dB)

$$\text{loss} = 10\log\frac{P_{\text{out}}}{P_{\square}}$$

Where, P_{in} is the power entering in connector of optical fiber cable at transmitting end and P_{out} is power coming out of the connector at receiving end as shown in Figure 10.1.

In addition, a link power margin is normally provided in the analysis to allow for component aging, temperature fluctuations, and losses arising from components that might be added at future dates. A link margin of 6 to 4 dB is generally used.

For example, for single mode fiber cable with two most commonly used wavelengths 1310 nm and 1550 nm. The attenuation measurement will vary depending upon which wavelength is in use. Attenuation is measured in dB and is quoted as attenuation in dB/km.

Table 10.1 Losses in single mode fiber

Optical fiber type	**Loss/Km**		**Loss**	
	in dB		**Connector**	**Splice**
	1310 nm	**1550 nm**	**in dB**	
Single Mode	0.35	0.23	0.50	0.09

The measured value of attenuation of an optical fiber link should not exceed the sum of allowable attenuation of each component. These components are fiber optic cable, FO connectors, splices.

Link Loss (dB) = Cable Loss + Connector Loss + Splice Loss + Safety Margin

Cable Loss = Cable length (Km) x Attenuation Coefficient (db/Km)

Connector Loss = Number of Connector Pairs x Connector Loss (dB)

Splice Loss = Number of Splices x Splice Loss (dB)

Safety Margin = 2 ~ 3 dB depending upon the length of link

Practical Activity 1. Calculate the budget of optical fiber link loss

Material required

Optical light source, Optical power meter, Connector, splice, system transmitter, system receiver

Procedure

Step 1. Make the test set as shown in Figure 10.2, using components of the optical fiber.

Step 2. Now, we will consider the loss of individual component such as fiber loss, splice loss, connector loss.

Step 3. Take a multimode optical fiber cable of 2000 m in length, operating at wavelength of 1300nm. The loss observes using power meter are as follows.

a. fiber loss at the operating specific wavelength

Cable length (km)	2.0 Km
fiber type	Multimode
Wavelength (nm)	1300nm
fiber attenuation (dB/km)	1 dB
Total fiber loss for system operating on multimode fiber at 1300nm	2.0 dB for 2km cable length

b. Connector Loss

Typical connector loss	0.5 dB
Total number of connector pairs	5 (including connectors on ends of cable)
Total connector loss	5 x 0.5 = 2.5 dB

c. Splice Loss

Typical splice loss	0.2 dB
Total number of splices	1
Total splice loss	0.2 x1=0.2 dB

d. Total Cable Plant Attenuation

Total fiber loss	2.0 dB
Total connector loss	2.5 dB
Total splice loss	0.2 dB
Other	0 dB
Total link loss	2.0+2.5+0.2+0=4.7 dB

Step 4. Now we can say that total link loss in the 2000m long multimode optical fiber is 4.7 dB.

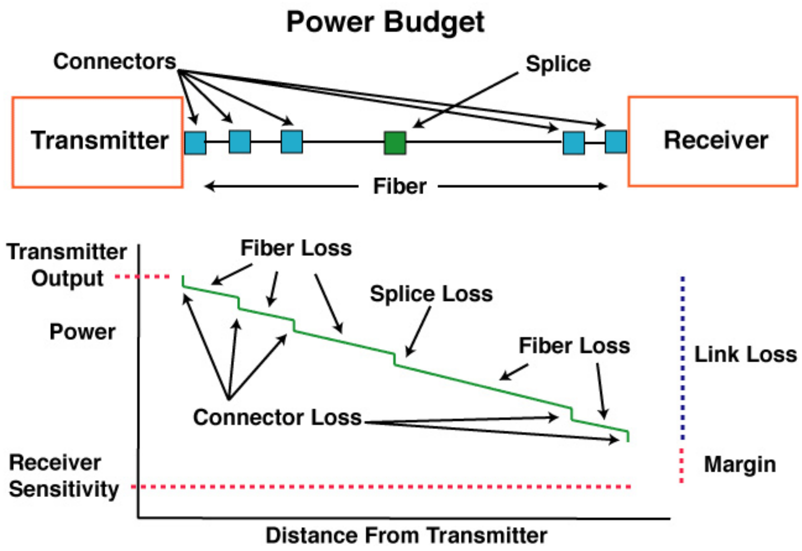


Fig. 10.2 Graphical representation of optical fiber link loss

Assignment 1. Calculate optical fiber link loss budget for the following parameters.

a) Cable length– 3 km
b) Number of connections– 2
c) Number of splices– 1
d) Operating wavelength– 1300 nm

CHECK YOUR PROGRESS

A. Multiple Choice Questions

1. When beginning a basic fiber optic system design, what should be the first things considered? (a) Data rate, transmission distance (b) Cable diameter, cable length (c) Inside plant, outside plant (d) Buffer type, jacket material
2. Optical fiber offers ________ bandwidth and _______ attenuation than twisted pair or coaxial cable. (a) Less, more (b) Equal, more (c) Greater, more (d) Greater, less
3. The link loss budget simply considers the total optical power loss P is allowed between (a) The light source and the photo-detector (b) The light source (c) The photo-detector (d) Splicers and connectors
4. The link loss budget is derived from the sequential loss contributions of each element in the link and each these loss elements is expressed in (a) Decibels (dB) (b) Meters (c) Kilometers (d) Centimeters

B. Fill in the Blanks

1. Link margin of ____ dB to _____ dB are generally considered in optical fiber cable.
2. Link power loss can be analyse by calculating the difference between ___ and ___.
3. Standard unit to measure link loss is ________
4. Fiber link loss includes ________ loss and ________ loss.
5. Multi-mode optical fiber of length 2000 m have an average link loss of …. dB.

C. Short Answer Questions

1. What is power budget analysis?
2. Which is point-to-point link analysis?
3. State the step of system Considerations in carrying out a link power budget?
4. Name the various types of losses the fiber optical cable has while performing the link analysis.

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: Safety And Hazards

Session 1. Safety And Hazards

Whether you work as a technician or an installer, your work with optical fiber can expose you to several workplace hazards. This includes the hazards ranging from laser light sources to ladders. Optical fiber technicians are responsible for their own safety as well as for the safety of your co-workers. This chapter includes the health of workers, their job holding efficiency, and environment. So that their job can be work efficiently.

Knowledge of safe work practices is necessary. This chapter also describes the types of hazards that you will encounter in the workplace and different methods of working safely around them.

PERSONAL PROTECTIVE EQUIPMENT

The kind of personal protective equipment required around a machine will depend up on the machine and the task employee is performing. Nevertheless, gloves, helmets, safety glasses, earplugs and other gears are important to use where necessary. For safety, signs can be post near panels reminding employees to wear PPE as shown in Figure 8.1.

Fig. 8.1 Personal protection equipment

Safety helmets

Safety helmets as shown in Figure 8.2, worker must wear at the installation site. It protects the worker from being hit by any falling material or object.

Fig. 8.2 Safety Helmet

Eye and Face Protection

LASER light is use as a source, so technician must be cautious while installing the optical fiber. It will damage the retina, if a person look directly to the laser light as shown in Figure 8.3.

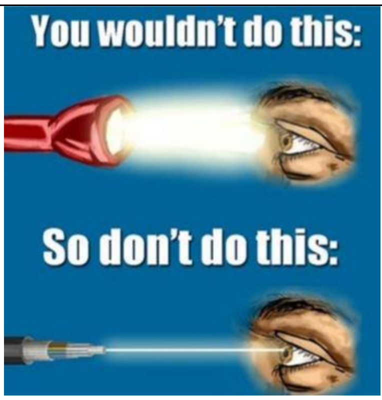


Fig. 8.3 Protection of light against LASER light

Whenever you are working with fiber, it is necessary to wear safety glasses as shown in Figure 8.4.

Fig. 8.4 Safety glass or goggles

Respiratory Protection

Respiratory or dust masks as shown in Figure 8.5 are to be wear when carrying out tasks that create inhalable dust or fumes, when handling certain chemicals or when working in dusty environments.

Fig. 8.5 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. Wearing clothes is shown in Figure 8.6.

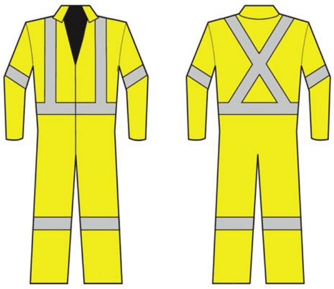


Fig. 8.6 Worker with loose clothes

Footwear

Boots must be wear at the site as shown in Figure 8.7. Rubber shoe has a protective strengthening in the toe, which prevents the foot from falling objects.

Fig. 8.7 Footwear

Gloves

Safety gloves of appropriate protective material as shown in Figure 8.8 must be wear. When handling optical fiber cable, sharp or hot materials, chemicals or dangerous liquids.

Fig. 8.8 Hand Gloves

fiber 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 chemicals.

Fig. 8.9 Laboratory coat

Always use insulated tools while working.

Fig. 8.10 Insulated tools

Chemical Hazards

If chemicals are improperly stored, there can be a chemical leak.

Fig. 8.11 Improper storage of chemical

Mishandling of chemicals due to inadequate training or negligence.

Fig. 8.12 Mishandling of Chemicals

Diseases and environmental illnesses can be caused by exposure to toxic substances in the workplace.

Fig. 8.13 Exposure of toxic substance can cause illness

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

- Chemical burns
- Itchy burning eyes
- Nausea, vomiting and diarrhoea
- Headaches
- Fever or chills
- Rapid heart rate

Fig. 8.14 Read all labels to work safe

Fire Extinguisher

A fire extinguisher is a protection device used to extinguish fire. It is the basic equipment, which is effectively use for controlling fire. A fire extinguisher is a cylindrical pressure vessel containing an agent, which discharge to extinguish a fire. Fire extinguisher is shown in Figure 8.15.

Fig. 8.15 Fire extinguisher

Different parts of fire extinguisher is shown in the Fig.8.16.

Fig. 8.16 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 8.17. Pull the safety pin.

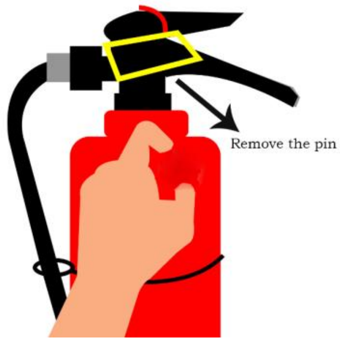


Fig. 8.17 Removing the pin

Step 2. Remove the seal from the handle as shown in Figure 8.18.

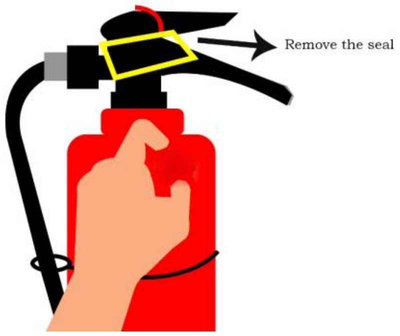


Fig. 8.18 Removing the seal

Step 3. Use the fire extinguisher by squeezing the lever and sweep it over the fire as shown in Figure 8.19.

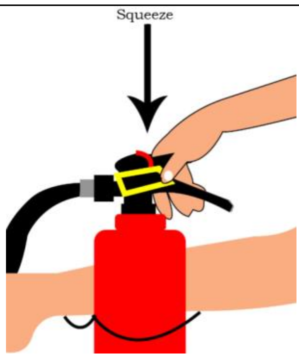


Fig. 8.19 Squeezing the handle

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 fire is due to the burning of paper, wood, cloth, plastic.

Fig. 8.20 Class A type fire extinguisher

Class B– This type of fire extinguisher is used, when fire is due to the gasoline, grease, oil, etc.

Fig. 8.21 Class B type fire extinguisher

Class C– This type of fire extinguisher is used, when fire is due to the electrical cables, wires, equipment etc.

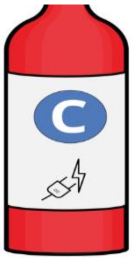


Fig. 8.22 Class C type fire extinguisher

Class D– This type of fire extinguisher is used, when fire is due to the combustible metal.

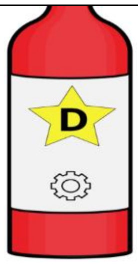


Fig. 8.23 Class D type fire extinguisher

Class K– This type of fire extinguisher is used, when fire is due to materials present in the kitchen.

Fig. 8.24 Class K type fire extinguisher

First aid

Accident at the site of working with cables can cause countless injuries. Injury can be minimised and many lives saved, if proper rescue techniques and treatment are used. Accidents may occur at any time or place. Timely response and treatment of victims is a major concern. When an accident occurs, due to the effect of muscle cramping, a victim is often incapable of moving or releasing the electrical conductor. Caution should be the primary consideration during any accident or emergency.

Fig. 8.25 First aid kit

A victim may require Cardio-Pulmonary Resuscitation (CPR). Steps to perform in CPR are shown in the Fig. 8.26, 8.27, 8.28.

Fig. 8.26 Chest Compression

Fig. 8.27 Open the mouth for airway

Fig. 8.28 Rescue breathing

If the victim is breathing and has a heartbeat, give first aid for injuries and treat for shock.

Ensure the victim gets medical care as soon as possible.

Physician attending the victim must have detailed information to properly diagnose and care for the victim. The physician must determine whether the victim should be sent to a 'Trauma or Burn Centre'.

Site Safety

Many of the locations for fiber optic components may be in areas that require special safety precautions. These 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

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

More to know

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

Table 8.1. Primary Treatments for Isopropyl Exposure

Type of exposure	Isopropyl	
	Effect of exposure	Emergency treatment[1]

Inhalation  Fig. 8.29 Inhalation	Irritation of upper respiratory tacks  Fig.8.30 Irritation	Move victim to area containing fresh air. Administer artificial respiration, if breathing is irregular  Fig. 8.31 Artificial respiration
Ingestion	Nausea, Vomiting  Fig. 8.32 Vomiting	Have victim drink water and milk. Seek medical assistance
Contact with skin  Fig. 8.33 Contact on skin via chemical	Skin Irritation  Fig. 8.34– Irritation	Wipe off the affected area of skin and wash with the soap and water.  Fig. 8.35 Washing of the hands
Contact with eyes	Eyes Irritation  Fig. 8.36 Eye Irritation	Wipe eyes with plenty of water for 15 min  Fig. 8.37 Washing of eyes

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

CHECK YOUR PROGRESS

A. Multiple Choice Questions

1. Never look directly the fiber light, since it will damage the (a) Eyes retina (b) Ears (c) Skin (d) Nose
2. LASER light will penetrate inside the eyes retina causing blindness since it is (a) Focussed beam (b) Unfocussed beam (c) Scattered beam (d) Transmitted beam
3. Which of the following is used to heal the burn injury in case of electrocuted. (a) Burnol (b) Soframycin (c) Burnol or Soframycin (d) None of the above
4. Which of the following is not the bleeding type. (a) Minor bleeding (b) Bleeding through artery or main blood circulatory system (c) Bleeding from vein (d) External bleeding
5. First aid box must contain following medicine (a) Tincture – iodine (b) Potassium permanganate (c) Sol-violate spirit (d) All of the above
6. What are the steps for using the fire extinguisher? (a) Identify the safety pin of the fire extinguisher which is generally present in its handle. (a) Break the seal and pull the safety pin from the handle. (b) Use the fire extinguisher by (c) squeezing the lever (d) All of the above
7. 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
8. 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 ___ gloes and shoes.
2. Keep stretching your arms, legs, neck and back while working to ensure that they are not ___.
3. The unconsciousness due to electric shock may cause damage to his/her _
4. When fire is due to combustible metal then __ type of fire extinguisher is used.
5. Defective or inadequate insulation may result ____

C. True or False

1. Fiber optic splicing and termination use various chemical cleaners and adhesives as part of the processes.
2. The broken ends of fibers and scraps of fiber created during termination and splicing can be extremely dangerous
3. Fire extinguishers for use on electrical fires will have a C, BC or ABC on the label.
4. Apply Burnol or Soframycin type creams to burnt part of body of electrocuted person and do the bandage.
5. All the parts of body of affected person be kept in straight position and should be laid down on even spot.
6. Fire extinguisher consists of a hand-held cylindrical pressure vessel containing an agent, which can be discharged to extinguish a fire.

7. Check the rating and physical condition of the components and cables.
8. Common injuries that can be caused due to lifting heavy loads include neck strain, wrist sprain, back sprain, shoulder pain.
9. The aim of first-aid treatment is to cool down the affected area rapidly to minimize damage and loss of body fluids, and therefore reduce the risk of developing shock.
10. Fire extinguisher is used in case of an earthquake.

D. Short Answer Question.

1. What are the factors that result in hazard?
2. List out the various remedies to be taken in workplace.
3. How will you protect yourself from electric shock in a lightning storm?
4. What are the precautions to be taken for preventing electric shock on the job?
5. List out the various items that must be in first aid box.
6. What are the first aid treatments in case of burn injury?
7. Write down the steps for correct way of operating a fire extinguisher in case of a fire emergency.

Glossary

Absorption– When referring to light, the conversion of specific wavelengths of light energy into heat through contact with impurities such as water or ions of copper or chromium. Absorption is one of the ways in which light can be lost during transmission through optical fiber.

Acceptance angle– The angle within which light can enter a fiber core of a given numerical aperture and still reflect off of the boundary layer between the core and the cladding. The acceptance angle is also known as the cone of acceptance.

Amplifier– A device used to increase the power of an optical signal.

Analog– A signal that varies continuously through time in response to an input. An analog signal is infinitely variable within a specified range.

Angle of incidence– The angle of a ray of light striking a surface or boundary as measured from a line drawn perpendicular to the surface. Also called as incident angle.

Angle of refraction– The angle of a ray of light that is refracted as it passes through an inter-face, as measured from a line drawn perpendicular to the interface.

Angular misalignment– The offset of fiber cores caused by the fiber ends meeting at an angle.

Array connector– A connector designed for use with multiple fibers.

Attenuation– Loss of power. In fiber optics, light energy is attenuated as it travels through fiber and hardware, due to impurities and manufacturing defects.

Attenuator– A passive device used to reduce the power of an optical signal.

Backbone– In networking, the part of a local communication system that carries data between branching points.

Bandwidth– The amount of information in the form of light pulses per second that an optical fiber can carry before the information is distorted or lost due to dispersion. In fiber optics, bandwidth is usually measured in megahertz (MHz), or millions of cycles per second, per kilometre of fiber.

Binary– A value that can only be expressed as one of two states. Binary values may be "1" or "0"; "high" or "low" voltage or energy; or "on" or "off" actions of a switch or light signal. Binary signals are used in digital data transmission.

Bit– A binary digit. The smallest piece of data possible in a digital communication system.

Bit error rate (BER)– Also known as bit error ratio, the ratio of bit errors to the total number of bits transmitted.

Bit rate– The actual number of light pulses per second being transmitted through a fiber optic link. Bit rates are usually measured in megabits per second (mbps) or gigabits per second (Gbps).

Cable modem– A modem that transmits and receives signals through copper coaxial cable.

Cable tray– A shallow tray used to support and route cables through building spaces.

Chromatic dispersion– The distortion of optical signals in single-mode fiber caused by the combined effects of waveguide dispersion and material dispersion.

Cladding– The component of an optical fiber surrounding the core. The cladding is not designed to carry light, but it has a refractive index only slightly lower than that of the core. The cladding may be made of glass or plastic.

Cleave– To cut a section of fiber by scoring the outside and pulling off the end.

Coating– The first true protective layer of an optical fiber. The coating is made of plastic and is added to the fiber immediately after the fiber is drawn. In addition to protecting the fiber from nicks and scratches, the coating adds tensile strength to the fiber.

Coaxial cable– A copper two-wire cable consisting of a central wire surrounded by an insulator and a braided outer conductor that also serves as electromagnetic shielding for the cable. The entire cable is surrounded with a heavy protective outer insulator.

Coherent light– Light in which photons have a fixed or predictable relationship. Coherent light is typically emitted from lasers.

Cone of acceptance– A cone-shaped region extending outward from an optical fiber core and defined by the core's acceptance angle.

Cordage– Fiber optic cable designed for use as patch cable or short-term connections. Cordage may be either single-fiber (simplex) or double fiber (duplex). Cordage is not meant for permanent installations.

Core– The light-carrying component of an optical fiber. The core has a higher refractive index than the surrounding cladding and is typically made of glass or plastic.

Critical angle– The smallest angle of incidence at which light passing through a material of a higher refractive index will be reflected off the boundary with a material of a lower refractive index. The angle is measured from a line perpendicular to the boundary between the two materials, known as normal. The critical angle is necessary for total internal reflection to occur.

Current– The flow of electrons through a conductor.

Decibel– A relative measurement of signal strength used to measure gain or loss of optical power in a system. The decibel scale is a logarithmic scale used to measure the ratio of a signal's transmitted strength to its received strength. For example, a loss of 3 decibels (dB) in a system means that about half of the original signal is left. A loss of another 3 dB means that half of the remaining signal is left.

Demodulate–To retrieve a signal from a carrier and convert it into a usable form.

Digital– A signal that uses binary values to carry information. Digital signals are used to communicate information between computers or computer-controlled hardware.

Dispersion– The spreading of light rays along the propagation path due to one or more factors within the medium through which the light is traveling. If dispersion becomes too great, individual signal components can overlap one another and degrade the quality of the optical signal. Dispersion is one of the most common factors limiting the amount of data that can be carried in optical fiber and the distance the signal can travel while still being usable.

Dispersion-shifted fiber– An optical fiber specially designed with a zero-dispersion point that occurs in the same wavelength as one of the fiber's points of low attenuation—about 1550 nm.

Dopants– Impurities that are deliberately introduced into the materials used to make optical fibers. Dopants are used to control the refractive index of the material for use in the core or the cladding.

Duplex– (1) A link that can carry a signal in two directions for transmitting and receiving data. (2) An optical fiber cable or cord carrying two fibers.

Dynamic loads– Loads such as tension or pressure that changes over time, usually within a short period.

Dynamic range– The difference between the maximum and minimum optical input power that an optical receiver can accept.

Edge-emitting LED–An LED that produces light through an etched opening in the edge of the LED.

Electromagnetic immunity– Protection from the interfering or damaging effects of electro-magnetic radiation such as radio waves or microwaves.

End separation– The separation of fiber ends, usually taking place in a mechanical splice or between two connectors.

End face finish– The condition of the end of a connector ferrule. End face finish is one of the factors affecting connector performance.

Extrinsic factors– When describing a fiber connection, factors contributing to attenuation that are determined by conditions of a splice or connector, as opposed to conditions in the fiber itself.

Ferrule– A metal or ceramic cylinder designed to hold the fiber firmly in the connector for accurate positioning.

Filter – A device that blocks certain wavelengths to permit selective transmission of optical signals.

Frequency– The number of times that corresponding parts of successive waves pass the same point in a fixed period, usually one second. Frequency is typically expressed in cycles per second, or Hertz.

Fresnel reflection– Reflection of a small amount of light passing from a medium of one refractive index into a medium of another refractive index.

Full-duplex– A system in which signals may be transmitted in two directions at the same time. A full-duplex system requires at least two separate fibers one for each direction of transmission. Full-duplex systems are often used for systems such as long-distance telephone connections, in which signals are transmitted and received at the same time.

Gain– An increase in power.

Graded-index– A fiber core with a refractive index that gradually gets lower from the center of the core to the outside of the core. Graded-index fiber is most commonly used to correct the problems that can occur in multi-mode fiber.

Half-duplex– A system in which signals may be sent in two directions, but not at the same time. In a half-duplex system, one end of the link must finish transmitting before the other end may begin.

Incoherent light– Light in which the electric and magnetic fields of photons are completely random in orientation. Incoherent light is typically emitted from light bulbs and LEDs.

Index matching gel– A clear gel used between fibers that are likely to have their ends separated by a small amount of air space. The gel matches the refractive index of the fiber, reducing light loss due to Fresnel reflection.

Insertion loss– Light or signal energy that is lost as the signal passes through the fiber end in the connector and is inserted into another connector or piece of hardware. A good connector minimizes insertion loss to allow the greatest amount of light energy through.

Interface– The boundary layer between two media of different refractive indices.

Intrinsic factors– When describing a fiber connection, factors contributing to attenuation that are determined by the condition of the fiber itself.

Isolator– A device that permits only forward transmission of light and blocks any reflected light.

Laser– A semiconductor diode that emits coherent light. Laser is an acronym for light amplification by stimulated emission of radiation. Lasers are used to provide the high-powered, tightly controlled light wavelengths necessary for high-speed, long-distance optical fiber transmissions.

Laser diodes– Semiconductor devices designed to produce laser light for fiber optic communications.

Light-emitting diode (LED)– A semiconductor device that produces incoherent light. LEDs are used in most fiber optic communication systems that do not require long distances or high data rates.

Loose-buffered– Also known as loose tube buffered, optical fiber that is carried loosely in a buffer many times the diameter of the fiber. Loose-buffered fiber is typically terminated with a breakout kit or a fan-out kit and connected to a patch panel.

Macro bend– An external bend in an optical fiber with a radius small enough to change the angle of incidence and allow light to pass through the interface between the core and the clad-ding rather than reflect off of it. Macro bends can cause signal attenuation or loss by allowing light to leave the fiber core.

Maximum tensile rating– A manufacturer's specified limit on the amount of tension, or pulling force, that may be applied to a fiber optic cable.

Media– In fiber optics, the material or materials through which light travels.

Messenger cable– A cable with a strong supporting member attached to it for use in aerial installations.

Metropolitan area network (MAN)– An interconnected group of local area networks (lans) within a metropolitan area.

Micro bend– Deformation of the core/cladding interface that changes the angle of incidence, allowing light to pass through the interface rather than reflect off of it. Micro bends are typically caused by crushing or other damage to the fiber.

Minimum bend radius– A fiber manufacturer's specified limit on the amount of bending that a fiber can take before its signal-carrying capability is diminished.

Modal dispersion– A type of dispersion caused when parts of an optical signal take different paths through a fiber. Modal dispersion potentially can cause parts of a signal to arrive in a different order from the one in which they were transmitted, rendering the signal unusable.

Modes– In an optical fiber, the possible paths light can take through the fiber core. A high-order mode is a path that results in numerous reflections off the core/cladding interface. A low-order mode results in fewer reflections. A zero-order mode is a path that goes through the fiber without reflecting off the interface at all. The number of modes in an optical fiber is determined by the diameter of the core, the wavelength of the light passing through it, and the refractive indices of the core and cladding. The number of modes increases as the core diameter increases, the wavelength decreases, or the difference between refractive indices increases.

Modulate – To convert data into a signal that can be transmitted by a carrier.

Multimode fiber – A fiber with a core diameter large enough to allow light to take more than one possible path through it.

Noise – Electromagnetic energy that is not considered part of the signal.

Normal– A path drawn perpendicular to the interface, or boundary layer between two media, that is used to determine the angle of incidence of light reaching the interface.

Numerical aperture– A dimensionless number that expresses the ability of an optical fiber core to collect light. The numerical aperture is determined by the refractive indices of the core and cladding. The numerical aperture is also used to determine the fiber's acceptance angle.

Operating wavelength– The wavelength at which a fiber optic receiver is designed to operate. Typically, an operating wavelength includes a range of wavelengths above and below the stated wavelength.

Optical combiner – A device used to combine fiber optic signals.

Optical coupler– A device used to combine or split signals in an optical fiber system.

Optical loss test set– A set of devices consisting of a light source and an optical power meter used for measuring loss through optical fiber.

Optical return loss– Optical loss in a fiber optic link caused by signals being reflected back toward the transmitter.

Optical splitter– A device used to split fiber optic signals.

Optical time domain reflectometer (OTDR)– A device used to test a fiber optic link, including fiber and connectors, by launching an optical signal through the link and measuring the amount of energy that is reflected back. The OTDR is a troubleshooting device that can pinpoint faults throughout a fiber optic link.

Outside plant– A description of fiber or fiber specifications with regard to their installation outside of any structure.

Patch cord– A two-fiber optical cable used for testing and temporary connections.

PC– The abbreviation for physical contact, which describes a connector that places the fiber end in direct physical contact with the fiber end of another connector.

Photodiode– A component that converts light energy into electrical energy. The photodiode is used as the receiving end of a fiber optic link.

Photon– A basic unit of light when it exhibits qualities of a particle.

Pigtail– A short length of optical fiber with a connector or hardware device such as a light source package installed by a manufacturer.

Raceways– Structures used within building spaces to support and guide electrical and optical fiber cables.

Rayleigh scattering– The redirection of light caused by atomic structures and particles along the light's path. Rayleigh scattering is responsible for some attenuation in optical fiber, because the scattered light is typically absorbed when it passes into the cladding.

Refraction– The bending of light as it passes from one medium into another. Refraction occurs as the velocity of the light changes between materials of two different refractive indices.

Refractive index– The value given to a medium to indicate the velocity of light passing through it relative to the speed of light in a vacuum. By comparing the refractive indices of two materials, you can determine how much light will bend, or refract, as it passes from one material to another.

Repeater– A device that receives, amplifies, and transmits a signal to extend its travel in a communication link. Repeaters are commonly used to overcome attenuation in long-distance systems.

Return loss– The amount of loss in an optical signal reflected back from the connector. A good connection provides a high return loss to minimize optical return.

Return reflection– Light energy that is reflected from the end of a fiber through Fresnel reflection.

Ripcord– A length of string built into optical fiber cables that is pulled to split the outer jacket of the cable without using a blade.

Sample– To measure values of analog data at regular time intervals and convert those measured values into digital data. The more often a signal is sampled, the more accurately the original information can be reproduced in a digital form.

Scattering– The redirection of light caused by atomic structures and particles along the light's path. See also– Rayleigh scattering.

Serial–In data transmission, data that is carried as signals that follow one another.

Sheath– The outer jacket of a fiber optic cable.

Signal to noise ratio– The amount of noise in a signal relative to the strength of the signal itself. The signal to noise ratio is commonly measured in decibels (db). The higher the ratio, the cleaner the signal that is being received at that power level.

Simplex – (1) A link that can only carry a signal in one direction. (2) A fiber optic cable or cord carrying a single fiber. Simplex cordage is mainly used for patch cords and temporary installations.

Single-mode fiber– A fiber with a core diameter large enough for light to take only one possible path through it.

Splice– The permanent connection of one fiber end to another through fusing or mechanical connection.

Spontaneous emission– The emission of random photons at the junction of the p and n regions in a light-emitting diode when current flows through it.

Step-index– A fiber that has a core with a single refractive index and a cladding with a single refractive index, and only one boundary between the two.

Stimulated emission– The process in which a photon interacting with an electron triggers the emission of a second photon with the same phase and direction as the first. Stimulated emission is the basis of a laser.

Surface-emitting LED– An LED in which incoherent light is emitted at all points along the pn junction.

Switch– A mechanical, optical, or optomechanical device that completes or breaks an optical path or routes an optical signal.

Tensile strength– Resistance to pulling or stretching forces.

Terminate– To add a component such as a connector or a hardware connection to a bare fiber end.

Test jumper– A single- or multi-fiber cable used for connections between an optical fiber and test equipment.

Tight-buffered– An optical fiber with a buffer that matches the outside diameter of the fiber, forming a tight outer protective layer.

Total attenuation–The loss of light energy due to the combined effects of scattering and absorption.

Total internal reflection– The reflection of all of the light in a medium of a given refractive index of the interface with a material of a lower refractive index. Total internal reflection takes place at the interface between the core and the cladding of an optical fiber.

Visible fault locator (VFL)– A testing device consisting of a red laser that fills the fiber core with light, allowing a technician to find problems such as breaks and macrobends by observing the light through the buffer, and sometimes the jacket, of the fiber.

Waveguide– A material or component that serves as a guide for electromagnetic waves along its length. In fiber optics, the fiber core is a waveguide.

Waveguide dispersion– The spreading of a signal in a single-mode fiber as some of the light passes through the cladding and travels at a higher velocity than the signal in the core due to the cladding's lower refractive index. Waveguide dispersion is one component of chromatic dispersion.

Wavelength– The distance between two corresponding points in a series of waves. Wavelength is preferred over the term frequency when describing light.

Answer

Module 1. Fundamentals of optical fiber technology

Session 1. Basics of optical fiber

A. Multiple Choice Questions

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

B. Fill in the Blanks

1. Electrical 2. Telephone 3. Glass or Plastic 4. Light source 5. Photo detector, amplifier, and demodulator 6. Core, Cladding, Buffer, and Jacket 7. About 125 µm 8. about 125 µm 9. Light 10. Glass or plastic.

C. State True or False

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

Session 2. Light propagation

A. Multiple Choice Questions

1. (b) 2. (c) 3. (a) 4. (b) 5. (b) 6. (d)

B. Fill in the Blanks

1. 3 × 10^8 m/s 2. Bending 3. Total internal reflection 4. Seven 5. Optical 6. 2 × 10^8 m/s.

C. True or False

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

Session 3. Light source and detector

A. Multiple Choice Questions

1. (b) 2. (a) 3. (a) 4. (b) 5. (b) 6. (a) 7. (b)

B. Fill in the Blanks

1. Diameter and Numerical Aperture 2. 20% 3. Greater 4. On-Off 5. Lower and Higher 6. Multi 7. Single 8. a

Module 2. Tools and equipment and safety precautions

Session 1. Optical fiber tools and equipment

A. Multiple Choice Questions

1. (d) 2. (d) 3. (c) 4. (a) 5. (b) 6. (b)

B. Fill in the Blanks

1. Clockwise 2. Counter clockwise 3. Eight 4. Ceramic, Metal 5. Easier, Faster 6. Length and type 7. Splice tape 8. Diamond 9. 1.5 mm and 2 mm 10. Fiber

Session 2. Optical fiber cable specification

A. Multiple Choice Questions

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

B. Fill in the Blanks

1. Tensile strength 2. Bending 3. Impact 4. Sealed 5. Military 6. UV 7. Mechanical and Environmental

C. Match the column

Indoor: –10 to +60
Outdoor: –20 to +60
Military: –55 to +85
Aircraft: –62 to +125

Module 3. Installation of optical fiber cable (OFC)
Session 1. Pre-Installation Testing of Optical Fiber Cables
A. Multiple Choice Questions
1. (b) 2. (b) 3. (a) 4. (c) 5. (a) 6. (b) 7. (a) 8. (a) 9. (a)
B. True or False
1. (F) 2. (T) 3. (T) 4. (T) 5. (T) 6. (T) 7. (F)

Session 2. Splicing
A. Multiple Choice Questions
1. (a) 2. (d) 3. (a) 4. (c) 5. (d) 6. (a) 7. (a) 8. (c) 9. (c) 10 .(c) 11. (b)
B. Fill in the Blanks
1. 0.1-0.5 dB 2. 0.1-0.3 dB 3. Perpendicular 4. Loss, Accuracy 5. Optical Time Domain Reflec-tometer 6. Chemical 7. Monitoring 8. Lint-free wipes or alcohol

Session 3. Indoor Optical Fiber Installation
A. Multiple Choice Questions
1. (d) 2. (b) 3. (c) 4. (b) 5. (d) 6. (d) 7. (a) 8. (b)
B. Fill in the Blanks
1. Outer 2. Lubricants 3. End 4. Durable 5. 0.1
C. True or False
1. (T) 2. (T) 3. (T) 4. (T) 5. (T) 6. (F) 7. (T) 8. (T) 9. (T)

Session 4. Link Performance Analysis
A. Multiple Choice Questions
1. (a) 2. (d) 3. (a) 4. (a)
B. Fill in the Blanks
1. 5, 10 2. Input power, Output power 3. Decibels (dB) 4. Splicing, connection 5. 6

Module 4. Optical Fiber Health & Safety
Session 1. Safety and Hazards
A. Multiple Choice Questions
1. (a) 2. (a) (c) 3. (b) 4. (d) 5. (d) 6. (c) 7. (d)
B. Fill in the Blanks
1. Rubber 2. Stiff 3. Brain 4. Class D 5. Electrocution
C. True or False
1. (T) 2. (T) 3. (T) 4. (F) 5. (T) 6. (T) 7. (T) 8. (T) 9. (T) 10. (F)