Optical Fibre Splicer

(Job Role)

Qualification Pack: Ref. id. TEL/Q6400

Sector: Telecom

Textbook for Class IX

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Textbook for Class IX

विद्यया ऽमृतमश्नुते

एन सी ई आर टी
NCERT

राष्ट्रीय शैक्षिक अनुसंधान और प्रशिक्षण परिषद्
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FOREWORD

The National Curriculum Framework–2005 (NCF–2005) recommends bringing work and education into the domain of the curricular, infusing it in all areas of learning while giving it an identity of its own at relevant stages. It explains that work transforms knowledge into experience and generates important personal and social values such as self-reliance, creativity and cooperation. Through work one learns to find one's place in the society. It is an educational activity with an inherent potential for inclusion. Therefore, an experience of involvement in productive work in an educational setting will make one appreciate the worth of social life and what is valued and appreciated in society. Work involves interaction with material or other people (mostly both), thus creating a deeper comprehension and increased practical knowledge of natural substances and social relationships.

Through work and education, school knowledge can be easily linked to learners' life outside the school. This also makes a departure from the legacy of bookish learning and bridges the gap between the school, home, community and the workplace. The NCF–2005 also emphasises on Vocational Education and Training (VET) for all those children who wish to acquire additional skills and/or seek livelihood through vocational education after either discontinuing or completing their school education. VET is expected to provide a 'preferred and dignified' choice rather than a terminal or 'last-resort' option.

As a follow-up of this, NCERT has attempted to infuse work across the subject areas and also contributed in the development of the National Skill Qualification Framework (NSQF) for the country, which was notified on 27 December 2013. It is a quality assurance framework that organises all qualifications according to levels of knowledge, skills and attitude. These levels, graded from one to ten, are defined in terms of learning outcomes, which the learner must possess regardless of whether they are obtained through formal, non-formal or informal learning. The NSQF sets common principles and guidelines for a nationally recognised qualification system covering Schools, Vocational Education and Training Institutions, Technical Education Institutions, Colleges and Universities.

It is under this backdrop that Pandit Sunderlal Sharma Central Institute of Vocational Education (PSSCIVE), Bhopal, a constituent of NCERT has developed learning outcomes based modular curricula for the vocational subjects from Classes IX to XII. This has been developed under the Centrally Sponsored Scheme of Vocationalisation of Secondary and Higher Secondary Education of the Ministry of Human Resource Development.

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

I acknowledge the contribution of the development team, reviewers and all the institutions and organisations, which have supported in the development of this textbook.

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

Hrushikesh Senapaty
Director
National Council of Educational Research and Training

New Delhi
January, 2018

About the Textbook

The Telecom industry in India is growing exponentially and it is the second largest in the world with a subscriber base of over 1.2 billion.

The telecommunication sector is made up of companies that make communication possible on a global scale, whether it is through the phone or the Internet, through airwaves or cables, through wires or wirelessly. These companies created the infrastructure that allows data in words, voice, audio, or video to be sent anywhere in the world. The largest companies in the sector are wireless operators, satellite companies, cable companies, and internet service providers.

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

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

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

The textbook has been developed by the coordinator for making it a useful and inspiring teaching-learning resource material for the vocational students. Adequate care has been taken to align the content of the textbook with the National Occupational Standards (NOSs) for the job role so that the students acquire necessary knowledge and skills as per the performance criteria mentioned in the respective NOSs of the Qualification Pack (QP).

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

1. TSC/N6400 Undertake splicing of optical fiber
2. TSC/N6401 Installation and Commissioning of Optical fiber cables (OFC)

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The NCERT acknowledges the contribution of the Review Committee members Kamlesh Mittal, *Professor* (Retd), NCERT, New Delhi and Aarti Goel, *Assistant Professor*, Hansraj College, University of Delhi for carefully evaluating and giving suggestions for the improvement of this book. The guidance provided by Prakash Khanale, *Professor* and *Head*, Department of Computer Science, DSM College, Parbhani is thankfully acknowledged.

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

We are thankful to the course coordinator Deepak D. Shudhalwar, *Professor* and *Head*, Department of Engineering and Technology, PSSCIVE, NCERT, Bhopal for developing the textbook and providing the photographs.

The Council is grateful to Saroj Yadav, *Professor and Dean* (A), NCERT, and Ranjana Arora, *Professor and Head*, Department of Teacher Education, for their sincere efforts in coordinating the review workshops for the finalisation of this book. The Council acknowledges the copy editing and valuable contribution of Soumma Chandra, *Assistant Editor* (Contractual) and Lalboy Doungel, *Proofreader* (Contractual) in shaping this book. The efforts of Pawan Kumar Barriar, *DTP Operator,* Nitin Kumar Gupta, *DTP Operator,* (Contractual), Publication Division, NCERT, for flawless layout design are also acknowledged.

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

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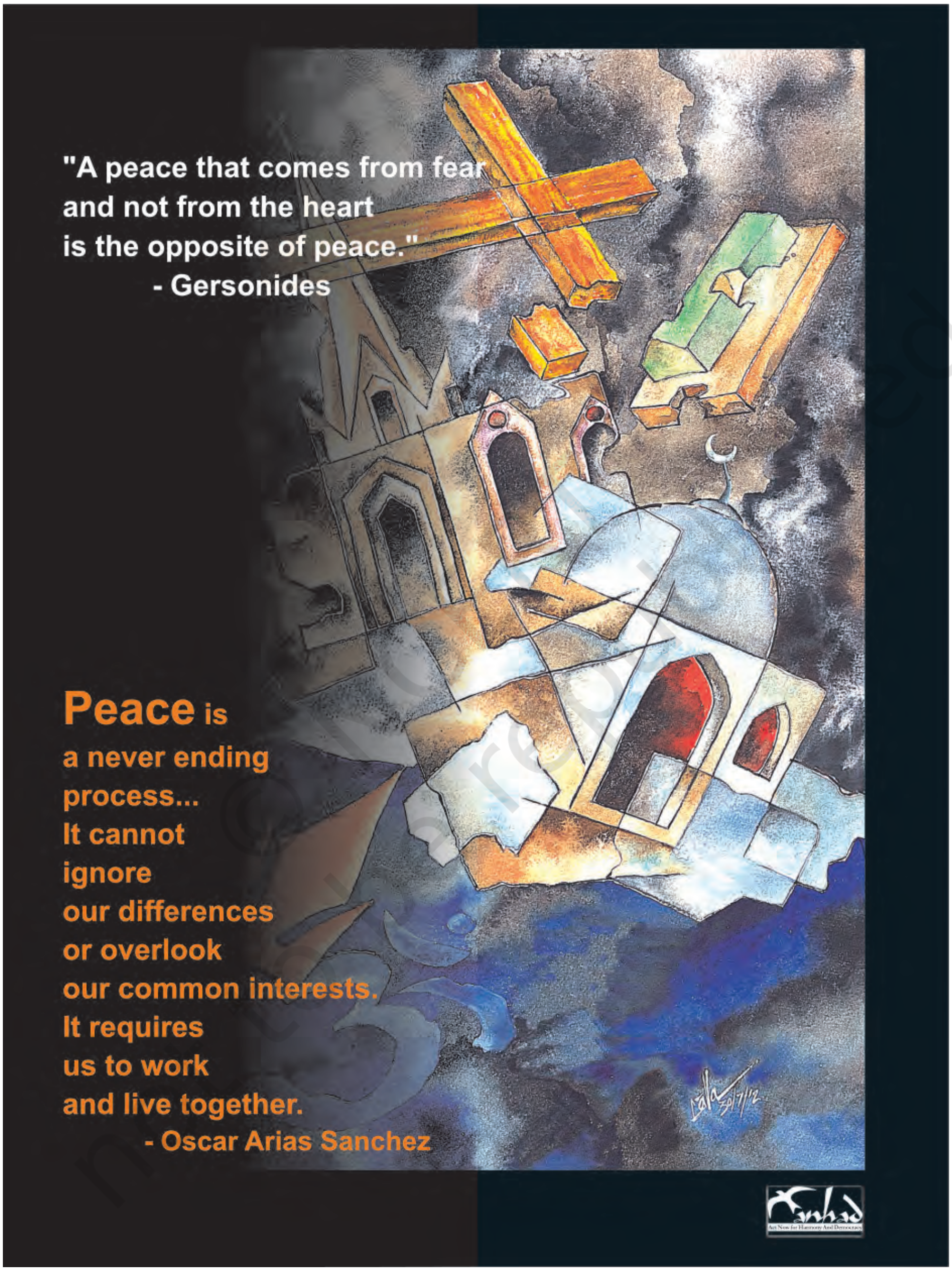
"A peace that comes from fear
and not from the heart
is the opposite of peace."
- Gersonides
Peace is
a never ending
process...
It cannot
ignore
our differences
or overlook
our common interests.
It requires
us to work
and live together.
- Oscar Arias Sanchez

Chapter 1

Broadband and Fibre Optic Technology

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Communication means transfer of information from one person to another. Two persons who are communicating with each other can either be communicating face to face or they can be at a distance apart from each other. Earlier, we used talking drums, chain of beacons and letters as tools of communication to form connections and convey our thoughts over a distance. Now-a-days telecommunication is used to serve the purpose. Telecommunication, also known as telecom, is the transfer of information over large distances by electronic methods like phones, Internet, etc., and refers to all types of voice, data and video transmission. The telecom sector is one of the fastest growing industries in India. India is the second largest telecom market in Asia after China.

Broadband Industry

Broadband communication is considered to have higher transmission speeds and wider bandwidth than that available over a telephone line. Wider bandwidth refers to increased information carrying capacity. It is a term frequently used while accessing the Internet using high speeds, usually higher than 248 kbps (kilo bytes per second). Broadband can be provided via phone line, cable, or satellite. Figure 1.1 shows the different types of broadband communication.

More to know

World Telecommunication Day is celebrated annually on 17th May since 1969. The date marks the anniversary of the founding of International Telecommunications Union (ITU) on 17th May 1865, when the first International Telegraph Convention was signed in Paris. In 2006, the name of the event was changed to World Telecommunication and Information Society Day (WTISD). The purpose of WTISD is to help raise awareness of the possibilities that the use of the Internet and other information and communication technologies (ICT) can bring to societies and economies, as well as of ways to bridge the digital divide.

Fig.1.2: Internet of Things

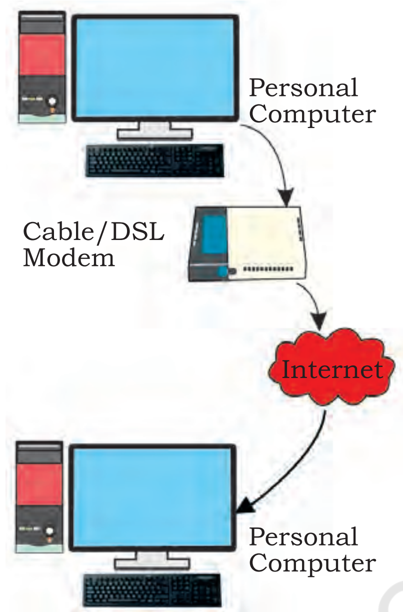

Fig.1.1: Broadband Communications

Types of broadband

The broadband services can be classified into different types. It includes several high-speed transmission technologies, such as,

1. DSL (Digital Subscriber Line)
2. Cable
3. Fibre Optics
4. Wireless
5. Satellite
6. Broadband over Power Line (BPL)

The broadband technology you choose also depends on a number of factors. Like whether you are located in an urban or rural area. Hence broadband is packaged with other services such as voice, telephone and home entertainment, via Internet.

Global broadband market

Countries around the globe have acknowledged the role of broadband in their economic and social growth. Several countries like the U.S., U.K. and China have shown tremendous progress towards it. For example, United States will have minimum download speed of 25 Mbps and coverage to 100 Million households (>80%) by the end of 2020.

China will have a minimum download speed of 50 Mbps in urban areas and 12 Mbps in rural areas, covering 98 per cent of administrative villages by the end of 2020. United Kingdom will have a minimum download speed of 24 Mbps and a coverage target of 95 per cent. Currently, 151 countries have rolled out ambitious national broadband plans.

Indian broadband market

India has the second highest number of citizens online in the world, accounting for 10 per cent of the world's internet population. It aspires to connect 800 million new citizens by 2020, of which 600 million would be broadband users. Customers would expect a high quality, high speed and high reliability network as they access videos and other high bandwidth applications.

Courtesy: Information from Wisconsin's Broadband Reference Guide produced by—WI Public Service Commission, UW-Extension Madison, and the Center for Community Technology Solutions, January 2014.

Telecommunication

The word telecommunication is derived from a French word *comunicacion*. Tele means 'far off', and communication means 'to share'. It is the exchange of information over large distances by electronic means. It refers to all types of voice, data and video transmission. It includes transmitting technologies like telephones (wired and wireless), microwave communication, fibre optics communication, etc. It consists of two stations, one is equipped with a transmitter and the other with a receiver as shown in Fig. 1.3. The medium of signal transmission can be via electrical wire or cable (also known as copper), optical fibre or the free space transmission known as wireless communication.

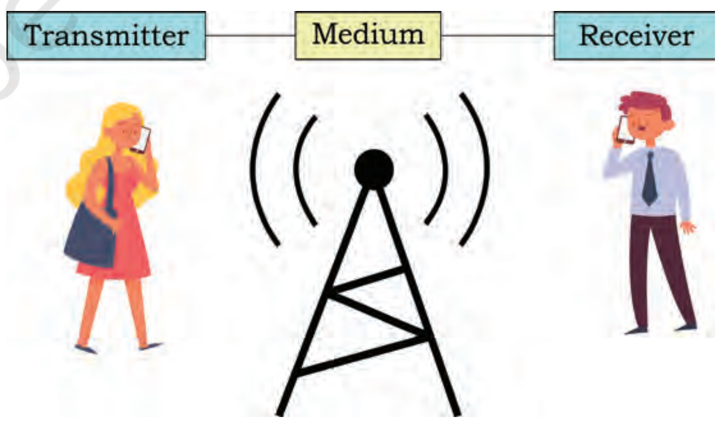

Fig.1.3: Block representation of telecommunication system

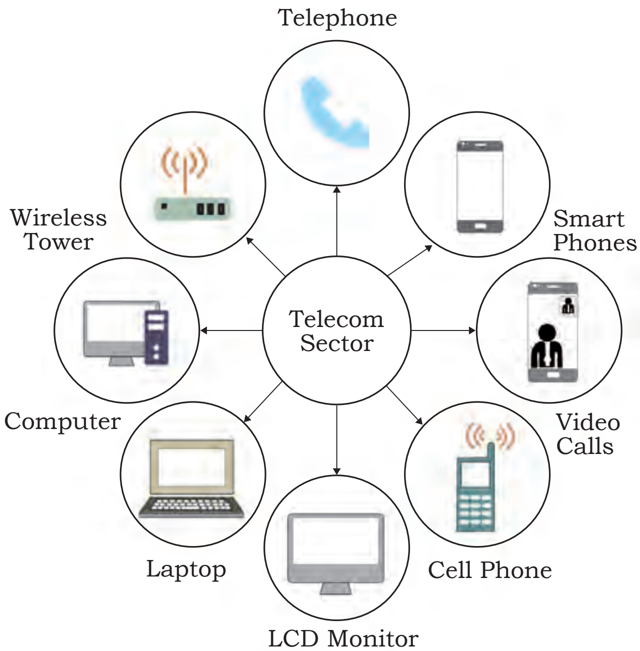

Fig. 1.4: Area under telecom sector

Telecom Sector in India

The Indian telecom industry is active from more than 165 years. Hence telecommunication sector is being greatly affected by the increased globalisation in a positive manner, which in turn has affected the Indian economy. This increase of revenue is the result of increased use of communication technologies in urban as well as rural areas. The various areas of telecom sector include mobile phones, fibre optic communication, broadband communication like access to high-speed internet phones, digital subscriber loops (DSL), satellite communication as shown in Fig 1.4.

Telecom sector has been the fastest growing industry in India with ample number of users. The government of India has generated liberal policies and proactive regulatory framework with an aim to attain rapid growth in this sector. By this growth, the economy of the country has been largely affected. Figure 1.5 addresses the benefits acquired from the Indian telecom industry.

Fig.1.5: Benefits of telecom industry

Indian Telecom Industry

There are many Indian telecom companies promoting the growth of telecom market.

Vodafone

It is one of India's leading telecom service providers. It provides pan India voice and data services across 2G, 3G and 4G platform. It supports the growing demand for data and voice. Hence, it greatly contributes towards creating Digital India.

Vodafone

BSNL

Bharat Sanchar Nigam Limited was developed on 15th September 2000. It provides the telecom services from 1st October 2000. It is one of the largest telecom service in India covering the remote areas. BSNL serves telecom services like Wireline, CDMA mobile, GSM mobile, Internet, Broadband, Carrier service, FTTH, etc.

BSNL

Bharti Airtel Limited

Bharti Airtel Limited is also known as Airtel. It is an Indian-based global telecommunications services company situated in Delhi, India. It provides GSM, 3G, 4G LTE mobile services, fixed line broadband and voice services. It is the third largest mobile network operator in India.

Airtel

Reliance Jio

Jio is an Indian mobile network operator owned by Reliance Industries. Jio does not offer 2G or 3G service, and instead uses digital method to provide voice service on its network. It is the largest mobile network operator in India.

Jio

Optical fibre technology

Fibre optic communication system consists of three main components as shown in Fig. 1.6. These are optical transmitter, fibre optic cable and an optical receiver. The optical transmitter converts electrical signal to optical signal. Fibre optic cable carries this optical signal from the optical transmitter to the optical receiver. Finally the optical receiver reconverts the optical signal to electrical signal.

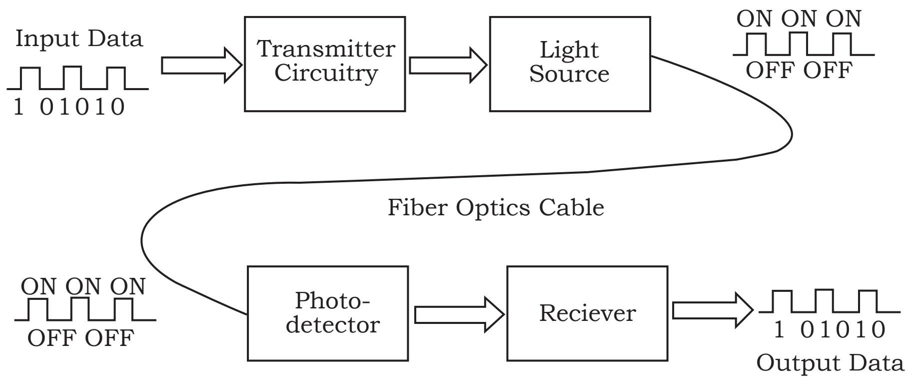

Fig. 1.6: Block diagram of optical fibre transmission system

Fig. 1.7: Optical fibre cable

Fig. 1.8: Signalling lamp for sending the message

Fig. 1.9: Alexander Graham Bell transmitted his voice as telephone signal

Optical fibre cables are used as a medium for telecommunication and networking because they are flexible and can be bundled as ordinary cables. These are advantageous for long-distance communication, because light propagates through the fibre with little attenuation compared to electrical copper cables. Figure 1.6 shows that all fibre optic transmission systems uses light carrying data to convey information from a transmitter to a receiver.

Timeline of optical communication

In earlier days light was used for transmitting information from one place to another. In 800 B.C., the Greeks used fire and smoke signals for communicating information like victory in a war, alerting against enemy, calling for help, etc.

During the second century B.C., optical signals were sent using signalling lamps so that any message could be sent (Fig. 1.8). Till the end of the 18th century there was no growth in optical communication and transmission paths were affected by atmospheric effects such as fog and rain.

More than a hundred years ago, in 1880 Alexander Graham bell transmitted his voice as a telephone signal through about 600 feet of free space (air) using a beam of light as the carrier. He demonstrated the basics of optical fibre communications. Therefore, he named his experimental device the photophone (Fig. 1.9).

Charles Kuen Kao is known as the father of fibre optic communications for his discovery of certain physical properties of glass in the 1960s, which laid the groundwork for high-speed data communication in the Information Age (Fig. 1.10). Before Kao's pioneering work, glass fibres were widely believed to be unsuitable as a conductor of information because of excessively high signal loss due to light scattering. Kao realised that, by carefully purifying the glass, bundles of thin fibres could be manufactured that would be capable of carrying huge amounts of information over long distances with minimal signal attenuation, and that such fibres could replace copper wires for telecommunication.

Fig.1.10: Charles Kuen Kao performing an experiment

Major breakthrough came in 1970, when Corning Incorporated scientists Robert Maurer, Donald Keck, and Peter Schultz created a fibre with a measured attenuation of less than 20 dB per km. It was the purest glass ever made. In April 1977, General Telephone and Electronics tested and developed the world's first live telephone traffic through a fibre-optic system. They were soon followed by Bell in May 1977, which covered a distance of approximately 1.5 miles (Fig. 1.11).

Fig. 1.11: Major breakthrough came in 1970

Optical fibre market overview

An optical fibre is a transparent and flexible fibre made by drawing glass or plastic, which is used to transmit light. The optical fibre has wide usage in fibre-optic communications, where they allow transmission over longer distances and at higher bandwidths than wire cables. The adoption of fibre optic cables to send signals with less amount of loss of optical signal has increased over the period, which drives the growth of the market.

Role of Fibre Optics in Digital India

Fibre optics will play a critical role in realising the dream of Digital India. The existing fibre-to-the-home (FTTH) is the infrastructure of the 21st century. As per the recent global survey, 71 per cent of subscribers are

> **More to know**
>
> According to the former President of India APJ Abdul Kalam, 400 million fibre km of infrastructure is required in order to form Digital India. As a result, it is obvious that fibre optics will play a critical role in realising the dream of Digital India.

expected to transition their networks to FTTH by 2025. The combination of fibre and wireless technology will meet the needs for the current and future demands of expanding bandwidth. Under the Digital India initiative, the Indian government is aiming to supply Internet access throughout the whole country, connecting 600,000 rural citizens to bridge the digital gap between cities and villages through a fibre optics network.

Role of Optical Fibre in Broadband Industry

Optical fibre uses light instead of electricity to carry a signal. Earlier copper cables were used to carry electric data signals. Optical fibre cables are made of glass that reflect light and hence carry the information with high speed across limitless distances.

Advantages of fibre optics broadband connectivity

Fibre optic cables have revolutionised network communication ever since their inception nearly four decades ago. Some of the most popular uses of fibre optic cables are listed below.

Internet

Fibre optic cables are capable to transmit large amount of data at very high speed. Therefore this technology is widely used for Internet. Fibre optic cables are lighter and more flexible than traditional copper wires and carry more data.

Cable television

The use of fibre optic 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. Also, fibre optic cables are cheaper as compared to the same quantity of copper wire.

Telephone

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

Computer networking

Fibre optic cables are useful in computer networking. Internet speed is increased with the use of fibre optic cables. It enables the transfer of information with high speed across networks.

Surgery and dentistry

Fibre optic cables are widely used in the field of medicine and are an important part of non-intrusive surgical methods, popularly known as endoscopy. In such applications bright light is used to light up the surgery area within the body.

Lighting and decorations

The use of optical fibres in the area of decorative illumination has also grown over the years. Fibre optic cables are widely used in lighting decorations, illuminating Christmas trees, etc.

Mechanical inspections

Fibre optic cables are widely used in the inspection of remote places. Some applications are on-site inspections for engineers and inspection of pipes for plumbers.

Military and space applications

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

Duties of optical fibre splicer

The primary responsibility of the Optical Fibre Splicer is to splice fibre optic cables placed both outdoors and indoors. Optical Fibre Splicer will be responsible for performing activities related to connecting, testing and validating the integrity of new and existing outside plant telecommunication networks. Optical Fibre Splicer should possess skills to properly design, install and maintain fibre optic networks. A splicer uses the latest

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fibre optic technology and equipment to learn how to do splicing, testing of spliced fibre, and troubleshoot optical fibre networks in order to increase efficiency, reliability and safety as well as reduce cost. The basic duties to be carried out by the optical fibre splicer are —

- Perform cable installation, construction, maintenance and repair works.
- Operate all types of splicing and testing equipment.
- Prepare and maintain splicing records, schematics and diagrams.
- Understand fusion splicing and mechanical splicing.
- Splice overhead, underground or submarine, multiple-conductor cables used in telephone and telegraph communication and electric-power transmission systems.
- Perform work in accordance with industry standards. Maintain the scope of work on the project and adhere to safety procedures.
- Handle responsibility for customer premise installations, including racking, cabling, etc.
- Perform fibre tests with OTDR's, light source and meters.
- Terminate, splice, bonds/grounds and tests fibre optic equipment to division standards.
- Provide accurate equipment location, splicing and terminating records for the fibre database. Assist construction/engineering departments in accepting and turning up the fibre network.
- Ability to solve problems and work independently.
- Strong communication and interpersonal skills.
- Monitor, communicate and perform corrective actions to fix problems affecting any fibre or fibre related equipment.
- Must be well versed in modern fibre splicing techniques.
- Must have experience with equipment like: fusion splicer, mechanical splicer, OTDR, power meters, traffic identifiers, digital multi-meters, cleavers,

strippers, buffer tube splitters, cable ring tools, hand tools.

- Ability to work under minimal supervision. Apply technical expertise to evaluate problems and implementing the best solutions.
- Validate and test end-to-end service provisioning for the cable network.
- Confirms accurate cable terminations on cross connect, patch panels, hubs, and routers.
- Review site surveys, condition discrepancy reports, design drawings, technical manuals for cable installation feasibility.
- Maintains safe and secure work environment by complying with government standards and legal regulations.

Optical fibre splicer – Knowledge, skills, and abilities

The optical fibre splicer should possess the following technical knowledge, skills and abilities to perform the splicing job with precision.

- Knowledge of fusion splicing.
- Ability to work with clients regarding engineering problems, confer with customer contacts while communicating with the outside plant supervisor.
- Ability to pay close attention to detail and make good decisions based on information given.
- Ability to multitask and stay organised under pressure.
- Possess knowledge in all types of splicing activities, cable and safety test equipment and use of all types of cable construction equipment.

Check Your Progress

A. Multiple Choice Questions

1. Broadband refers to ____________.
   (a) wide band of frequencies
   (b) narrow band of frequencies
   (c) large number of channels
   (d) less number of channels

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2. Broadband provides the data rate in ________________.
   (a) Kbps (Kilo bits per second)
   (b) Mbps (Mega bits per second)
   (c) Bps
   (d) 56 bps
3. Broadband describes the future of ______________ communications.
   (a) digital
   (b) analog
   (c) pulse mode
   (d) saw-tooth
4. Digital Subscriber Line or DSL is a communication medium used to transfer digital signals over _________.
   (a) television
   (b) computer
   (c) mobile phones
   (d) standard telephone lines
5. India is the world's fastest growing industry in the world in terms of a number of wireless connections after_____.
   (a) China
   (b) Japan
   (c) America
   (d) Europe
6. Which of the following organisations is meant to regulate tariffs and policy making?
   (a) TRAI
   (b) MTNL
   (c) BSNL
   (d) AIRTEL
7. Fibre optics will play a critical role in realising the dream of ______________ India.
   (a) analog
   (b) digital
   (c) modern
   (d) traditional
8. Broadband over Powerline (BPL) is the delivery of broadband over the existing _______________.
   (a) low and medium voltage electric power distribution network
   (b) medium voltage electric power distribution network
   (c) low voltage electric power distribution network
   (d) power distribution network

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9. Optical fibres are widely used in fibre optic communications, which permits transmission over other forms of communication through ______________.
   (a) longer distances and at higher bandwidths (data rates)
   (b) short distances and at higher bandwidths (data rates)
   (c) longer distances and at narrow bandwidths
   (d) less distances and at narrow bandwidths
10. Which of the following methods was used in 800 BC., by Greeks for sending information like victory in a war, alerting against enemy, call for help, etc.?
   (a) Fire and smoke signals
   (b) Electrical signals
   (c) Wireless signals
   (d) Transmission media
11. Which of the following equipment is needed to allow home computers to connect to the Internet?
   (a) Modem
   (b) Gateway
   (c) Monitor
   (d) Peripheral
12. The server on the Internet is also known as a __________.
   (a) hub
   (b) host
   (c) gateway
   (d) repeater
13. Which of the following is true in the context of modems?
   (a) Digital signal is amplified.
   (b) Several digital signals are multiplexed.
   (c) A digital signal changes some characteristic of a carrier wave.
   (d) None of the above
14. World Wide Web pages can be described as multimedia pages. This means that the pages may contain _________.
   (a) text, pictures, sound
   (b) text and pictures only
   (c) video clips, sound, text, pictures
   (d) None of the above

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B. Fill in the Blanks

1. Primary responsibilities of the optical fibre splicer is to splice ___________.
2. Satellite broadband is another form of ___________ broadband, and is also useful for serving remote or sparsely populated areas.
3. Optical fibre technology converts an ________signal to a _________ signal for the purpose of granting access to broadband Internet.
4. The highest data rate is provided by _________ medium.
5. Transmission media are usually categorised as _____________, ___________ and ___________.
6. _____________ transmission mode is used for data communication along telephone line.
7. For carrying digital data over long distance using either analog signal or digital signal at approximately spaced points, we must have _____________.

C. State whether True or False

1. A server can run on a workstation computer.
2. Optical fibre communication is a high speed broadband communication technology.
3. In a peer-to-peer network, any client computer can also be a server.
4. Today fibre-optic cable is the media of choice for backbone networks.
5. Optical fibre is only used for wireless communication.
6. A wireless network access point is a device that allows computers to access a wired network using radio waves.
7. A telephone modem is a device that connects your computer to your phone line so that you can access another computer or network.
8. Wireless communications media transmits information over a closed, connected path.
9. A repeater is a device that receives a radio signal, strengthens it, and sends it on.
10. Bandwidth refers to the capacity of the communications line.

D. Answer in one Sentence

1. What is the full form of TRAI?
2. What are the components of telecommunication?
3. What is broadband?
4. List the various broadband technologies.
5. How does broadband work?
6. What is meant by the term Telecommunication?

7. List out the various telecom industries in india?
8. What is the job of a splicer?
9. List the components of fibre optics communication technology.

E. Short Answer Questions

1. Discuss the evolution of fibre optics.
2. What is the role of fibre optics in the broadband industry?
3. Discuss the role of splicer in the fibre optics market? Why is splicer required?
4. What is broadband? State the different types of broadband.
5. What are the major telecom companies in India?
6. How does fibre optics technology work?
7. What do you mean by wired communication?
8. What are the advantages of fibre broadband connectivity?
9. Discuss the Indian broadband market.
10. What kind of knowledge is required by optical fibre splicer?

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Chapter 2

Data Communication

17907CH02

Computer generates a lot of information through data processing. The information is not useful in itself. It has to be communicated to the people. This information, also known as, data (text, audio or video) must be delivered to the people at the right time. It is important to transmit the information from one location to another at a very fast speed. This process is known as data communication. The computing devices such as computer, tablet and mobile devices are used to send the digital data. Advances in communication technology, combined with rapidly evolving computer technology, have made enormous progress in this field.

Electronic communication consists of telecommunication and data communication. Telecommunication refers to the use of telephone, telegraph, and radio or television facility to transmit information, either directly or via computer. Data communication means the transfer of data or information between computing devices. In this chapter, we will study the various modes of data communication.

Data

Data refers to the raw facts that are collected and processed to deduce information, while information refers to processed raw data that enables us to take decisions. For example, when exam results are declared they contain data of all students. This data provides the relevant information that whether a student passed or failed.

Data representation

Data can be represented in various forms such as.

- Text: It includes combination of alphabets in small case as well as upper case. It is stored as a pattern of bits.
- Numbers: They are a combination of digits from 0 to 9. It is stored as a pattern of bits.
- Images: In computers images are digitally stored in the form of pixel. Pixel is the smallest element of an image. A picture or image is a matrix of pixel elements. The size of an image depends upon the number of pixels (also called resolution). Commonly used image formats are jpg, png, bmp, etc.
- Audio: This data is in the form of sound which can be recorded and broadcasted. Audio data is continuous, not discrete.
- Video: It refers to broadcasting of data in form of picture or movie.

Types of electronic communication

Electronic communication is divided into two types.

(a) Data communication: The transfer of data between two points is called data communication.

(b) Telecommunication: When the transmission of data can take place from a long distance by means of towers, satellite or microwave system it is called telecommunication.

Data communication

To make communications possible using computers, there must be a signal translator called a modem. The

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modem, which is short for modulator and demodulator, first converts digital signals into analog and again back to digital signals which enables information to move across the telephone line.

Using electricity, radio waves or light, information and data in the form of codes are transmitted through a physical medium such as wire, cable, or even the atmosphere.

In a computer network, computers, printers, scanners and cameras are connected. Computers can exchange and share information and resources. Using hardware and software, these interconnected computing devices can communicate with each other through defined rules of data communications. A computer network may operate on wired connections or wireless connections. Networks are communication systems designed to transmit the information from origin to destination.

Characteristics of data communication

The effectiveness of a data communication system depends on three fundamental characteristics.

Delivery

The data should be delivered to the correct destination and correct user.

Accuracy

The communication system should deliver the data accurately, without introducing any errors. The data may get corrupted during transmission affecting the accuracy of the delivered data.

Timeliness

The system must deliver data in a timely manner. Data delivered late is useless. In the case of video, audio and voice data, timely delivery means delivering data, in the same order that they are produced, and without significant delay. This kind of delivery is called real-time transmission.

Components of data communication

The transmitter sends the message and the receiver receives the message. The medium is the channel over which the message is sent and the protocol is the set of rules that guides how the data is transmitted from encoding to decoding. The message is the data that is being communicated. Fig 2.1 shows the basic components of communication system. These are—

(a) Transmitter
(b) Receiver
(c) Medium
(d) Message
(e) Protocol

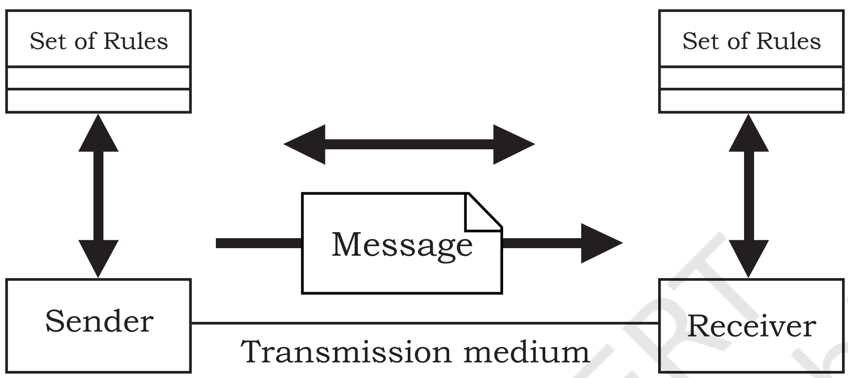

Fig. 2.1: Components of a data communication system

Sender or Transmitter

The sender is the device that sends the message. It can be a computer, workstation, telephone handset, video camera, and so on.

Receiver

The receiver is the device that receives the message. It can be a computer, workstation, telephone handset, television, and so on.

Transmission Medium

The transmission medium is the physical path by which a message travels from sender to receiver. It can be wired or wireless and many subtypes in both. It consists of twisted pair wire, coaxial cable, Fibre-optic cable, laser or radio waves.

Message

Message is the information to be communicated by the sender to the receiver.

Protocol

A protocol is a set of rules that governs data communication. A Protocol is a necessity in data communications. Without a protocol, two devices may be connected but not communicating, just as a person speaking English cannot be understood by a person who speaks only Marathi.

Modes of data communication

Two devices communicate with each other by sending and receiving data. There are three modes of data communication according to their way of communication.

(a) Simplex

(b) Half Duplex

(c) Full Duplex

Simplex

In simplex mode, communication is unidirectional shown in Fig. 2.2. Only one device sends the data while the other one only receives the data.

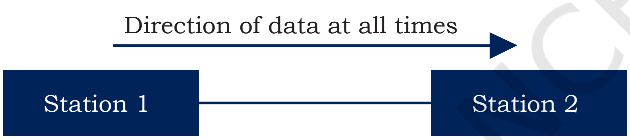

Fig. 2.2: Simplex mode of communication

For example, while watching television (TV), we can receive the information from TV. It sends or transmits the information in unidirection to the audience.

Half duplex

In half duplex both the stations can transmit as well as receive but not at the same time as shown in Fig. 2.3. When one device is sending the other can only receive and vice-versa. Walkie-talkie is an example of a half duplex device. It has a "push-to-talk" button which is used to turn on the transmitter and turn off the receiver. It can either transmit or receive the information at a time. An advantage of half duplex is that the single track is cheaper than the double tracks.

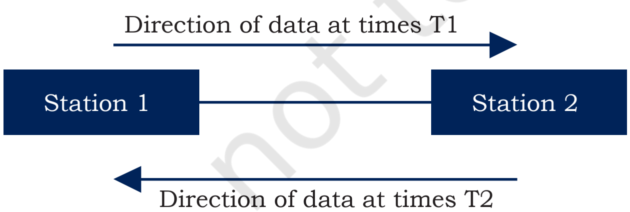

Fig. 2.3: Half duplex mode of communication

Full duplex

A full duplex communication mode is able to transmit data in both directions at the same time as shown in

Fig. 2.4. For example, during the telephone conversation people at both ends of a call can speak and be heard by each other at the same time. Thus, the full duplex mode increases the efficiency of communication.

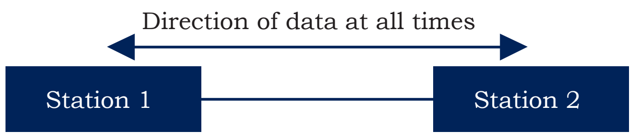

Fig. 2.4: Full duplex mode of communication

Data and signals

The information stored in computer systems and transferred over a computer network can be divided into two categories: data and signals. Data are entities that convey meaning within a computer or computer system. To transfer this data from one point to another, either by using a physical wire or by using radio waves, it has to be converted into a signal. Signals are the electric or electromagnetic encoding of data. Signals are used to transmit data.

Types of data

There are basically two types of data – analog and digital, used in data communication shown in Fig. 2.5.

Analog data — The data which is represented in physical properties and can be expressed as any value along a continuous scale is called analog data. The sound made by a human voice and analogue clock are the simple examples of analog data.

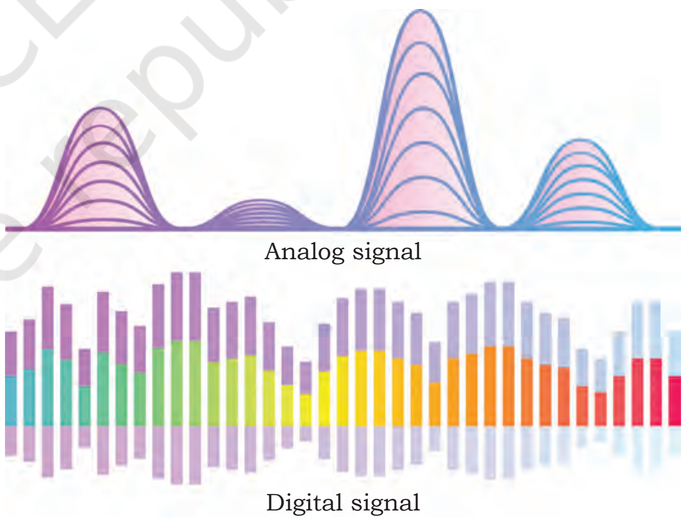

Fig. 2.5: Analog and digital data

Digital data — Discrete and discontinuous representations of information are called digital data. Most electronic devices such as digital clock, calculators, computers, cameras and mobile phones store and process data in form of numbers which is called digital data. These numbers are in form of binary number meaning 0 and 1, represent the switches for power on or off. For example, when we store the audio data in form of ones and zeroes, the audio devices such as CD Players, etc., read these ones and zeroes and translate them into actual signals.

Signals

In data communication, signals are used to send the data from one location to another. Signals are electromagnetic or light rays which carry the data. The simplest form of signal is a direct current (DC) that is switched on and off.

Classification of signals

Signals can be classified as

(i) Electrical Signal

(ii) Optical Signal

(iii) Electromagnetic Signal

Electrical signal

Electrical signals communicate between two electrical devices. Electrical signal is the way of transferring the information through use of electricity which carries the message. Microphones, fax machines, remote controls for television sets, etc., are some of the examples of the devices using electrical signals.

Optical signal

Optical signal is the advanced technology in which data travels by means of electric voltage over the optical fibre.

Electromagnetic signal

Electromagnetic signal builds with two components, one is electric energy and the other is magnetic wave which are perpendicular to each other in an electromagnetic wave. Electromagnetic signal travels through the free space, as in wireless networking.

Transmission media

Transmission media is a means by which a communication signal is carried from one system to another as shown in Fig. 2.6. Transmission or communication media can be divided into two categories— physical or conducted media, such as wires, and radiated or wireless media, which use radio waves. Conducted media include

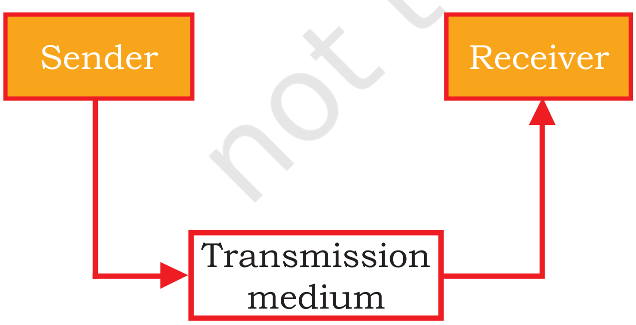

Fig. 2.6: Transmission of data from sender to receiver through a medium

twisted pair wire, coaxial cable, and fibre optic cable. In wireless transmission, different types of electromagnetic waves, such as radio waves, are used to transmit signals.

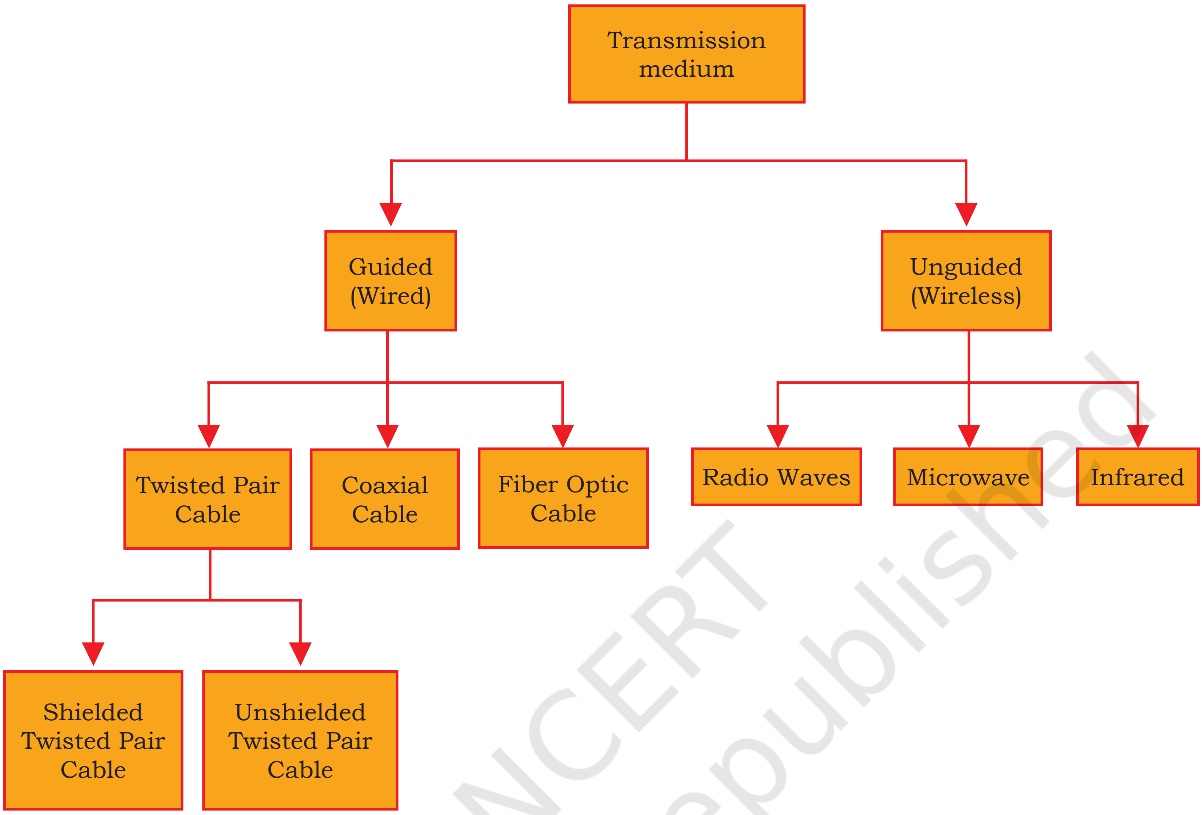

Fig. 2.7: Classification of transmission medium

Guided (bounded or wired) media

Guided transmission media uses a cabling system that guides the data signals along a specific path. Guided media is also known as bounded or wired media. Depending on the type of transmission medium used the bounded media can be further classified into three types —

- (i) Twisted pair cable
- (ii) Coaxial cable (in the form of electric signals)
- (iii) Fibre optic cable (in the form of light)

Twisted Pair (TP)

Twisted pair is least expensive and most widely used for telecommunication. It consists of two insulated copper wires arranged in a regular spiral pattern.

- A wire pair acts as a single communication link. It may be used to transmit both analog and digital signals. For analog signals amplifiers are required about every 5 to 6 km. For digital signals, repeaters are required every 2 to 3 km.
- Twisted pair is the most commonly used medium in the telephone network. Compared to other commonly used transmission media, TP is limited in distance, bandwidth and data rate. When two copper wires conduct electric signal in close proximity, a certain amount of electromagnetic interface (EMI) occurs.
- This type of interference is called crosstalk. Twisting the copper wire reduces crosstalk. Twisted pair comes in two varieties.
  - Unshielded Twisted Pair (UTP)
  - Shielded Twisted Pair (STP)

Unshielded Twisted Pair (UTP)

Fig. 2.8: Unshielded twisted pair cable

UTP is a set of twisted pairs of cable within a plastic sheath shown in Fig. 2.8. UTP is an ordinary telephone wire. This is the least expensive of all the transmission media commonly used for LAN, and is easy to work with and simple to install. UTP is subject to external electromagnetic interference. Fig. 2.8 shows unshielded four pair cable.

Shielded Twisted Pair (STP)

Fig. 2.9: Shielded twisted pair cable

STP offers a protective sheathing around the copper wire. STP provides better performance at lower data rates. They are not commonly used in networks. Installation is easy. Special connectors are required for installation. Cost is moderately expensive. The distance is limited to 100 metres for 500 Mbps. STP will still suffer from outside interference but not as much as UTP. Fig. 2.9 shows the STP cable.

Coaxial cable

- It is made up of two conductors that share a common axis. It consists of a hollow outer cylindrical conductor that surrounds a single inner wire conductor shown in Fig. 2.10.

- Coaxial cable is used to transmit both analog and digital signals. Data transfer rate of coaxial cable is in between TP and fibre optic cable. Coaxial cable must be grounded and terminated.
- Coaxial cable transmits information in two modes — baseband mode and broadband mode.
- In baseband mode, the cable bandwidth is devoted to a single stream of data. The high bandwidth capability allows high data rates over a cable. Mostly used in local area networks (LAN). In LAN, only one data stream is present at any time.
- In Broadband mode the bandwidth is divided into different ranges. Each range typically carries separate coded information, which allows the transmission of multiple data streams over the same cable simultaneously. Cable television is an example of multiple signals.

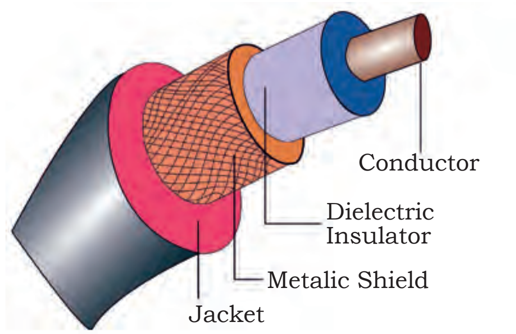

Fig. 2.10: Coaxial cable

Optical Fibre Cable (OFC)

- OFC is a light pipe which is used to carry a light beam from one place to another. Light is an electromagnetic signal and can be modulated by information as shown in Fig. 2.11.
- Since the frequency of light is extremely high, hence it can not only accommodate wide bandwidths of information, but also higher data rate can be achieved with excellent reliability.
- The modulated light travels along the fibre and at the far end, is converted to an electrical signal by means of a photo electric cell. Thus the original input signal is recovered at the far end.
- OFC transmits light signals rather than electrical signals. Each fibre has an inner core of glass or plastic that conducts light. The inner core is surrounded by cladding, a layer of glass that reflects the light back into core.


Fig. 2.11: Optical Fibre Cable (OFC)

- A cable may contain a single fibre, but often fibres are bundled together in the centre of the cable. OFC may be multimode or signal mode.

  Multimode fibres use multiple light paths, whereas signal mode fibres allow a single light path.

Unguided (unbounded or wireless) media

Depending on the method of transmission the unbounded media can be further classified into three types:

- Radio links
- Microwave links
- Infrared light transmission

Fig. 2.12: Radio transmission in residential area

Radio links

Radio waves shown in Fig. 2.12 have frequencies between 10 kilohertz (kHz) and 1 gigahertz (GHz). Radio waves include the following types—

(a) Short wave

(b) Very high frequency (VHF) television and FM radio

(c) Ultra high frequency (UHF) radio and television

Fig. 2.13: Mobile tower uses microwave for communication

Microwave links

It is a communication system which uses a beam of radio waves in the microwave frequency range above 100MHz to transmit information between two fixed locations on the earth. It consists of a pair of antennas spaced some kilometers apart and is used to send information.

Fig. 2.14: Infrared light is used in TV remote

Infrared light wave transmission

Infrared light waves are widely used for short range communication. The remote control used in TV, VCR and stereos all use infrared communication as shown in Fig. 2.14.

Check Your Progress

A. Multiple Choice Questions

1. Cabling have allowed people across the world to communicate with one another via _____________.
   (a) fax
   (b) phone
   (c) computer
   (d) printer
2. Which of the following is not an element of communication?
   (a) Sender
   (b) Receiver
   (c) Medium
   (d) Node
3. All types of cabling consist of a conductive material protected by one or more sheathing and/or insulation components which is _____________.
   (a) clad
   (b) core
   (c) fibre
   (d) copper
4. Which of the following is not unguided transmission media?
   (a) Radio waves
   (b) Infrared
   (a) Microwave
   (a) Fibre optic
5. Which of the following is not a conducted transmission media?
   (a) Coaxial cable
   (b) Twisted paircable
   (c) Microwave
   (d) Fibre Optic Cable
6. Total internal reflection is a phenomena used in _______.
   (a) endoscopy
   (b) fibre optics
   (c) coaxial cables
   (d) twisted cables
7. Coaxial cabling is found in the following types of networks except _____________.
   (a) cable television
   (b) broadband Internet access
   (c) VHF/UHF antenna connections
   (d) residential telephone networks

8. Coaxial cabling is used in ____________.
   (a) voice messages
   (b) TV signals
   (c) video messages
   (d) audio messages
9. One of the primary disadvantages of fibre optic cabling is ____________.
   (a) cost
   (b) resistance to weather
   (c) interference
   (d) flexibility

B. Fill in the Blanks

1. In half-duplex transmission data can be transmitted in ____________ direction.
2. In simplex transmission data can be transmitted in ____________ direction.
3. The quality of transmission primarily depends on the characteristics and nature of ____________ media.
4. Coaxial cables can be used for ____________.
5. Satellite communication use ____________.
6. Fibre optic cabling is exempt from the problems of ____________ and ____________ interference.
7. Fibre-optics work on the principles of ____________ and ____________.
8. Cable transmissions result from the generation of signals using either optics or ____________.
9. The most common types of interference are ____________ and ____________.
10. The three major types of cabling include ____________, ____________ and ____________.
11. Twisted cable can be used for the distance of ____________.
12. Light propagates inside the fibre cable using principle of ____________.
13. Core of the fibre is made up of ____________ and ____________.
14. The twisting in the twisted-pair cables reduce the ____________ which is generated due to the electromagnetic interference.
15. The principle to ____________ is responsible for the optical signal propagation in fibre optic cables.

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C. State whether True or False

1. Electromagnetic is a type of radiation in which both electric and magnetic field do not vary.
2. Bandwidth is defined as a range of frequencies within a given band which is used for transmitting the signal.
3. Fibre Optics is more practical and widely used as the transmission medium for optical communication systems.
4. Fibre-optic networks form the core or backbone of the Internet.
5. A major disadvantage of fibre-optic cables is their limited information-carrying capability.
6. Fibre optics cables are cheaper than coaxial cables.
7. Speed of light in free space < speed of light in water < speed of light in glass.

D. Answer in one sentence

1. What are the major components of telecommunication?
2. What are the different modes of fibre optics communication?
3. Who was the father of fibre optics communication? How did it bring about a change in the field of communication?
4. Define electromagnetic spectrum.
5. List the different range of frequencies with their applications.
6. What are the standards of twisted cable wires?
7. Which type of light source is used in single and multi-mode fibres?

E. Short Answer Questions

1. How does the telecom growth benefit the nation?
2. On what parameters the quality of transmission depends in case of guided transmission media?
3. Why wires are twisted in case of twisted pair of transmission medium?
4. Give a popular example where coaxial cables are used for broadband signalling.
5. In what way do multi-mode and single-mode fibres differ?
6. Give practical examples used in our daily lives where different modes of communication are used.

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7. State eight benefits of fibre optics cables over electrical cables for communication. Name six typical communication applications for fibre optic cable.
8. Explain how light is propagated through a fibre optic cable. Name the three basic types of fibre optic cables, and state the material from which they are made.
9. Explain in detail the various elements of fibre optics communication.
10. Define wireless communication. State different types of wireless communication.

Chapter 3

Fibre Optic Communication

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All of us know about the famous Hindi movie "Sholay". One day Ram's father announced at home that he wanted to watch that movie. Ram searched all channels in a television to see if that movie is currently being played. But unfortunately, it was not. So Ram downloaded the movie in fraction of minutes and he started playing it on his computer. Naturally Ram's father was very happy.

This was possible because of the high speed Internet connection received through optical fibre cable broadband services. In this chapter, we will understand the basics of optical fibre, need of optical fibre communication, advantages and disadvantages of optical fibre communication. Also, we will discuss various applications of optical fibres.

Optical Fibres

Optical fibres are simple threads like human hair, made up of glass or plastic. The light propagates from one end to another end through these optical fibres.

Example: Fibre optic cables are used for data transmission in high-level data security fields of military and aerospace engineering. These are used in wiring in aircrafts, hydrophones for SONARs (sound navigation ranging) and seismic applications.

Assignment: List the different application areas where optical fibres are used.

Basic structure of an optical fibre

The basic structure of an optical fibre consists of the following parts—

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

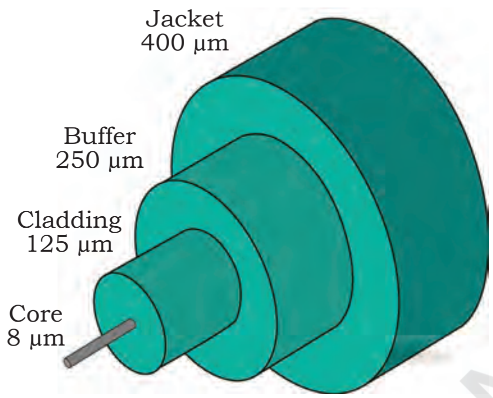

Fig. 3.2: Optical fibre structure

Core

It is the thin glass centre of the fibre where light travels. Light propagates mainly along the core of the fibre.

Cladding

It is the outer layer of optical material surrounding the core. It reflects the light back into the core. It traps the light in the core using an optical technique.

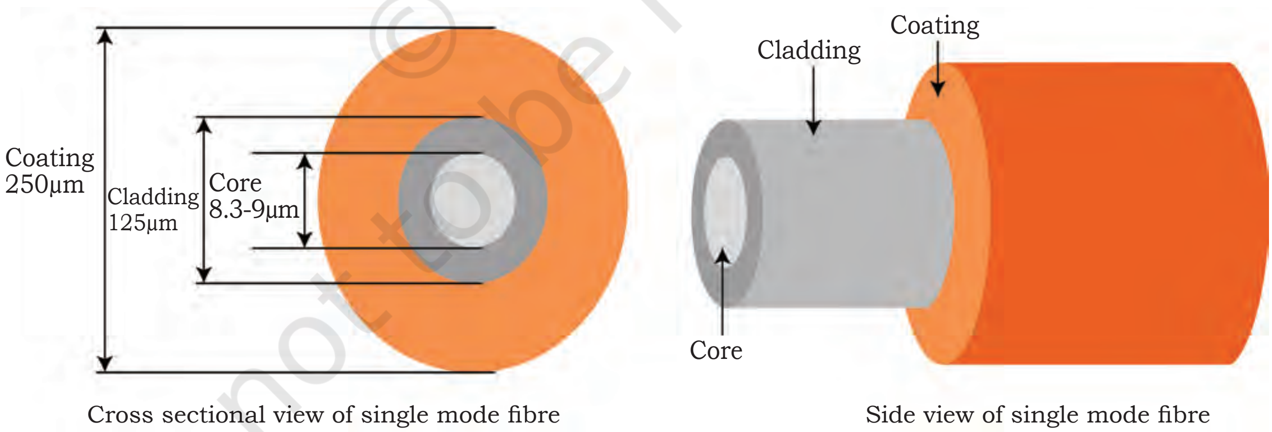

Fig. 3.3: Core and cladding of an optical fibre cable

Core and cladding of optical fibre are available in different diameter. Some of the core and cladding are mentioned in the Table 3.1.

Table 3.1

Optical fibre part	Single-mode optical fibre (Diameter in µm)	Multi-mode optical fibre—Step index (Diameter in µm)			Multi-mode optical fibre—Graded index (Diameter in µm)		
Core	8–10	62.5	100	1000	50	62.5	85
Cladding	125	125	140	1200	125	125	125

Buffer

Optical fibre is a combination of core and cladding. Number of fibres bind together to form cable. These fibres are coated with a protected layer known as buffer. It is made of hard-plastic coating.

Strength Member

Strength members run between the buffer and the outer jacket. It helps to increase a cable's tensile strength. It also protects the fibre against stretching and excessive bending.

Jacket

The jacket is the fibre's outer protective layer. This part must protect the fibre from the worst outside environment, including sunlight, ice, equipment accidents. Jackets are made up of plastic.

Example: The following table illustrates material used to manufacture optical fibre.

Table 3.2

Parts of optical fibre 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, polymer
Jacket	Polyethylene, polyvinyl chloride, polyurethane, polyester elastomers

Assignment: Match the following components of the fibre with their appropriate features.

Name of the components of fibre	Feature
Cladding	It reflects the light back into the core. It traps the light in the core using an optical technique.
Core	It protects the fibre from the worst outside environment.
Buffer	Buffering consists of a buffer layer in which optical fibres is attached tightly.
Strength member	It is the thin glass centre of the fibre where the light travels.
Jacket	It runs between the buffer and the outer jacket

Assignment: Identify the type of cable in Fig. 3.4 and name the different parts of cable from the following options.
Central strength member, fibres, buffer, outer jacket, core, cladding.

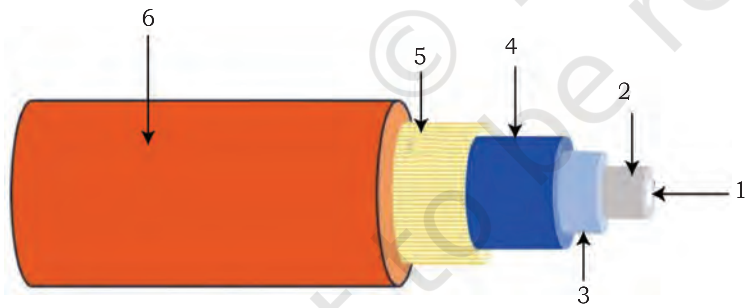

Fig. 3.4 Optical fibre cable

Importance of fibre optics communication systems

An optical fibre has various advantages over copper wire or radio system, and so it is widely used in the telecommunication industry. The following are the main advantages of optical fibres.

a. Small in size and light weight: Optical fibres are thinner than coaxial cable or bundled twisted pair cable and hence they occupy much less space in the ground when it is installed.

b. Greater bandwidth: Bandwidth of an optical fibre is higher than that of an equivalent wire transmission line.

c. Data rate: It is much higher in an optical fibre, hence more information can be carried through optical fibre than copper cables. At high frequency, data rates of 2 Gbps over 10 kilometres have been demonstrated. Coaxial cable can practically carry hundreds of Mbps over about 1 kilometre whereas twisted pair carries just a few Mbps over 1 kilometres.

d. Attenuation: It refers to the signal loss via optical fibre. Optical fibre uses light as a carrier and hence there is very less signal loss as compared to copper wire. So, long distance transmission is possible without repeaters.

e. Ruggedness and Flexibility: The optical fibre cable can be easily bent or twisted without damaging it. It is free from pollution and radiation. It is nominally affected by the nuclear radiation. Its life is longer than copper wire. It is superior to copper cable in terms of installation, transportation, storage, maintenance, strength and durability.

f. Electromagnetic Interference: Electromagnetic waves generated from electrical disturbances or electrical noises do not interfere with light signals. Even optical fibres are non-inductive and non-conductive in nature, so there is no radiation and interference in the other circuits and systems. Hence, the optical fibre system is not vulnerable to interference, impulse noise or cross-talk.

g. Secure Communication: It is difficult to tap optical fibres hence transmission is more secure and private.

h. Electrical Isolation: As optical fibres are good dielectric, hence, isolation coating is not required. Optical fibres allow transmission between two points without regard to the electrical potential between them.

i. Lower Channel Cost: The cost of channel is lower than that of the equivalent wire cable system. Thus optical fibre communication system is more economical than any communication system of other types.

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j. Easy Installation: Optical Fibre cables are easier to install as compared to copper conductors of equivalent signal carrying capacity. It requires less duct space, weighs 10 to 15 times less and costs less than copper.

k. Metal Free: Optical fibre cables do not have any metal conductors, and hence they do not pose the shock hazards as in copper cables. They do not emit sparks or cause short circuits, which is important in explosive gas or flammable environments.

l. Electrical Isolation: Optical fibre allows transmission between two points irrespective of the electrical potential between them.

Generations of communication systems

The development of fibre-optic communication emerged around 1975. The enormous progress realised over a 40-year period extending from 1975 to 2018 can be grouped into several distinct generations.

In the first generation, commercial telephone systems were operated at a wavelength of 820 nm. They operated at a bit rate of 45 Mbit/s and allowed repeater spacings of up to 8-10 km. It is important to stress that even the first generation systems transmitted nearly 700 telephone calls simultaneously over a single fibre.

Second generation commercial telephone systems operated at a wavelength of 1300 nm without repeaters with single mode fibres. This provided a transmission rate of up to 45 Km.

Third generation systems operating at a wavelength of 1550 nm is anticipated, which will employ single mode fibre. It will provide transmission rate of 1.3 Gb/sec over a distance of 45 Km.

Fourth generation commercial telephone systems will have a transmission rate of 2 Gb/sec over a fibre link of 1330 Km.

Additional high bandwidth capabilities have been extended into the gigahertz range. These are glimpses of future generation of fibre optics communications.

Propagation of light wave through optical fibre

Fibre is made up of glass or plastic. The working of an optical fibre depends on the very basic principles of optics and the interaction of light with matter. To understand how light propagates through the fibre, it is necessary to understand the concept of light, and how this thin fibre carries the light through the fibre.

Nature of light

Light has a dual nature containing either particle or electromagnetic waves.

Light as a electromagnetic spectrum

In fibre optic technology, the definition of light states that:

Light is the electromagnetic radiation or energy in the wavelength range including infrared, visible, and ultraviolet.

Light is a small part of the total electromagnetic spectrum, as shown in Fig. 3.5. Light is higher in frequency and shorter in wavelength than the common radio waves. Visible light's wavelength ranges from 380 nanometres (far deep violet in color) to 750 nanometres (far deep red). Infrared radiation has longer waves than visible light. Most fibre optic systems use infrared light between 800 and 1550 nanometres. This region is referred to as near-infrared (near-IR).

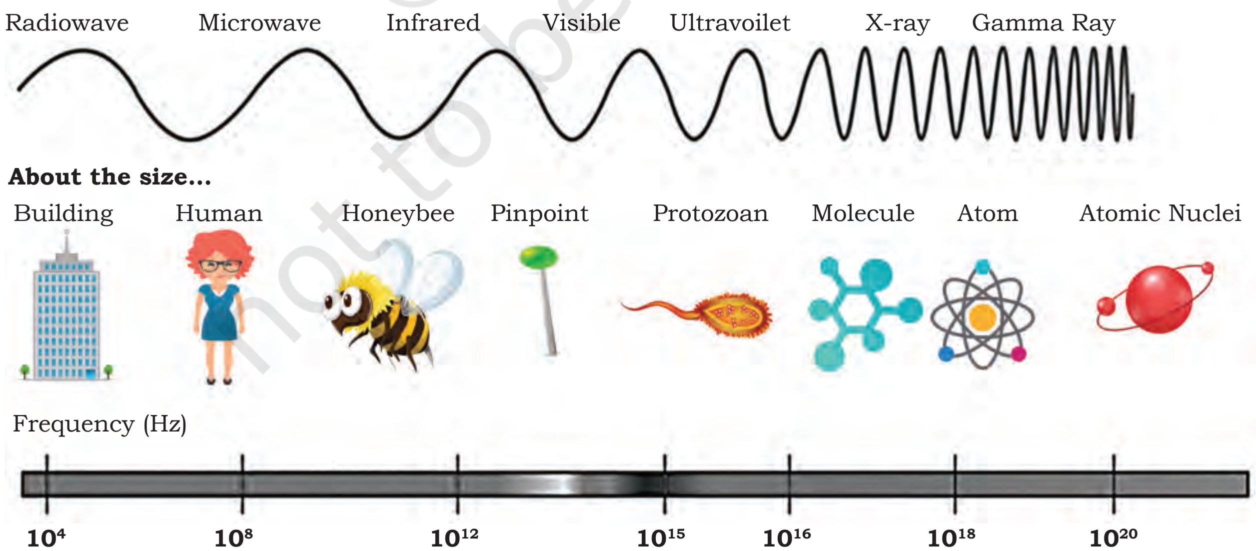

Fig. 3.5: Electromagnetic spectrum

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Following is a list of the band of frequencies under which various devices operate like microwave, mobile phones, radio, television, and military.

Various bands of frequency	Applications
Radio Waves The range is 1000 meters to 1 cm.	Radio waves are found at the longest wavelengths on the electromagnetic spectrum. These are the light waves that are used to send signals to your AM/FM Radio or your television (unless you have cable).
Microwaves The range is one-tenth of a mm to 1 cm.	They have shorter wavelength than radio waves. Microwaves are used in radar and also in your microwave appliance at home that you use for heating food.
Infrared Radiation The range of infrared wavelengths is about sub-millimeters (mm) to micrometers (µm) (the size of bacteria).	Infrared radiation is what we like to describe as heat. We can't see infrared waves, but we can feel them. Your body gives off heat, so it is an emitter of infrared radiation. They have longer wavelength than visible light and are given off by every person in the form of heat.
Visible Light The range of visible wavelengths is 400 to 700 nanometers (nm).	Visible light is the light that we can see, and thus is the only light detectable by the human eye. White light is visible light, and it contains all the colours of the rainbow, from red to violet.
Ultraviolet The range for ultraviolet light is 10^{-8} to 10^{-10} meters.	Ultraviolet light is the radiation from the sun that causes sunburn when you have been outside for too long on a sunny day. You can't see ultra-violet light, so you can still get sunburnt on a cloudy day. Ultraviolet waves have more energy than visible light.
X-Rays The range for X-rays is 10^{-10} to 10^{-12} meters.	X-rays are very energetic, and are used in X-ray machines to take pictures of your bones. They are able to easily penetrate through many objects.
Gamma Rays The range for a gamma ray is in picometers (10^{-12} meters).	Gamma rays have the smallest wavelengths and the most energy of any wave in the electromagnetic spectrum. They are produced by the hottest neutron stars in the universe. On Earth, gamma waves are generated by nuclear explosions and lightning.

Light as a particle

Light also exhibits some particle-like properties. A light particle is an individual unit of energy. The energy of light depends on its frequency. The higher the frequency, the greater will be the energy. Light is also characterised by its wavelength. Shorter the wavelength, higher is the frequency.

Light travels in a straight line. It travels with the speed of 300000 Km/sec or 186,000 miles/sec in a free space. The speed of light depends on the medium through which it passes. If it passes through a plane surface then it bounces back, causing *reflection* and if it passes from one medium to another, say from air to water it bends, causing *refraction.*

Reflection

Reflection occurs when the rays of light that are deflected by a surface (sent back toward their source) are reflected. You can see your image on the mirror, because the light from the plane polished surface of the mirror gets reflected to your eyes.

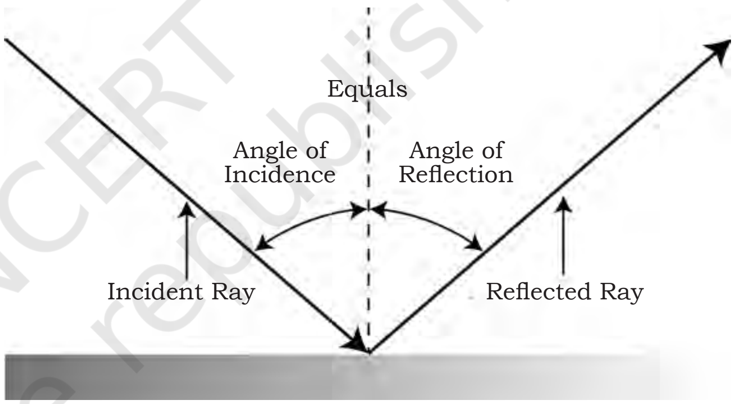

Fig. 3.6: Reflection of light

The incoming light ray is called the incident ray. The light ray moving away from the surface is the reflected ray. The most important characteristic of these rays is their angles in relation to the reflecting surface. These angles are measured with respect to the normal of the surface. The normal is an imaginary line perpendicular to the surface. The angle of incidence is measured between the incident ray and the surface normal. The angle of reflection is measured between the reflected ray and the surface normal, as shown in Fig. 3.6.

The Law of Reflection states that, *the angle of incidence is equal to the angle of reflection and the incident ray, reflected ray, and the normal, all lie in the same plane.*

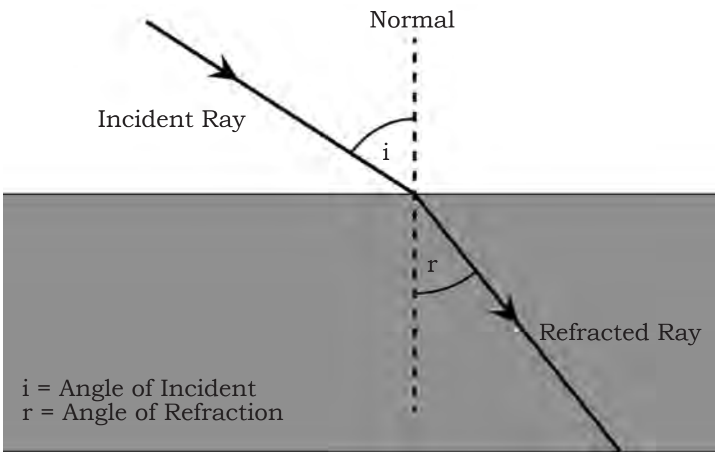

Fig. 3.7: Refraction of light

Refraction

Refraction occurs when the light ray changes mediums. Light travelling through air and then going through water is an example of a light ray changing medium. The speed of the light ray changes when it enters a different medium. In most cases the direction of the light also changes. We say the light bends. Notice that a straw in a glass of water looks (from certain angles) like it is bent, as shown in Fig. 3.7.

Refractive index

The most important optical measurement for any transparent material is its refractive index (n). As a light ray passes from one transparent medium to another, it changes direction. This phenomenon is called refraction of light. How much that light ray changes its direction depends on the refractive index of the medium. The refractive index of any light-conductive medium is the ratio of the speed of light in a vacuum, to the speed of light in the medium. The speed of light in any material is always lower than in a vacuum, so all refractive indices are greater than one. The speed of light (c) is 300000 km/second. Refractive index measures how much a material refracts light. Refractive index of a material, abbreviated as ***n***, is defined as the ratio of speed of light in vacuum (c) to the velocity of light in vacuum (v).

$$n = c/v$$

Snell's law

In 1621, a Dutch physicist named Snell derived the relationship between the different angles of light (Fig. 3.8) as it passes from one transparent medium to another. When light passes from one transparent material to another, it bends according to Snell's law which is defined as:

$$n_1 \sin\theta_1 = n_2 \sin\theta_2$$

Where,

n_1 = the refractive index of the medium the light is leaving.

θ_1 = the incident angle between the light beam and the normal (normal is 90° to the interface between two materials).

n_2 = the refractive index of the material the light is entering.

θ_2 = the refractive angle between the light ray and the normal.

Note: For the case of $\theta_1 = 0°$ (i.e., a ray perpendicular to the interface) the solution is $\theta_2 = 0°$ regardless of the values of n_1 and n_2. That means a ray entering a medium perpendicular to the surface is never bent.

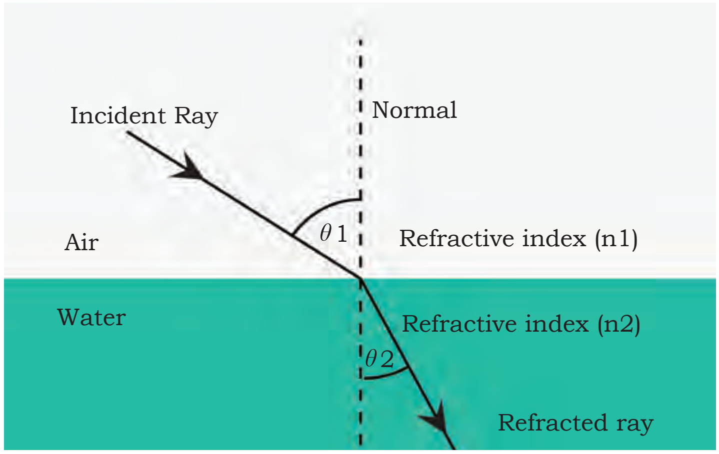

Fig. 3.8: Refraction through air-water interface

Practical Activity 1

To prove the law of reflection through a plane mirror (shown in *Fig. 3.9*).

Material Required

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

Procedure

1. Place the paper on the board and fix it.
2. Place the mirror vertically on the white sheet of paper and trace its edge.
3. Draw a line at right angles to the edge and of the edge of the mirror to act as the normal-ON.
4. Stating with angle *i* as 30 degree, draw an incident ray and place two pins, P and Q along it.
5. With your eyes at position shown, place two other pins R and S to coincide with the images of P and Q as seen in the mirror
6. Remove pins R and S and join the dots left with a straight line.
7. Measure and record angle r.
8. Repeat procedure 4, 5, 6 and 7 for angles i = 35 degree, 40 degree, 45 degree, 50 degree and 55 degree.

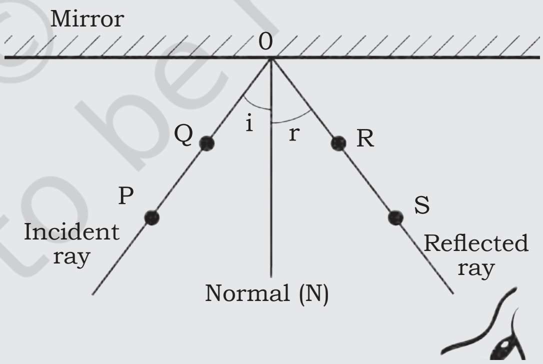

Fig. 3.9: Practical activity to prove the law of reflection

Record the results in a table.
On carefully observing the result one will clearly see that:

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

Practical Activity 2

To Understand Total Internal Reflection

When light hits an interface between two different media, it can behave in two different ways. Typically, the light partially refracts (bends) and partially reflects. The refractive index of the material is what determines how fast light travels in a material. Light travels about one and a third times faster in air than in water. Learn about total internal reflection in this activity as shown in Fig 3.10.

Material Required

- Laser pointer (preferably green)
- Empty 2-liter soda bottle (clear)
- Rubber plug
- Bucket
- Water

Procedure

1. Make a circular hole close to the bottom of the empty soda bottle. The hole should be about 1 cm in diameter; big enough so that the stream is clear, small enough so you can observe the guided light for long enough to see the effect. Plug the hole with the rubber plug or your thumb and fill with water.
2. Situate the soda bottle above the bucket. Try this a few times so the area stays dry. You might want to have an assistant hold the bottle.
3. Aim the laser pointer through the soda bottle to the hole. As a safety precaution, do not point the laser at anyone! The laser light can reflect and refract in unintended directions.
4. Remove the plug and allow the water to pour into the bucket.
5. You should be able to see a green splash of light where the water lands in the bucket and some of the reflections of the green light in the stream of the water. The light is being guided through the water, which has a higher refractive index than air. You can perform this experiment with different clear materials such as glass.
6. Turn off the laser before the water level gets to the hole.
7. This experiment makes use of total internal reflection that occurs in optical fibre. Typical optical fibre is made from glass and there is a core and a cladding. The core is where the light is guided and has a slightly higher refractive index than the cladding.

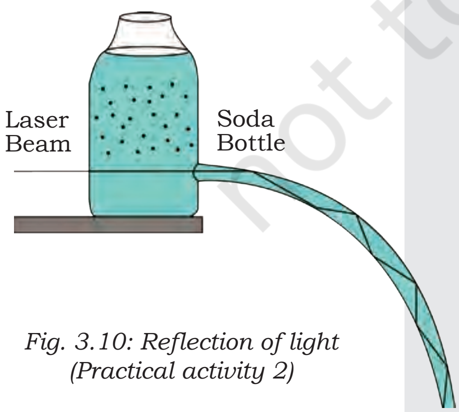

Fig. 3.10: Reflection of light (Practical activity 2)

Total internal reflection

When light hits an interface between two different media, it can behave in two different ways. The light partially refracts and reflects. A special phenomenon occurs when light passes from a higher refractive index medium to a lower refractive index medium. The refractive index of the material determines speed of the light in that material.

Example

We can take the interface between glass and air as an example shown in Fig. 3.11. Glass has a higher refractive index than air. When light passes from glass to air, at all angles less than a certain critical angle say θ_c, the light gets transmitted inside the air. But when the angle is greater than the critical angle then all of the light gets reflected inside the glass. This reflection of light is called total internal reflection.

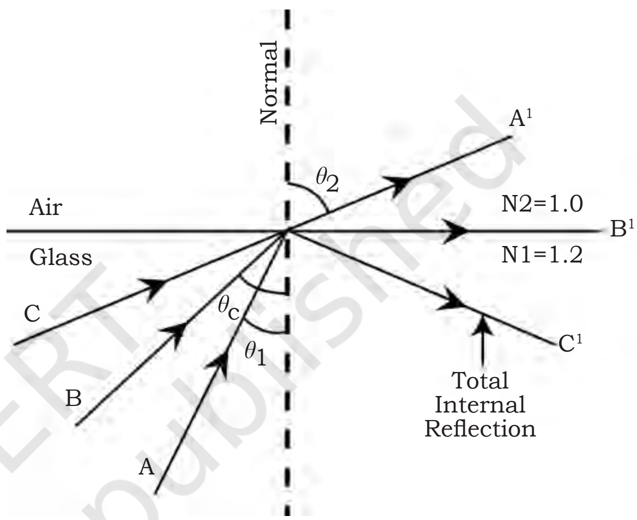

Fig. 3.11: Total internal reflection

Fig. 3.11 shows three rays of light A, B and C. When light travels from medium of glass which is denser to the second medium air which is rarer, it bends away from the normal. Light ray A shows the first case of refraction. Light ray B shows the refracted ray which 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.

Fig. 3.12 shows the structure of the fibre optics. It shows the way the total internal reflection of light takes place 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 to the core only. But the angle of light entering the fibre must be greater than the critical angle to enable total internal reflection.

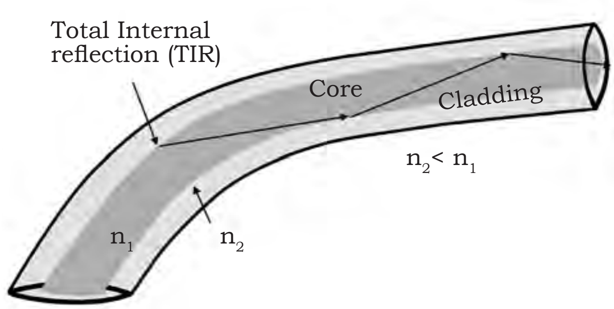

Fig. 3.12: Propagation of light through fibre by total internal reflection

Because of this light passes through the glass fibre for long distances.

Classification of optical fibres

Optical fibres can be classified based on the materials used and mode of propagation of light.

'Mode' refers to the number of paths for the light rays within the cable.

Material based classification

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

Glass fibres

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

Plastic fibres

The plastic made fibres 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.

Comparison between plastic and glass fibres

1. Plastic fibres are more flexible than the glass fibres. The flexibility is required in the medical applications of endoscopy.
2. Plastic fibres are used for short distance communication since they have lesser operation temperature ranges for computer applications.

Classification based on modes of propagation

When the light wave is guided through the optical fibre, it exhibits certain modes. These modes can be thought of as a ray of light. Modes of the fibre are classified into two types, namely single mode and multimode fibres. Multimode fibres can further be classified as step index and graded index.

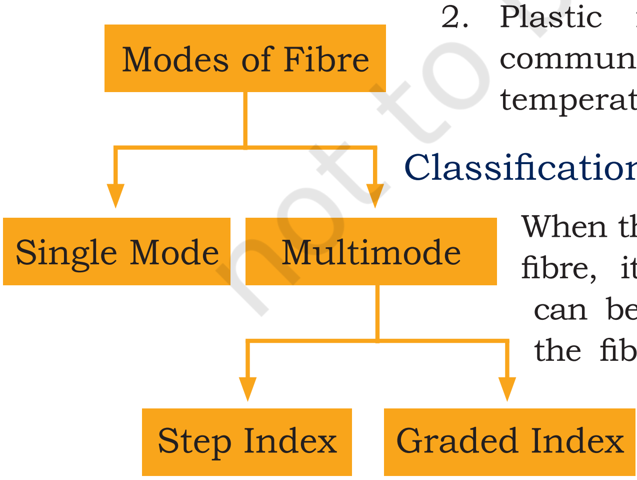

Fig.3.13: Modes of fibre

Single mode

As the name suggests, in case of single mode only one light ray or mode is used to send the data for transmission as shown in Fig. 3.14. Data travels in the form of light signals.

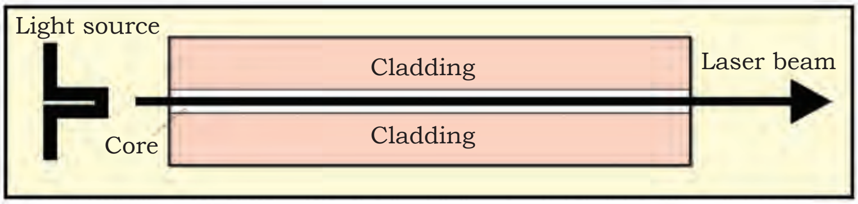

Fig. 3.14: Single mode fibre

Multimode fibre

As the name implies, multimode allows more than one modes like two, three or more to propagate along the fibre. The multiple modes move through the core in different paths (Fig. 3.15).

Multimode can further be divided into step index and graded index.

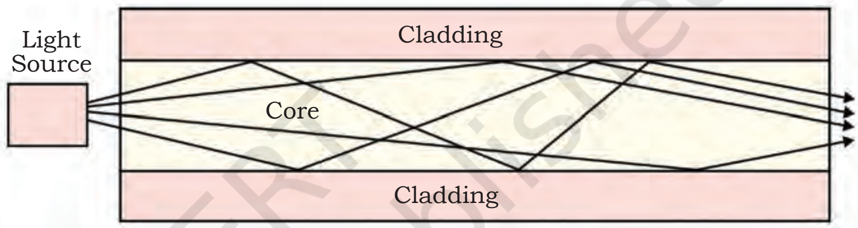

Fig. 3.15: Multimode fibre

Step index fibres

In step index fibres, the light rays propagate in zigzag manner inside the core as shown in Fig. 3.16. It shows the sudden change of light along the fibre like in a staircase or ladder. LED sources are used to launch light in this type of fibre.

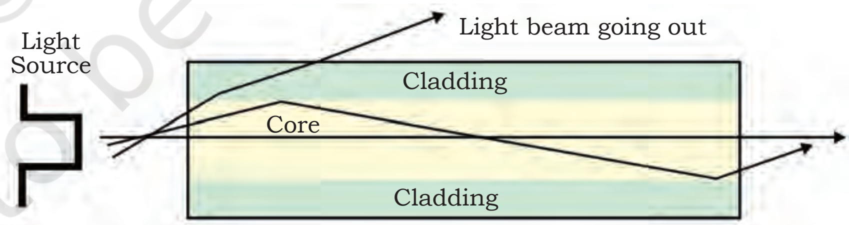

Fig. 3.16: Step index fibre

Graded index fibres

In graded index fibre, the light rays propagate in the form of skew rays or helical rays inside the core of the fibre as shown in Fig. 3.17.

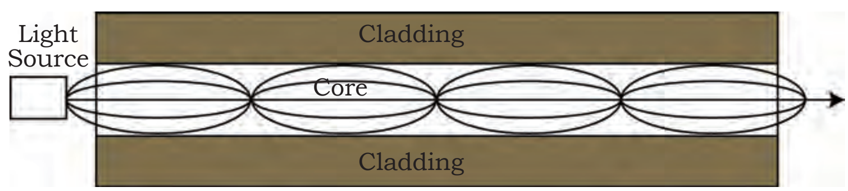

Fig. 3.17: Graded index fibre

Comparision of single mode and multimode fibres

S.No.	Single mode	Multimode
1	Only a single light ray passes through the core of the fibre.	More than one light ray travels along the fibre core.
2	They are used for long distance communication (50 to 60 Km.)	These fibres are used for short distance communication such as building or campus upto 10-15 Km.
3	It has higher bandwidth and less attenuation.	It has lower bandwidth and higher attenuation.
4	It allows less dispersion.	It allows more dispersion.
5	LASER (Light Amplification by Stimulated Emission of Radiation) beam are used to pass the light in the fibre.	LED (Light emitting diode)is used to pass the light in the fibre.
6	It is best suitable for WAN (Wide area network), MAN (Metropolitan Area network), campus, etc.	It is best suitable for LAN (Local area network).

Optical fibre communication

Optical fibre communication is known for transferring digital data. It requires light source for transmission. LASER or LED is the light source for optical fibre transmission. Fig. 3.18 shows the transmission of digital data through the optical fibre. The digital data in form of 0's and 1's is passed through the transmitter. The receiver receives the data and produces the output.

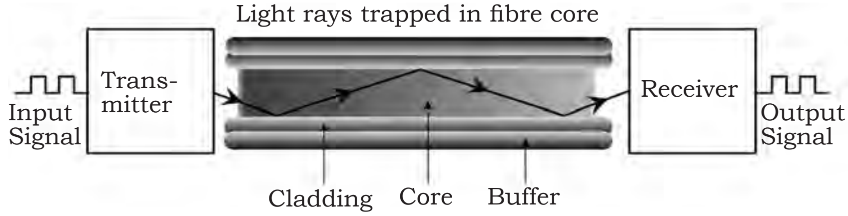

Fig. 3.18: Digital data transmission in fibre optics communication

Elements of an optical fibre communication system

Optical fiber communication system consists of transmitter stage, receiver stage and optical fibre as a medium of propagation as shown in Fig. 3.19. The transmitter stage consists of light source (Light Emitting Diode or LASER) and drive circuitry. The receiver stage consists of photodetector (photodiode or PIN Diode), an amplifier and a signal restorer. Now we will discuss in detail the stages of optical fibre communication system.

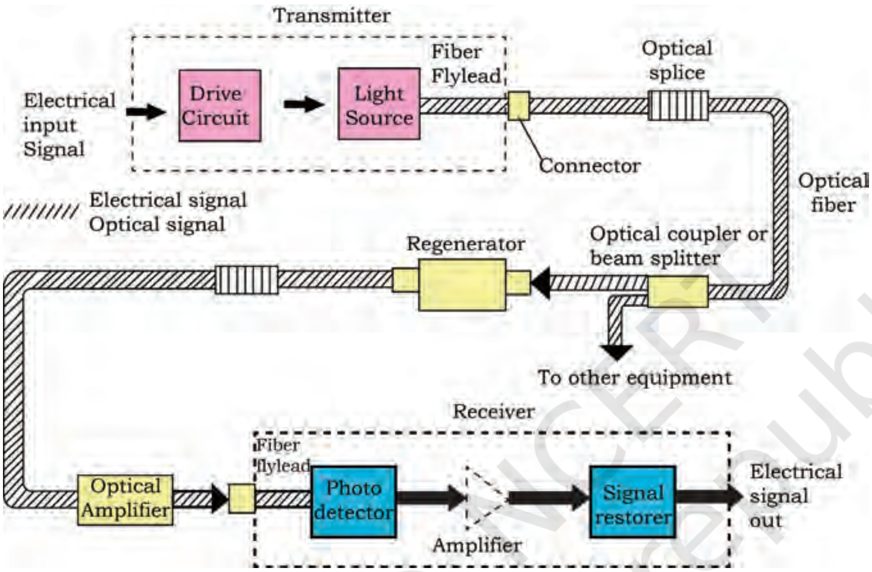

Fig. 3.19: Elements of optical fibre communication system

Transmitter

The transmitter transmits optical light to the fibre cable. It consists of interface circuit, driver circuit, and optical source as shown in Fig. 3.20.

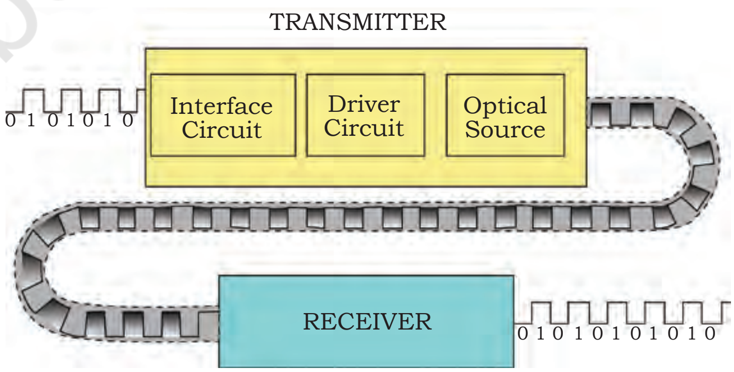

Fig. 3.20: Transmitter in optical fibre communication

Interface circuit: It processes the electrical circuit.

Driver circuit: It processes the input electrical signal, which contains information for the light source.

Optical source: It produces the light signal for the optical fiber. It can be LED or LASER.

Transmission channel

It consists of a fibre cable between transmitter and the receiver. This transmission channel transmits optical light from one end to another. Other components in fibre optics are as follows:

Optical Coupler or Splitter: Optical fibre coupler directs the beam of light from main fibre to other two or more fibres. Alternately, it can be said that coupler splits the light propagating inside main fibre to branching fibre.

Optical Connector: It is for temporary joints between two individual optical fibres that are broken or to be joined for communication. By using connectors, we can connect or disconnect optical cable as and when required.

Optical Splice: It is used to permanently join two individual optical fibres which are broken.

Receiver

Optical signal is applied to the optical receiver. Receiver stage consists of photo detector, signal amplifier and signal restorer as shown in Fig. 3.21.

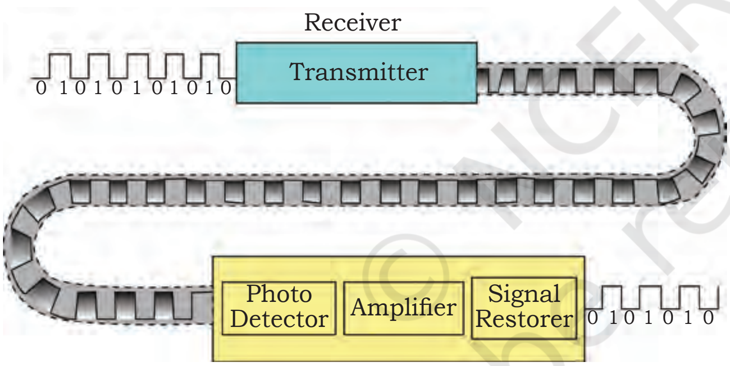

Fig. 3.21: Receiver in optical fibre communication

Photodetector: 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

Name of the element of optical fibre communication	Feature
Transmitter	
Interface Circuit	
Driver Circuit	
Optical Source	

Optical Receiver	
Transmission Channel	
Optical Coupler or Splitter	
Optical Connector	
Optical Splice	

Fig. 3.22: Light emitting diode

Light sources for optical fibres

Fibre optics is used for the transmission of light from one end to another. Hence, at transmitter side a source is required which can emit light and inject into the fibre. There are two main light sources used in the field of fibre optics.

(a) LED (Light Emitting diode)

(b) LASER (Light Amplification by Stimulated Emission of Radiation) beam

a) LED: The LED diode converts electrical energy into light energy which can inject into the fibre optics. When current is passed to LED, it emits light. It is an incoherent source of light meaning it is not focussed in a particular direction like a bulb. LED appears in a transparent capsule usually with a lens to let the light escape and to focus on it. They are used in traffic signals, microprocessors, digital computers, DJ's, etc.

b) LASER: A laser diode is an LED with a highly focussed beam of light, i.e., it is coherent in nature as shown in Fig. 3.23. For single mode fibre, lasers are used widely. Remember that laser beam of light cannot be seen with naked eyes otherwise it can damage the retina of the eyes.

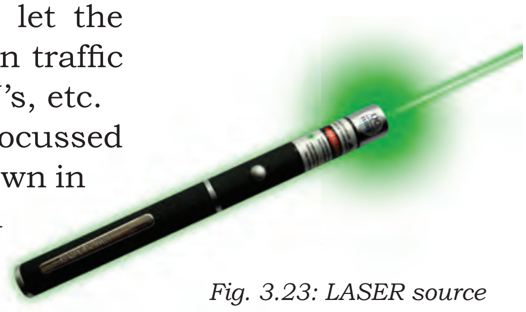

Fig. 3.23: LASER source

Losses in optical fibres

The optical fibre does not experience the loss in terms of intensity of light. However, the presence of impurities, scattering at the edges, geometry of structure and dispersion of light causes some losses. In optical transmission, light is a carrier of data which transmits the optical signal in the cable from one end to another.

The optical transmission media consists of three basic elements, i.e., transmitter, receiver, and optical media. Losses may occur while transmitting. The optical fibre does not experience the loss in terms of intensity of light. However, the presence of impurities, scattering at the edges, geometry of structure and dispersion of light causes some losses. Due to decrease in the intensity or spreading of the light in different directions, 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. Fig. 3.24 shows the signal degradation in optical fibre. This attenuation and dispersion mainly occur when light traverses along the length of the cable transmission channel. Attenuation limits the magnitude of the optical power transmitted, whereas dispersion limits the rate at which data may be transmitted through the fibre, since it governs the temporal spreading of the optical pulses carrying the data.

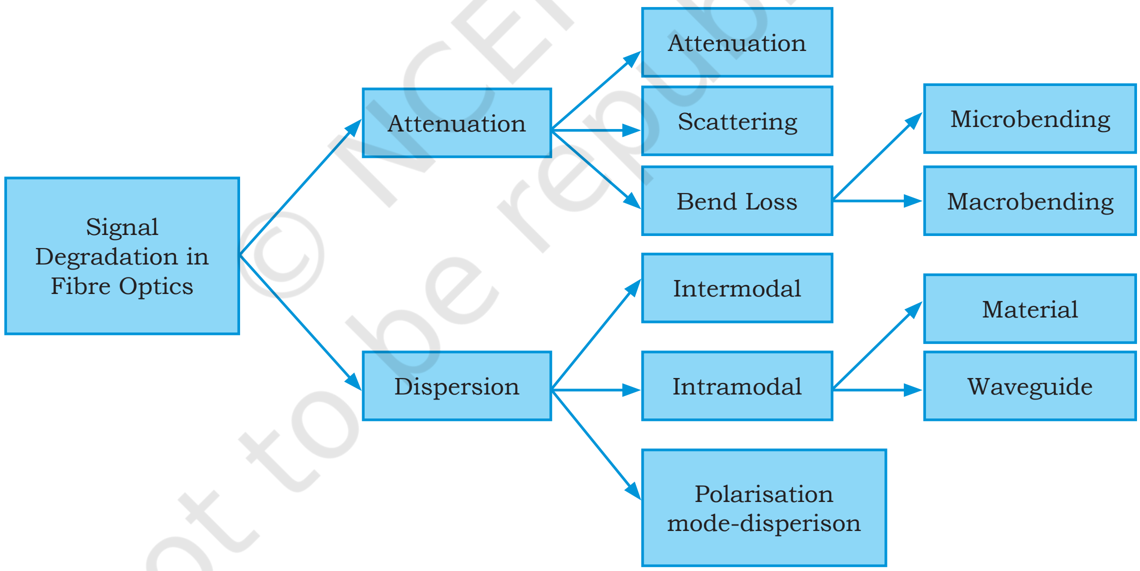

Fig. 3.24: Classification of signal degradation

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

Attenuation

The strength of the light signal goes on decreasing as it travels along the length of fibre. This is termed as *attenuation*. Hence, it determines maximum unamplified or repeater-less distance between transmitter and receiver. Attenuation is measured in logarithmic unit of **decibel (dB)**. The decibel is used for comparing the power levels and is defined as a ratio of input (transmitted) optical power P_i into the fibre to the output (received) power P_o from the fibre as—

$$\text{Number of decibels (dB)} = 100 \log \frac{P_i}{P_o}$$

In optical fibre communication attenuation can also be expressed as decibels per unit length or rate of loss per unit length(dB/km) as

$$\alpha_{dB} L = 10 \log \frac{P_i}{P_o}$$

α_{dB} = signal attenuation/length in decibels. It is a fibre loss parameter

L= Length of the fibre cable

It is directly proportional to the length of the fibre cable. It means that as length or distance of communicating medium increases attenuation increases. When the light signal reaches the receiver, it has very low strength. Because of this attenuation, it is difficult to extract the information from the light signal. Since light signal is in digital form (0's and 1's), when it is weakened it becomes difficult to distinguish between the 0's and 1's. The bits sometimes becomes so weak that the bit 1 may represent '0'. Hence, to rectify this problem of attenuation a device known as amplifiers or repeaters are required to regain the strength of the signal. These amplifiers are added before the signal is sent to the receiver. They restore the strength of the weak signal and finally increase to an appreciable level at receiver. The attenuation is caused due to the absorption, scattering loss and bend loss in optical fibres.

Absorption

It is a type of attenuation basically caused by the fibre material. Light is absorbed by the fibre material and its energy is converted to heat due to presence of the impurities contained in the fibre material. Fibre is made up of glass and this glass contains impurities

Notes

such as iron, copper manganese, etc. Presence of these impurities causes dispersion.

Scattering

It means light is dispersed in all directions with some of the light escaped through the fibre core. Scattering is caused because of the structural imperfection in the fibre material. In case of scattering loss, light is radiated from the fibre as shown in Fig. 3.25, i.e., light is scattered in different directions. Glass fibre absorbs the light signal and instantly re-emits the light in another direction that are considered as scattering.

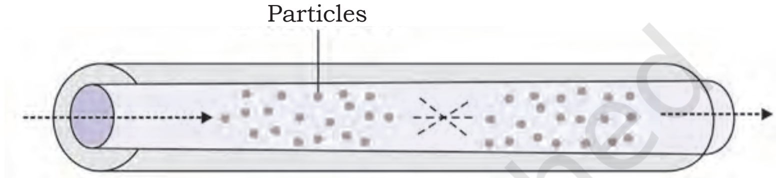

Fig. 3.25: Scattering of light in optical fibre cable

Bend loss

Incorrect fibre optic handling is one of the common problems that can results in fibre optic loss, like bend loss as shown in Fig. 3.26. When fibre optic cable is bent it causes loss of light in the fibre. There are two general types of bends. The first is micro bending, and the second is macro bending.

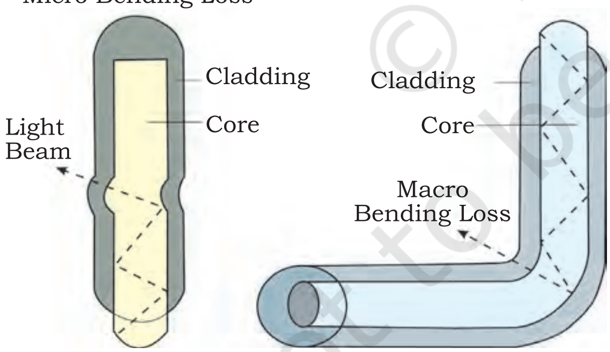

Fig. 3.26: Macro and micro bending in optical fibre cable

Micro and macro bends are common problems in installed cable systems because they can induce signal power loss. It occurs when the fibre core deviates from the axis and can be caused by manufacturing defects, mechanical constraints during the fibre laying process, and environmental variations such as, temperature, humidity, or pressure during the fibre's lifetime.

Macro bending happens when a bend in the radius of the fibre is two millimetres or more. To minimise the bend loss, the following points should be considered:

- Deviation of fibre core from axis
- Manufacturing errors
- Environmental factors like temperature, humidity, or pressure should be monitored.

Dispersion

Dispersion refers to the broadening or spreading of the light pulse as they travel through the fibre. Overlapping of the two signal pulses at the output of the fibre end creates error at the receiver output in transmission channel. It limits the bandwidth of the fibre. In other words it limits the information carrying capacity of the fibre as shown in Fig. 3.27. When a short pulse of light travels through an optical fibre its power is 'dispersed' in time so that the pulse spreads into a wider time interval.

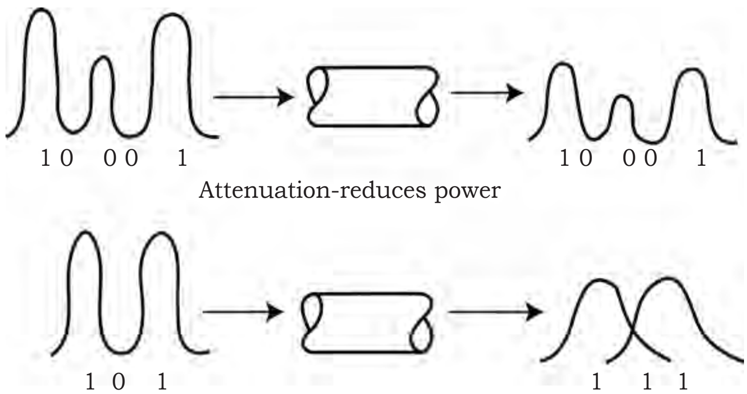

Fig. 3.27: Attenuation and dispersion

There are four sources of dispersion in optical fibres. Dispersion is classified as:

(a) Intermodal dispersion

(b) Intramodal dispersion

(c) Pulse mode dispersion

Intermodal dispersion

Intermodal dispersion occurs in multimode fibre as shown in Fig. 3.28. When a light pulse is injected into the fibre all of the light energy does not reach the end of the fibre simultaneously. In multimode fibres different rays travel inside the fibres with different velocity and they arrive at the fibre end at different times. But sometimes there is overlapping of the rays at the fibre output. Because of this the ray is spread or dispersed

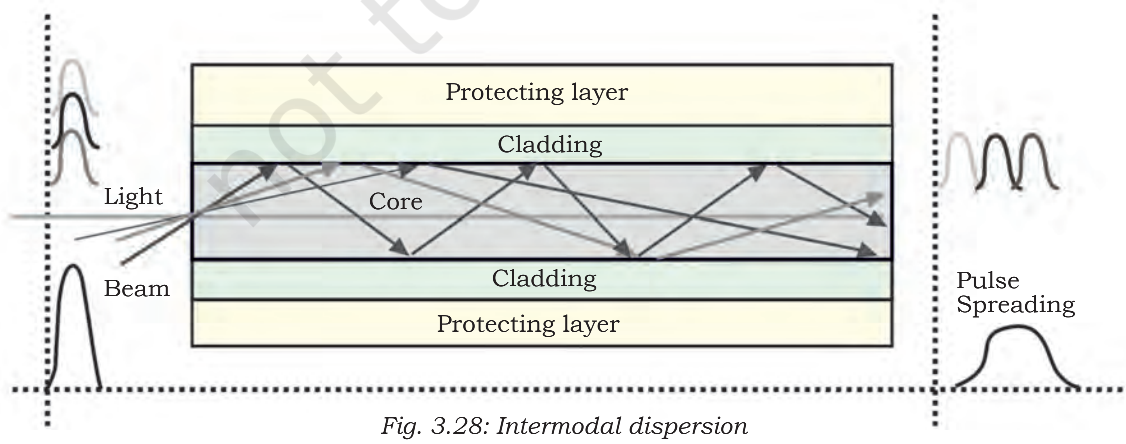

Fig. 3.28: Intermodal dispersion

and it is difficult to distinguish between them at the output of the receiver. Pulses of the signal broaden or spread and they overlap to each other. After certain distance it is difficult to distinguish these pulses. This can be due to the material composition or structure deformities of the fibre. Hence, it leads to pulse spreading at the output which leads to loss of information. For example, if we are sending 101 as digital bit then at receiver end it is received as 111. Hence, it becomes necessary to eliminate the problem of dispersion. This type of dispersion is negligible in single mode fibre since in single mode only one ray travels through the fibre.

Intramodal or chromatic dispersion

Intramodal dispersion is also known as chromatic dispersion. Intramodal dispersion mainly occurs in single mode fibre where single ray is used to carry the information as shown in Fig. 3.29. It occurs because a light pulse is made up of different wavelengths, each travelling at different speeds down the fibre. For example, white light has seven colours and when it passes through the fibre the blue light travels faster and redlight travels slower. Hence, total difference in the width causes the pulse to be broadened. At the end of the receiver output the pulses get overlapped to each other if two pulses travel through the fibre. If there is a large overlap the detector is unable to detect the signal. Hence, we get an error at the output. Therefore, it is difficult to retrieve the information at the output of the receiver. These different propagation speeds reduce the signal-to-noise ratio (SNR) and increases bit error in the information received.

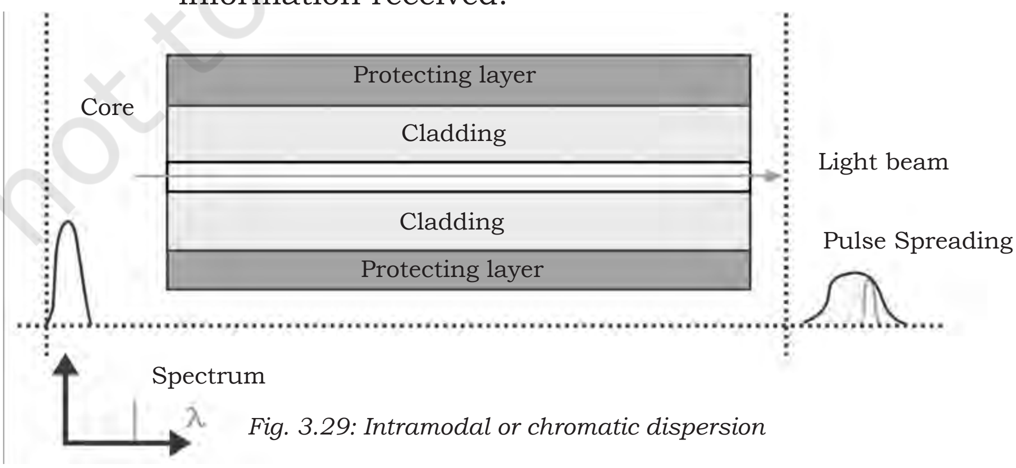

Fig. 3.29: Intramodal or chromatic dispersion

Intramodal dispersion is divided into two parts—

- Material dispersion
- Waveguide dispersion

Material dispersion

Glass is a dispersive medium, i.e., its refractive index is a function of its wavelength. An optical pulse travels in a dispersive medium. The pulse is composed of different wavelengths each travelling at a different velocity, its width spreading. This type of dispersion mainly occurs due to the property of glass. Glass is used to make fibre but it has an important property. It splits the light into seven colours having different speeds. For example, a prism is made up of glass and when white light is passed through it, it is split into 7 colours as shown in Fig. 3.30. This type of dispersion is due to the material property of fibre glass, which leads to spreading of the light inside the fibre and they arrive at fibre end at different times. Material dispersion can't be removed since it is due to the material of the fibre itself.

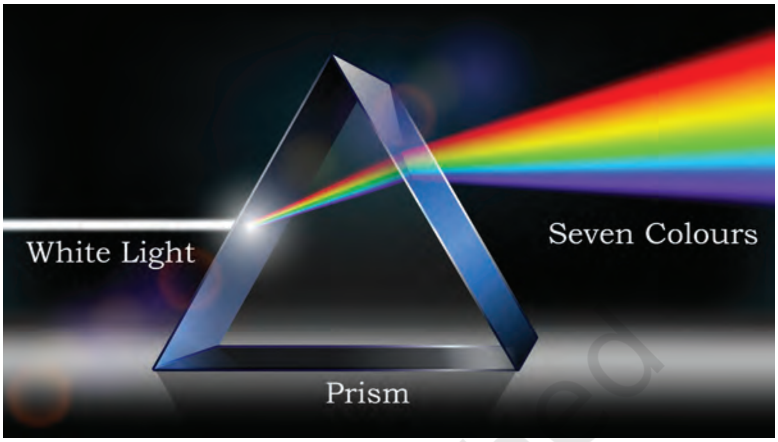

Fig. 3.30: Light is passed and split into seven colours by prism

Waveguide dispersion

This type of dispersion occurs because a single mode fibre restricts only about 80 per cent of the optical power to the core and the rest 20 per cent of light propagating in the cladding travels faster than the light confined to the core (Fig. 3.31). Hence, more rays travel in cladding than in the core. This type of dispersion mainly occurs in single mode fibre since it has small core diameter.

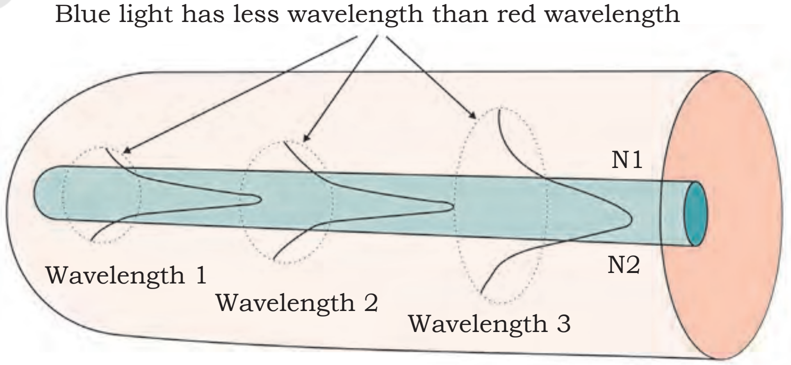

Fig. 3.31: Waveguide dispersion

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Polarisation mode dispersion

Polarisation mode dispersion (PMD) is a basic property of single-mode fibre and it affects the magnitude of the transmission rate. When there is a difference in propagation speeds of the energy of a given wavelength, which is split into two polarisation axis perpendicular to each other as shown in the Fig. 3.32 then it results in polarisation mode dispersion. The main causes of PMD are non-circularities of the fibre design and externally applied stresses on the fibre such as macro bending, micro bending, twisting, and temperature variations. The PMD causes the transmission pulse to broaden when it is transmitted along the fibre. This phenomenon generates distortion, increasing the bit error rate (BER) of the optical system. The consequence of PMD is that it limits the transmission bit rate.

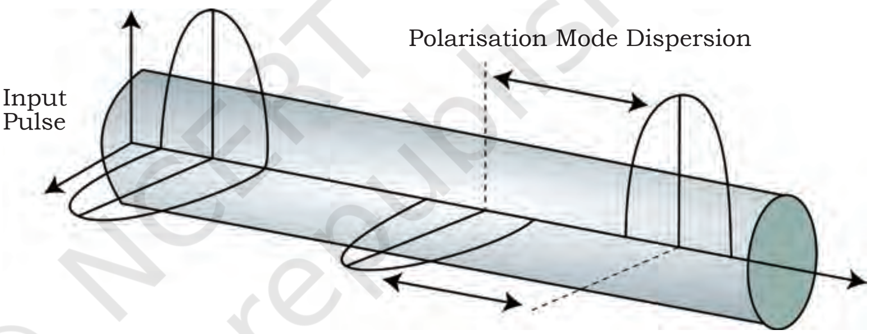

Fig. 3.32: Polarisation mode dispersion

Check Your Progress

A. Multiple Choice Questions

1. Buffer coating in the fibre optics outside the core-cladding interface provides ______________.
   (a) mechanical strength
   (b) propagation of light
   (c) propagation of electricity
   (d) physical strength
2. Speed of light coming from the sun to earth is ________.
   (a) 300000Km/sec
   (b) 200000Km/sec
   (c) 100000Km/sec
   (d) 400000Km/sec

3. Method of reflection on the surface of smooth polished mirror means _______________ of light.
   (a) bouncing
   (b) absorption
   (c) transmission
   (d) bending
4. Method of refraction at the air-water interface leads to _______________ of light.
   (a) bouncing
   (b) scattering
   (c) bending
   (d) transmission
5. If light is passed through the glass to air and angle of transmitted light is greater than the critical angle then it leads to _______________.
   (a) total internal refraction within glass
   (b) total internal refraction within air
   (c) total internal reflection within glass
   (d) total internal reflection within air
6. White light coming from the sun is composed of _______________ colours.
   (a) seven
   (b) eight
   (c) six
   (d) nine
7. Phenomena of total internal reflection takes place in _______________.
   (a) optical fibre
   (b) coaxial cable
   (c) twisted pair of cable
   (d) shielded twisted pair of cable
8. Single mode fibre is used in carrying _______________ of light.
   (a) two-rays
   (b) one-ray
   (c) three-rays
   (d) multiple-rays
9. Light through the optical fibre propagates inside _______________ by total internal reflection.
   (a) core
   (b) cladding
   (c) jacket
   (d) buffer-coating

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10. Optical splitter is used for _____________.
    (a) splitting the signal to other devices
    (b) merging the signal to other devices
    (c) transmitting the signal
    (d) receiving the signal
11. Optical regenerator is responsible for _____________ the signal.
    (a) suppressing
    (b) regenerating
    (c) multiplexing
    (d) demultiplexing
12. Optical fibre splice is used for _________ the fibres ends.
    (a) connecting
    (b) joining
    (c) disconnecting
    (d) soldering
13. Photodetector converts _____________.
    (a) optical signal to heat
    (b) optical signal to electrical signal
    (c) electrical signal to optical signal
    (d) electrical signal to heat
14. Structure of the fibre consists of elements like ________.
    (a) core
    (b) cladding
    (c) core and cladding
    (d) core, cladding and buffer
15. Intermodal dispersion occurs in _____________.
    (a) single mode fibre
    (b) multimode fibre
    (c) both single mode and multimode fibre
    (d) coaxial cable

B. Fill in the Blanks

1. If you dip a spoon inside a glass filled with water then the spoon appears to be ____________.
2. If white light is passed through the prism the light splits into ____________colours.
3. Total internal reflection is a method which allows the light to pass through the ____________part of the fibre.
4. Light appears to flow like a fountain of water because of ____________.
5. When light is passed from glass to air at particular angle known as critical angle then at that time light is ____________ to the surface of the glass.

6. Diameter of the core is ______________ than the cladding.
7. Buffer-coating is made up of ______________.
8. Buffering to the core-cladding provides ______________.
9. Speed of light becomes ______________ when it travels from rarer medium to denser medium.
10. Speed of light becomes ______________ when it travels from denser medium to rarer medium. Signal restorer converts signal ______________ for restoring.
11. The receiver stage consists of ____________, _________ and ___________.
12. Intramodal dispersion is also known as ______________.
13. LED which does not focus in a particular direction is called as _____________ source of light.
14. In ____________ light rays propagate in helical manner inside the core.
15. Attenuation occurs because of ________, __________ and ______________ losses.

C. State whether True or False

1. Combining the colours of rainbow we get white light.
2. Speed of violet colour is less than red colour in the rainbow.
3. Plants reflect the sunlight falling in them.
4. The glass used in making core is very hard and cannot be broken easily.
5. Thickness of fibre is greater than thickness of coaxial cables.
6. Refractive index of core is greater than that of cladding that is why light is confined to the core part only.
7. Total internal reflection takes place in the cladding section of the fibre.
8. Cladding of fibre is also responsible for the propagation of the light through the fibre.
9. Information security cannot be achieved with the help of optical fibre.
10. Fibre optic cables are not used for sending the information from one computer to another.
11. Fibre optic cables are very heavy and bulky in weight than coaxial cables.
12. Speed of carrying the information in fibre optics is very fast compared to other wired communication media.
13. LED light rays are not used with multimode fibres.
14. Laser beam is used to inject light in single mode fibre.
15. Fibre optic cables are very cheap in cost.

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D. Answer the following in one sentence

1. Name the material by which optical fibre is made.
2. Name the various structural elements of optical fibre.
3. Why optical fibre core and cladding is covered with buffer-coating?
4. The Snell's Law is related to what?
5. How does rainbow appear in the sky?
6. List the seven colours of the rainbow and draw them in your notebook.
7. What is electromagnetic spectrum?
8. In which range of electromagnetic spectrum does fibre optics lie?
9. How light is injected into a fibre?
10. What type of information is carried by light, i.e., analog or digital and why?
11. What element is applied if the signal is weakened along the length of the fibre?
12. What is the difference between the attenuation and dispersion?
13. What is the effect of attenuation in the fibre?
14. What is the effect of dispersion in the fibre?

E. Answer in Brief (50 words)

1. Draw a labelled diagram showing the structure of optical fibre.
2. Name the different modes of optical fibre.
3. Compare step and graded index fibres and state which one is best.
4. Why optical fibre is used for transmitting information?
5. Define total internal reflection, critical angle and at what angle the light is injected inside the fibre?
6. Write and draw at least seven places in real life, for example, in the fields of medicine, military, etc., where total internal reflection takes place.
7. What is critical angle when reflection of light takes place from glass to air in a fibre?
8. Explain how light passes through fibre.
9. Draw the structure of fibre and briefly explain each parts.
10. What are the elements of optical fibre transmission link?
11. What are the elements of optical fibre receiver link?
12. How is the attenuation in fibre measured?

13. Why is it not possible to measure material dispersion? Give example.
14. What are various optical sources and what types of light is emitted by them?
15. Why does dispersion occur? What are the different types of dispersion?
16. What do you mean by bend loss? Explain.

NOTES

Chapter 4

Tools and Equipment

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

Basic Hand Tools

Basic hand tools are those used in our day to day life whenever we are dealing with any repairing, drilling, cutting, etc. These tools are discussed below.

Screwdriver

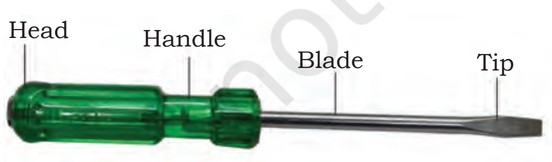


Fig. 4.1: Screwdriver and its parts

Screwdriver is a hand tool, specifically designed to insert and tighten the screws as well as to loosen and remove screws from the job. A screwdriver comprises a head or tip which is fixed to the screw head and force is applied to the screwdriver to tighten it in clockwise direction and to loosen it in anticlockwise direction. A typical simple screwdriver has a handle and a shaft as shown in Fig. 4.1.

The ending tip of the screwdriver is put into the screw head by the user before turning the handle as shown in Fig. 4.2.

The shaft is usually made of tough steel. It is used to resist bending or twisting. Handles are made up of wood, metal, or plastic. Handles are usually hexagonal, square, or oval in cross-section to improve grip. This will be helpful while twisting the screwdriver and will prevent the tool from rolling on the head of screw. Some screwdrivers have interchangeable tips that fit into a socket on the end of the shaft and are held in mechanically or magnetically. These often have a hollow handle that contains various types and sizes of tips as shown in Fig. 4.3.

Fig. 4.2: Tip of the screwdriver is put into the screw head

Fig. 4.3: Interchangeable tips of screwdrivers

Tips to use screwdrivers

The size of the screw and the type of opening it has determines which driver to use. Following are a few tips to use a driver.

1. Never use a driver to do another tool's job. It should be used for which it is designed.
2. Never push a driver beyond its capacity, never put excessive pressure on the screw head.
3. Never expose a driver to excessive heat, it will damage the shaft of the driver.
4. Never use a driver at an angle to the screw, it is always used in a perpendicular direction of screw head.
5. Never depend on a driver's handle or covered blade to insulate you from electricity.
6. Discard damaged or worn drivers.

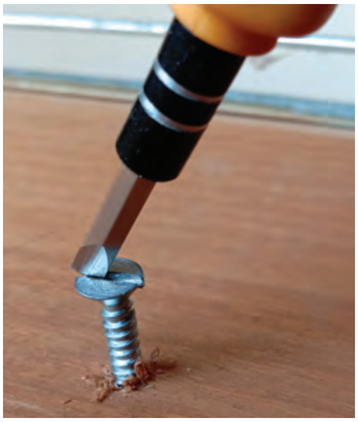


Fig. 4.4: Slip of tip of screwdriver

Slipping of tip of screwdriver

When driving certain types of screws, the screwdriver bit can slip out of the screw head, when a lot of torque (turning force) is applied (Fig. 4.4).

Stripping a screw head

A stripped screw head is the term used to describe a screw that has been damaged by a screwdriver bit (Fig. 4.5).

Stripped screws are the result of a number of things, Like,

- general wear and tear.
- using the wrong size or type of bit for the screw.
- the screwdriver slipping out of the screw's drive and damaging its surface.

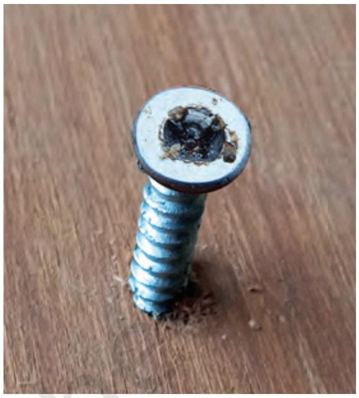


Fig. 4.5: Screwdriver damages the surface of screw

Fig. 4.6: Scissors

Scissors

Scissors are hand-operated tools. A pair of scissors consists of a pair of metal blades which are pivoted. The sharpened edges slide against each other when the handles (bows) opposite to the pivot are closed. Scissors are basically utilised for cutting purpose like paper, cardboard, metal foil, cloth, rope, and wire. A typical part of scissors is shown in Fig. 4.6. Fig. 4.7 shows the various parts of a scissor.

Precautions to be taken while handling the scissors are—

(a) Do not touch the blade of the scissors.

(b) Observe tip of scissors while cutting fibre threads.

Fig. 4.7: Parts of Scissor

Cable cutting knife

It has a sharp blade with comfortable, full-sized, handle. Its blade is made of the finest steel, tough and carefully tempered to hold its edge as shown in Fig. 4.8. The handle is textured for comfort and firm grip. A typical cable-cutting knife is shown in Fig. 4.8.

Fig. 4.8: Cable cutting knife

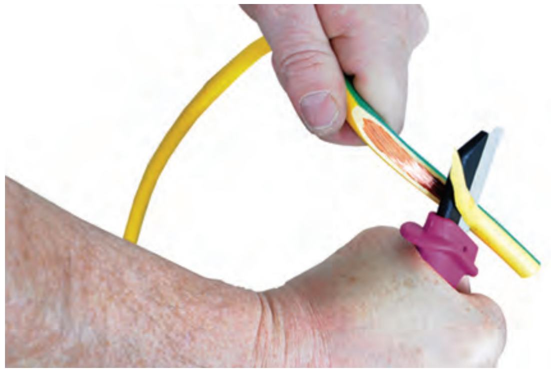


Fig. 4.9: Cable insulation stripping using cable cutting knife

Plier

Pliers are used for gripping or twisting of wires or cables. A typical plier is shown in Fig. 4.10. There are different parts of the plier like handles, jaws, cutter each with a specific operation. They are used to grip, splice or cut wires, and strip insulation.

Parts of pliers are as follows—

Handles

The handles of pliers have a plastic coating, for added comfort while holding it. It also provides good grip to the hands. The size and length of the handles will depend on the size of the pliers. Those designed for use by electricians and linemen have insulated handles.

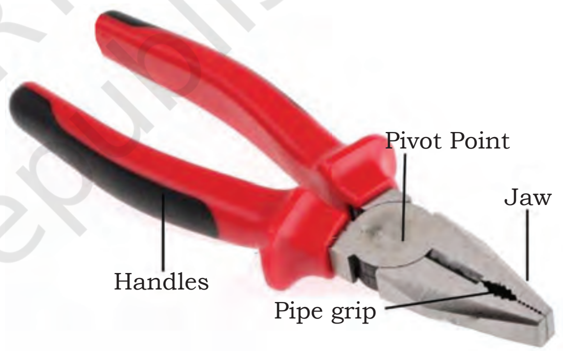


Fig. 4.10 Combination plier and its parts

Jaws

Handles are used to open and close the jaws of pliers. They have flat edges for general gripping, which are often serrated for extra grip, although sometimes they are smooth. They usually have squared tips.

Cutter

The cutters built into the jaws of combination pliers are usually designed to cut cables and wire.

Pipe grip

The pipe grip is a rounded, cut-out in the jaws. It is primarily used for gripping rounded stock, like pipes and cables.

Pivot point

The pivot point is a kind of hinge that allows the handles and tips to open and close so the jaws can grip or cut, and then be opened again.

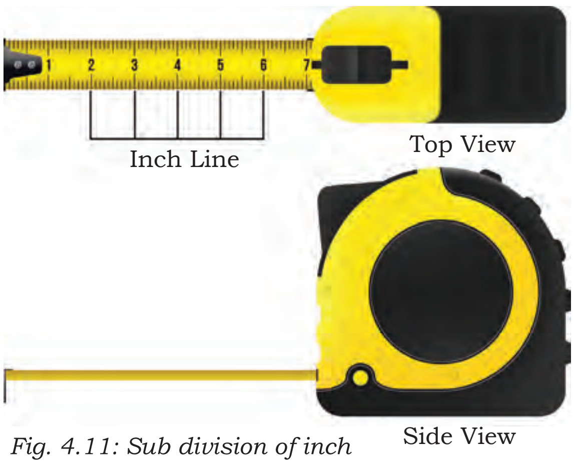


Fig. 4.11: Sub division of inch line on measuring tape

Measuring tape

This is used for measurement of cable during splicing. A typical measuring tape is shown in Fig. 4.11.

Tube cutter

This compact and light weight tool is used for removing the outer jacket and buffer coating from fibre. This tool has automatic return spring for ease of use and speed. Fig. 4.12 shows a typical tube cutter.

Fig. 4.12: Cable tube cutter

Operation of tube cutter

Place the optical fibre cable inside the jaws of the loose tube cutter. Inside the jaws there is a blade which is used to cut the optical fibre cable as shown in Fig. 4.13. Rotate the tube cutter around the fibre cable as shown in Fig. 4.14. Now gently pull the tube cutter to cut the fibres as shown in Fig. 4.15. The blade inside the jaws cuts the cable along the direction of the pulling (cuts the cable sheath). Pulling the cut outer jacket will reveal the inside fibre strands from it.

Fig. 4.13: Fibre cable inside tube cutter

Fig. 4.14: Rotation of tube cutter around the cable

Fig. 4.15: Pulling out the jacket from cables

Optical fibre stripper

It is used for cutting and removing the primary coating of the optical fibres while splicing the optical fibre cable. A typical splicing tool is shown in Fig. 4.16. It enables the user to perform the combined operation of cutting and stripping. There are three slots or holes of cutting the fibre each with a different operation, i.e., stripping the fibre jacket (Fig. 4.19), fibre buffer, and fibre coating. Stripping activity of fibre optic cable is shown in Fig. 4.17 and the stripped cable after stripping is shown in Fig. 4.18.

Fig. 4.16: Stripping tool

Fig. 4.17: Stripping of optical fibre cable

Fig. 4.18: Stripped optical fibre

Practical Exercise

Activity

Steps to use optical fibre stripper.

Step 1: Use fibre optic stripper to strip fibre jacket as shown in Fig. 4.19.

Fig. 4.19: Hold the fibre with the help of stripping tool

Step 2: Take down the stripped fibre jacket.

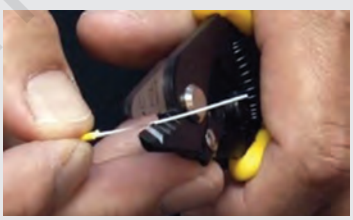


Fig. 4.20: Removal of the jacket of the optical fibre

Tools used for splicing

Splicing is a specialised technique of joining the broken ends of the optical fibre. The procedure of splicing requires special tools. Some of the important tools are discussed below.

Optical fibre splicing machine

A typical machine for fusion splicing fusion splicing is shown in Fig. 4.21. It is a small, lightweight machine with an LCD screen. This screen shows the splicing operation and internal view of the operations performed in machine during splicing. LCD screen shows the process of alignment in two directions, the fusion operation of the fibre. The optical joint machine calculates the power loss in the joint. It also has thermal heater to shrink the protection sleeve on the fibre.

Fig. 4.21: Fusion splicing machine

Fibre optic cleaving tool

Fibre cleaving is used to cut the fibre ends perfectly perpendicular to the axis before joining. Cleaving is different from normal cutting of cable using steel blade/knife. This method of cutting is applied specially for fibre since it is made up of glass. Glass cutting requires fine and polished ends for cutting and it can be done using the diamond cutter. It is a process of controlled breaking of glass of a bare fibre. When optical fibres are spliced, the fibre ends, i.e., core need to be prepared such that they have clean surfaces as shown in Fig. 4.22. Hence, the fibre to be cut is kept horizontally and the diamond blade is kept vertically. To get perfect splicing it is necessary to have cleaving. Hence, it is important that the surface is either perpendicular to the fibre axis or has a well-defined angle against the fibre axis.
Two types of cleaving tools are used for fibre cutting. They are—

- Scribe cleaver
- Precision cleaver

Scribe clever

These types of cleavers were used in earlier days. Fig. 4.22 shows the scribe cleaver. It is used to cleave the fibre manually. It is a traditional cleaving method, typically used to remove extra fibre from the end, using a simple hand tool called a scribe. Scribe cleavers are usually shaped like ballpoint pens with a diamond tipped blade. The scribe has a hard, sharp tip, generally made of carbide or diamond that is used to scratch the fibre manually. Then the operator pulls the fibre to break it. Since both the scribing and breaking processes are under manual control, this method varies greatly in repeatability. Most field and lab technicians don't use it for cleaving as they are not accurate. However, if in skilled hands, this scribe cleaver offers significantly less investment for repairs, installation, and training classes.

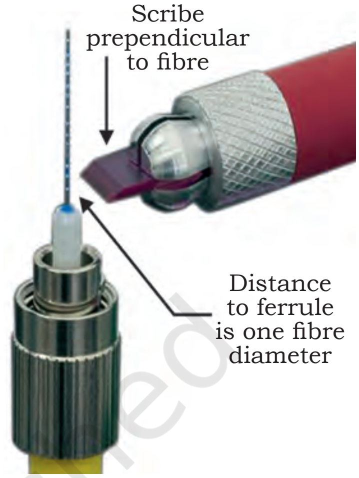


Fig. 4.22: Scribe cleaver

Precision cleaver

Precision cleavers are the most commonly used cleavers in the industry (Fig. 4.23). They use a diamond or tungsten wheel/blade to cut the fibre. Tension is then applied to the fibre to create the cleaved-end face. The advantage of these cleavers is that they can produce repeatable results through thousands of cleaves by simply just rotating the wheel/blade accordingly. Although more expensive than scribe cleavers, precision cleavers can cut multiple fibres while increasing speed, efficiency and accuracy. In the past, many cleavers were scribes, but over time with fusion splicers, good cleaving became the key to low splice loss.

Precautions to be taken

- Handle the scribe cleaver carefully.
- Don't place your finger at the diamond blade. It will cut your finger.
- Keep your mouth and nose away, at least at an arm's distance from alcohol.
- Label the bottle of alcohol and wash your hands with soap after using it.

Protection sleeves

Fibre optic protection sleeve is used during the process of optical fibre splicing as shown in Fig. 4.26. As we know, spliced bare fibres are fragile. Therefore, a good protection for the spliced fibres during fibre optic splicing

Fig. 4.23: Precision cleaver

Fig. 4.24: Protection sleeves

is extremely necessary. Hence, a protection sleeve perfectly solves the issue. The sleeve acts like a strong coat for the fibre splices to prevent unpredictable fractures. Typical lengths of protection sleeves are 30 mm and 40 mm in diameter. The sleeve colour is selective, but most people would choose the transparent tube for better inspection of the fibre. Although the sleeve is very small, it provides great support for the fibre joint. Fibre optic splicing, especially fusion splicing, has become increasingly important. The process is done by joining the two ends to create longer cable runs.

Protection sleeves are made up of three parts:

1. Outer tube (heat shrinkable)
2. Inner tube (hot-melt glue)
3. Strength member

Outer tube (heat shrinkable)

It is made up of polyolefin based on polyethylene material. The outer high quality heat shrinkable tubing provides an instant shrink-force and drives the adhesive liner into all areas of the splice and excludes all the air.

Inner tube (hot-melt glue)

The hot-melt adhesive in the inner tube bonds to both the fibre and the heat shrinkable outer tube to encapsulate the fusion splice joint and provides vibration damping and an environmental seal, protecting the fibre from damage and contaminants.

Strength member

A choice of strength member (stainless steel, ceramic, or non-metallic) provides additional rigidity to prevent misalignment, micro bending or breaking of the Fibre.

Precautions to be taken while using protection sleeves

While utilising the fibre protection sleeves, the operator should take the following precautions to avoid unnecessary loss and secure the fibre for a long-term use.

1. Do not leave air bubbles in the protection tube. This ensures the long-term reliability of the fibre splices.
2. The tension applied to the fibre should be uniform so that the fibre can stay straight in the protective sleeve.
3. The tension applied to the fibre should not be too large in case fibre cracks increase.
4. Avoid fibre twisting because this may cause micro-bending and unnecessary fibre loss.
5. Do not release the tension until the heat-shrinkable tube is completely shrunk, cooled, and shaped. This can avoid the uneven heating which leads to fibre bending.

Tools for mechanical splicing

Basic tools used for the mechanical splicing are as below.

Mechanical splice connector

Fig. 4.25 and 4.26 show the basic mechanical splice connector and its structural description. Mechanical splicing creates temporary joints and can be disconnected. This type of splicing is less accurate than fusion splicing.

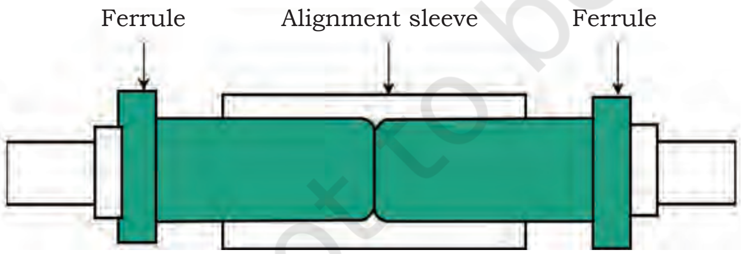


Fig. 4.25: Top view of mechanical connector

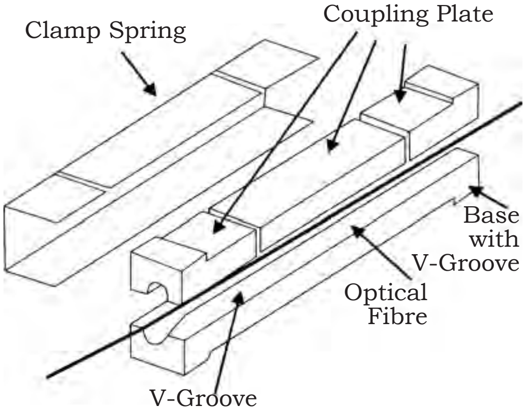


Fig. 4.26: Side view of mechanical connector

Ferrule

A ferrule is a component in optical fibre used for protecting and aligning the stripped fibre end. Material for a ferrule is selected keeping in mind a variety

Fig. 4.27: Ferrule inserting into the optical fibre cable

of factors such as durability of the material, cost, connector mating frequency, surface finish over time and the material's ability to retain end-face geometry. Ferrules can be manufactured from plastic, glass, metal or from any ceramic material. Ceramic is considered the best material for ferrule. The end face of the ferrule should be precisely shaped, as this helps in having the optimum physical contact between each of the mated fibre pair as shown in Fig. 4.27.

V-groove

V-groove is the most commonly used alignment mechanism for mechanical fibre splices. Precision holes or V-groove is drilled or moulded through the centre of each ferrule allowed for fibre insertion and alignment. Precise fibre alignment depends on the accuracy of the central hole of each ferrule. The fibre alignment is done by using splicing machine having V-groove as shown in Fig. 4.29.

Fig. 4.28: Fibre splicing machine

For this, the steps followed are —

- cleaved fibres are placed into the groove.
- index matching gel is used to bridge the gap between the two ends to prevent gap loss.
- a locking mechanism/clamp then holds the fibres in position and provides mechanical protection for the fibres.
- index matching epoxy can be used in place of index matching gel. The epoxy is usually cured with ultraviolet light. The epoxy can hold the fibres in place.

Fig. 4.29: Fibre splicing machine having V-groove

Matching gel

It is a gel which is used to match the refractive index of a material. The index-matching material is a substance, usually a liquid, cement (adhesive), or gel, which has an index of refraction that closely approximates that of fibre-optic. When two substances with the same index are in contact, light passes from one to the other with neither reflection nor refraction. The fibre is inserted into the thin structure of the ferrule and provided with an adhesive or matching gel to prevent contamination as well as to give it long-term mechanical strength. When the fibre ends are inserted, an adhesive, normally an epoxy resin, bonds the fibre inside the ferrule (Fig. 4.30).

Fig. 4.30: Matching gel using for index matching

Clamp spring

After the fibre is properly aligned and joined/spliced by gel, the clamp is pressed above it protecting the jointed portion. It is used as a lock mechanism to hold the spliced fibre. A typical clamp spring is shown in Fig. 4.31.

Fig. 4.31: Clamp spring

Cleaning tools and safety materials

Cleaning swab

Today's splicing equipment is fast, efficient and requires minimal maintenance due to advances in splicing technology. However, environmental contamination, such as dust, dirt and fibre coating debris, as well as, the silica deposits generated during the fusion process eventually find their way to the optical elements and V-grooves. This contamination offsets the fibre and degrades its performance. The cleaning swabs are high absorbency swabs and remove dust and other contaminants as shown in Fig. 4.32. They work well with solvent applicator like alcohol and offers outstanding particle entrapment. They have ideal size of 4.5 mm in length and their dimension is suitable for fusion splice mirror cleaning. They are available in durable, field-ready, transparent tubes.

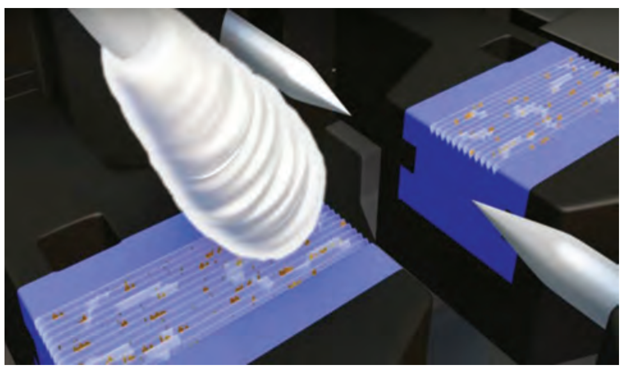


Fig. 4.32: Cleaning swab

Applications

- For fusion splice mirror cleaning
- Dust removal from precision surfaces

Fig. 4.33: Tissue paper

Tissue paper

It is a lightweight paper used for cleaning the fibre after stripping it. It is made by recycling paper pulp. It comes in bundle or packet and white in colour as shown in Fig. 4.33. It is very cheap and is used to clean the jelly which is above the core and cladding. Dry tissue paper is taken with few drops of isopropyl alcohol above it and then it is used to clean the fibre.

Note

- Don't touch the tissue paper with dirty or wet hands.
- Used tissue paper should be disposed off in bin and cannot be reused.

Alcohol

Fig. 4.34: Isopropyl alcohol

This fast-acting cleaner can be used with dry fibre wipes or tissues to remove jelly above the fibre core, or dust from optical fibre prior to termination and fibre optic splicing or to clean the end of the fibre. A fast evaporating alcohol based chemical named as isopropyl is used with the tissue paper to clean the bare fibre as shown in Fig. 4.34.

Fig. 4.35: Hand gloves

Gloves

Gloves are used for safety during splicing as shown in Fig. 4.35.

Check Your Progress

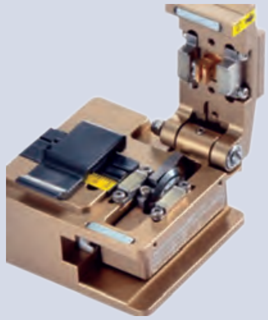
Notes

A. Multiple Choice Questions

1. Which of the following is not a part of screw driver?
   (a) Head
   (b) Shaft
   (c) Tip
   (d) V groove
2. Which of the following is not a type of screw driver tip?
   (a) Cabinet
   (b) Keystone
   (c) Square
   (d) Triangle
3. Which of the following is not a part of scissors?
   (a) Tip
   (b) Blade
   (c) Inside ring
   (d) Handle
4. Which of the following is not a part of plier?
   (a) Jaws
   (b) Pivot point
   (c) Cutter
   (d) All of the above
5. Which of the following cutting tool is rotated around the optical fibre several times to create a cut in the buffer tube?
   (a) Plier
   (b) Nose plier
   (c) Tube cutter
   (d) Cleaver
6. Which of the following tool enables the user to perform the combined operation, i.e., cutting and stripping?
   (a) Optical fibre stripper
   (b) Nose plier
   (c) Cleaver
   (d) Scissor
7. Which of the following is the most commonly used alignment mechanism for mechanical fibre splices?
   (a) Cleaning swab
   (b) V-groove
   (c) Matching gel
   (d) Clamp spring

NOTES

8. Identify the following picture and choose the appropriate name for the equipment from the given options.



(a) Scriber cleaver
(b) Precise cleaver
(c) Optical power meter
(d) Optical Time Domain Reflectometer

9. Identify the following picture and choose the appropriate name for the equipment from the given options.

(a) Clamp spring
(b) Mechanical spring
(c) Optical spring
(d) Precise cleaver

B. Fill in the Blanks

1. In order to tighten the screw, the force applied to the screwdriver is in ______________ direction.
2. In order to loosen the screw, the force applied to the screwdriver is in ______________ direction.
3. Cable can be placed in a figure of ______________ which prevents the twisting of fibre cables.
4. Ferrules are typically made of __________, ____________ or quality plastic.
5. Tube cutter is ______________, ______________, and more convenient way of cutting cable.
6. Before installation of the cable, check the ___________ and ______________ of the cable.
7. For temporary joint of optical fibre cable ______________ is used.
8. For cleaving the optical fibre _____________ material is used.

9. Typical lengths of protection sleeves are ______________ and ________________ in diameter.
10. Coupling device is a part of the connector body that keeps the _____________ in place when attached to another device.

C. Answer in Brief

1. Define the following terms
   (a) Precise cleaving
   (b) Cable pulling
   (c) Cable placement
   (d) Matching gel
   (e) Cleaning swab
2. What is the significance of using matching gel and how is it used?
3. Name the tools used for fibre splicing.
4. Write down the safety and care measures taken to handle various tools and equipment.
5. Write down the tips to use a screwdriver.

Notes

Chapter 5

Splicing

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Optical fibre is used as transmission media for data communication. In general, for any line communication, transmission media has a requirement of both joining and terminating the connection. Proper fibre-to-fibre connection is required so that there is very low loss with minimum signal distortion. Fibre 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 optical fibre cable (OFC), two fibre cables are joined together by a method, known as splicing. Hence, splicing is the method in which broken fibre ends are joined permanently. Splicing is nothing but a sort of noble name of “soldering”. The sophisticated term of splicing is used with fibre optics since these cables carry light signal and not the electrical signal. The OFC consists of a core through which the light propagates. Hence, joining the OFC cables requires proper core-to-core alignment so that light can pass through it without any leakage. In this chapter, we will study the method of splicing.

Soldering the broken wire at home

Wire is commonly used to connect the parts of an electrical circuit at home to use various appliances like tube light, bulb, etc. The wire must extend from surface to surface, and if not protected properly from external climatic conditions, accidental breakage might lead to the damage of the wire hence interrupting the work of electrical appliances. If a wire becomes damaged, it does not necessarily need to be replaced. The circuit may be restored by soldering it. The broken wires can be joined by cutting, stripping, soldering and then covering by the tape.

Requirement of splicing

Fibre cables are widely applied in today's communication network. They are buried under the street or under the sea. Fibre cables are quite indispensable for information transmission and data providing. They are just like the veins of communication systems. Once fibre cables are damaged or cut, network will be interrupted. Since optical fibre cable is made up of glass it requires repairing if broken or damaged. The repairing done to join the damaged cable is not same as the repairing or soldering done on the electrical wires at home. It requires specialised technique to join the damaged optical cable because the cable of optical fibre is composed of glass. This technique of joining the fibre optics cable is called splicing. Splicing is a costly method of repairing the fibre. It requires expensive machines and technicians to repair. Fig. 5.1 shows a damaged cable.

Fig. 5.1: Damaged fibre

Notes

Factors affecting OFC

There are various factors that lead to the damage of fibre optics cable.

In the telecommunications industry, we focus a lot on how to build our fibre optic outside plants quickly and efficiently while providing a highly functional network. What happens to that buried fibre after the heavy equipment and construction crew leave? Several factors can destroy buried fibre optic cable and interrupt network traffic, triggering significant repair costs and lost revenue. The various factors affecting OFC are—

- Water
- Rodents
- Lightning or Incidental Voltage
- Construction
- Ice Crush

Water

Water is very harmful for fibre optic strands. Modern-day fibres benefit from advanced coatings that protect them from water, except in the splice enclosures where the tips of the fibre strands are stripped off their coatings so the splices can be fused without contaminants. Today, most water damage happens in splice enclosures that have failed to keep water away from the fibre.

Fig. 5.2: Damage in splice enclosure due to water

Fig. 5.3: Damage in fiber cable due to rodents

Rodents

Since they have a life-long drive to gnaw, rodents are often responsible for extensive damage to fibre optic cable. Even metal armoured cable can get cut in two by these furry creatures.

Lightning or incidental voltage

When lightning strikes the ground, it searches for the best conductor available, even if it is underground. If that happens to be the armour or trace-wire of your fibre cable, then damage to the cable sheath and even the fibre itself is very likely (Fig. 5.4).

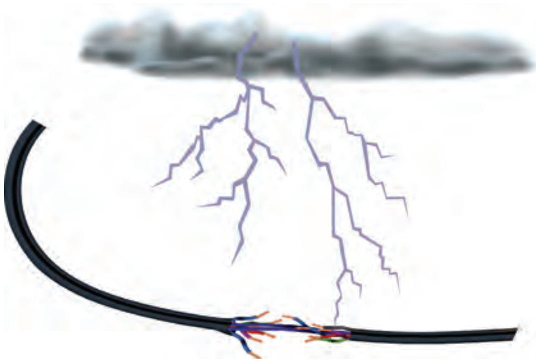


Fig. 5.4: Damage in fiber cable due to lightining

Construction

Construction can be the biggest cause of damage to buried cable. Backhoes, post hole augers and even hand shovels can all bring network traffic to a halt by severing your fibre optic cable (Fig. 5.5).

Fig. 5.5: Damage to the fibre cable due to construction

Ice crush

In colder climates, water that enters a splice enclosure can freeze, crushing the fibre strands and leaving you with a costly network outage. When ice crush occurs, an emergency network repair is needed to avoid additional damage and downtime. Given the harsh conditions, however, access to the splice enclosure is often very hard to reach. In such scenarios, it is not uncommon to find the handhole buried under a snowbank, with the lid frozen shut, and full of water that has completely frozen. (Fig. 5.6).

Fig. 5.6: Damage to the fibre cable due to ice crush

Assignment: Classify the factors effecting the damage of the cables by natural and man-made reasons on table below.

Factors	Man-made	Natural
Ice crush		
Thunderstorm		
Fire		
Squirrel, rats, insects		

NOTES

Nuclear radiation		
Factory smoke and air pollution		
Construction of site		
Salt water, moisture		
Temperature change		
Earthquake		
Traffic (cars, trucks)		
Nuclear radiations		

Types of splicing

Splicing can be divided into the following two types—

- Fusion splicing
- Mechanical splicing

Splicing can be performed in two ways either mechanically or electrically. If splicing is done mechanically it is called mechanical splicing. But if splicing is done electrically it is called fusion splicing. Fusion splicing is done by heating the ends of the fibre using electric arc. It is useful to join the fibre ends permanently together. 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 splicing.

Steps to perform fusion splicing

Practical Activity 1: Fusion Splicing using Electric Arc Method

Material required

- Optical fibre ends to be spliced
- Optical fibre splice machine
- Optical fibre cleaver
- Tissue paper
- Alcohol
- Protection sleeves
- Round tube cutter
- Fibre cutter/stripper
- OTDR (Optical time domain reflectometer)

Procedure to be followed

Preparation

Step 1: Fibre Preparation

First take the damaged fibre to be spliced as shown in Fig. 5.7.

Fig. 5.7: Damaged fibre cable

Note: It is mentioned on the cable fibre whether it is designed as single mode or multimode. Based on it the necessary setting is on the fibre splicing machine to carry out the splicing.

Prepare the fibre cable for splicing: For preparing the cable to be spliced break the fibre at damaged area into two parts using pliers shown in Fig. 5.8.

Fig. 5.8: Breaking damaged fibre using pliers

Now prepare each end perfectly so that both broken parts of the fibre can be joined/spliced perfectly core-to-core without any losses. Fig. 5.9 shows two parts of cable to be prepared for splicing.

Fig. 5.9: Fibre cable for preparation

Step 2: Clear the damaged area

Now take any one of the broken parts of the fibre cable out of the two parts (shown in previous step). Now we will illustrate Step 3 onwards for only one broken end since all the steps for the other broken end is repeated in a similar way.

Step 3

Take a round cutter and put the fibre inside its round jaws at a distance of around 3 to 5 inches away from the end of the cable to remove its jacket part. Rotate it twice or thrice around the cable. A round cut mark is formed on the cable. Now push the jacket with your finger towards fibre end to remove it as shown in Fig. 5.10.

Fig. 5.10: Working of round cutter on the fibre

Fig. 5.11: Throwing waste jacket of the fibre in dustbin

Discard the jacket of the fibre in dustbin (shown in Fig. 5.11)

Now you will be left with the coating of the tube around the fibre as shown in Fig. 5.12.

Fig. 5.12: Coating of tube around the fibre

Take a stripping tool and place the fibre inside it to remove the tube shown in Fig. 5.13 and 5.14.

Fig. 5.13: Stripping tool removing the fibre tube

Fig. 5.14: Fibre after tube removal

Now take a tissue paper with little alcohol poured on it to clean the jelly above the bunch of fibre shown in Fig. 5.15.

Fig. 5.15: Removal of the jelly around bunch of fibres with tissue paper

Finally you are left with hair-like thin long fibres of different colours (in set of 12 bunches of multiples of 12 like 24, 36 fibres) shown in Fig. 5.16.

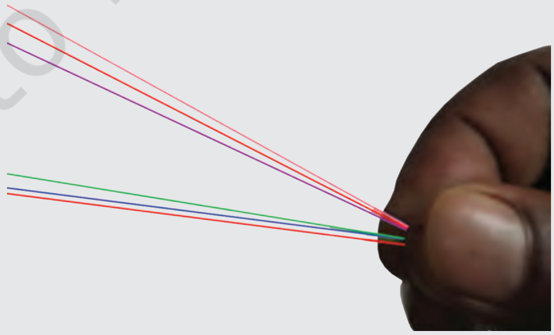


Fig. 5.16: Hair type fibre of different colours

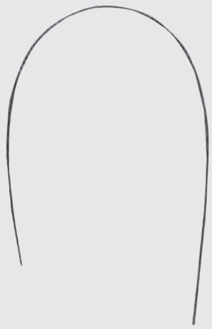


Fig. 5.17: Single fibre to be spliced

Take any one fibre of any colour, say, red. Now use for splicing this fibre (Fig. 5.17).

Step 4: Placing the protection sleeve over the fibre

Take a 60 mm protection sleeve and put the single hair-like red colour fibre inside it. Move it around 5 inches backward from the end of the fibre (shown in Fig. 5.18). As already studied in the previous unit, protection sleeve contains inner tube (hot-melt glue) and strength member. The hot-melt adhesive in the inner tube bonds to both the fibre and the heat shrinkable outer tube to encapsulate the fusion splice joint and provides vibration damping and an environmental seal, protecting the fibre from damage and contaminants. Strength member (stainless steel, ceramic or non-metallic) provides additional rigidity to prevent misalignment, micro bending or breakage of the fibre.

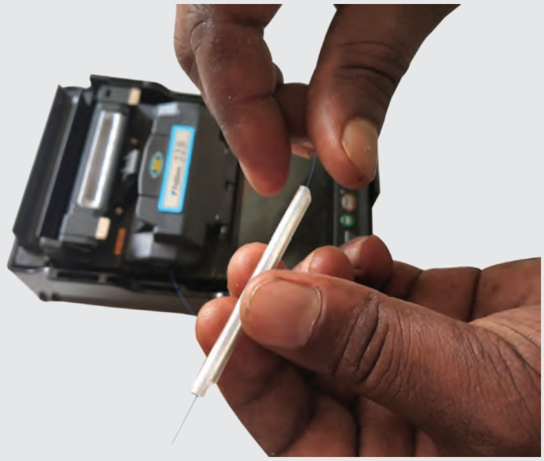


Fig. 5.18: Placing protection sleeve inside the fibre

Step 5: Stripping the fibre

Take the stripping tool and put this red single fibre inside its first slot. This will remove the buffer and now you are left with the tube/cladding inside the jacket as shown in Fig. 5.19.

Fig. 5.19: Removing buffer using stripper

Again take the stripper and put the cladding part inside the third slot of the stripper. This will reveal the core part with jelly above it.

Note: You will find a transparent sticky jelly below the core. Don't touch this jelly directly with hands. Take a clean dry tissue and use it to wipe off the jelly shown in Fig. 5.20.

Again, take a tissue and wet it with a few drops of alcohol and clean the core once again so that no dust is left above the core as shown in Fig. 5.21.

Fig. 5.20: Cleaning the jelly with dry tissue

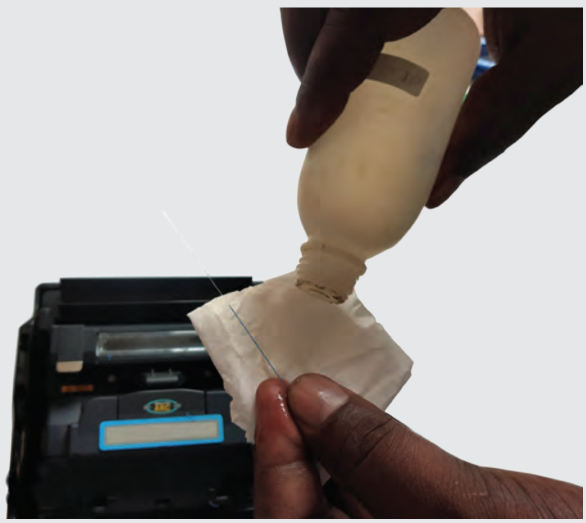


Fig. 5.21: Cleaning the jelly with tissue and alcohol

Fig. 5.22: Precise cleaver

Note

- It is necessary to clean the fibre so that the dust cannot enter inside the protection sleeve which can result in attenuation.
- Don't touch the bare fibre with hands. The glass on the fibre can cut the fingertip.

Step 6: Cleaving the fibre

Take the precise cleaver and place the cleaned thin hair-like core of the fibre inside it as shown in the Fig. 5.23(a). The round diamond blade cutter is suitable for cutting the fibre. Exactly 50 degree of cleaving is done in which core part of the fibre in the machine is kept horizontally and the machine blade cuts the fibre end vertically. This gives very accurate cut. It involves three steps—

(a) Place the fibre in the cleaver

(b) Adjust the blades

(c) Finally cleave it by pressing the cap above (Fig. 5.23(b))

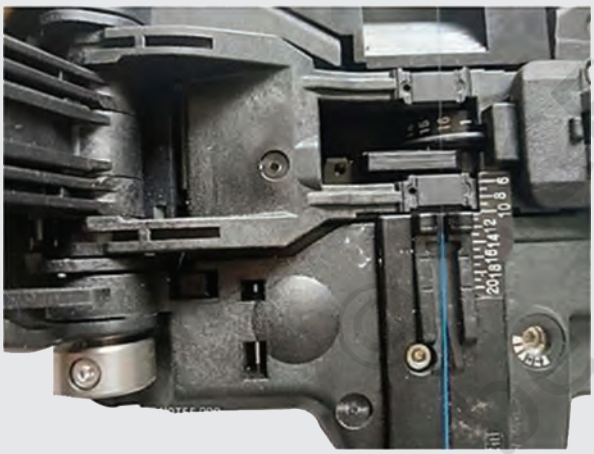


Fig. 5.23(a): Place the fibre in cleaver and adjust the blades

Fig. 5.23(b): Cleave it by pressing cap

Precautions to be taken

- Don't place your finger inside the cutter
- Wear hand gloves
- The cleaved or cut extra portion of the fibre has to be carefully put inside the dustbin. When optical fibres are cleaved, fibre scraps with extremely sharp ends are obtained. They may stick to a finger and can then be transported into the eyes. They can also easily penetrate the skin and are hard to pull out. Fibre scraps should also not be ingested. For such reasons, it is important to carefully dispose the optical fibre scraps into a properly marked container before they get lost.

Step 7

The other end of the fibre is also prepared using the same steps from 3 to 7 except step 5, i.e., don't put protection sleeve above the fibre. Only one protection sleeve is enough for one single fibre splicing process.

Step 8: Operation with splicing machine

Optical fibre splice machine is used for fusion splice. The machine has two steps of operation. Firstly, it aligns the cores of the two fibres to be joined and then the two electrodes inside it performs fusion of the fibre. The splicing machine is shock resistant, dust resistance and rain resistance. It is easy to handle. It performs total splicing operation in less than a minute. It produces high quality of spliced fibres with an attenuation loss less than 0.1db/km. Due to high precise work the cost of machine is high.

Components and parts of the machine

Fig. 5.24 shows the different components and parts of the machine with each part responsible for the complete splicing procedure. It is a small, lightweight machine with an LCD screen. This screen shows the splicing operation and internal view of the operations performed in machine. LCD screen shows process of alignment and the fusion operation going inside the machine. The keypads on the machine help in the initial settings.

Fig. 5.24: Components and parts of the splicing machine

Practical Activity: Steps of working with the fusion splicing machine

1. Switch on the splicer machine using the ON/OFF button. This machine can be operated with the help of the pluggable lithium battery or 230V AC power supply also. The word "Ready" is displayed on the LCD screen of the splicer machine indicating that machine is ready for operation. Whether the battery is charged or discharged is also indicated on the screen. Fig. 5.25 shows the LCD screen of the machine.

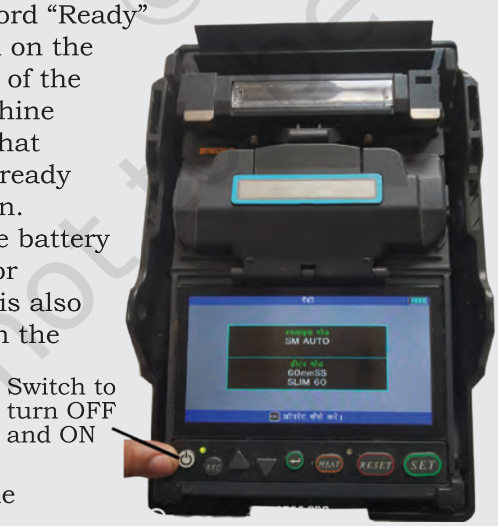


Fig. 5.25: LCD screen after machine is turned ON

Fig. 5.26: LCD Display

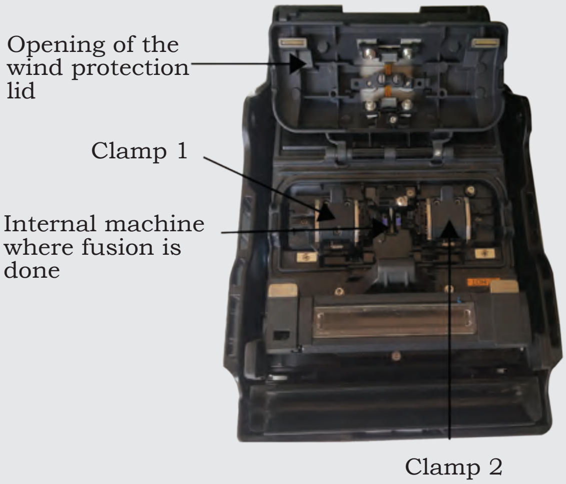


Fig. 5.27: Internal view of the machine

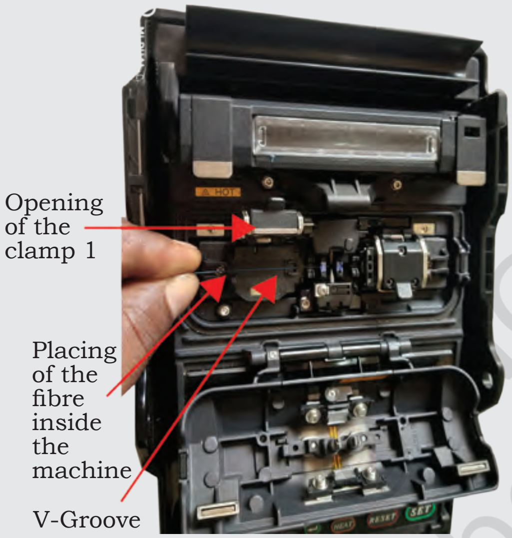


Fig. 5.28: Placing the fibre inside the machine

Fig. 5.30: Fixing the fibre inside the machine by closing the left clamp

Read the screen which shows the following modes of operation:

SM Auto: This tells that the machine is working with single mode fibre. 60 mm SS and SLIM 60 indicates the heating mode of protection sleeve of 60mm.

2. LCD Brightness adjustment: After the splicing machine is powered on with the “Ready” interface, press [ ] [] button for brightness increasing or decreasing indicator and press Key.

3. Open the wind protector and clamps and you will see the internal part of the machine where fusion is done (as shown in Fig. 5.27). After opening the wind protector there are two electrodes that are responsible for splicing as shown in the Fig. 5.27.

4. Place the first end of the prepared fibre of Step 6, inside the V-groove so that the tip of the fibre is located between V-groove edge and the tip of the electrode as shown in Fig. 5.28 and Fig. 5.29.

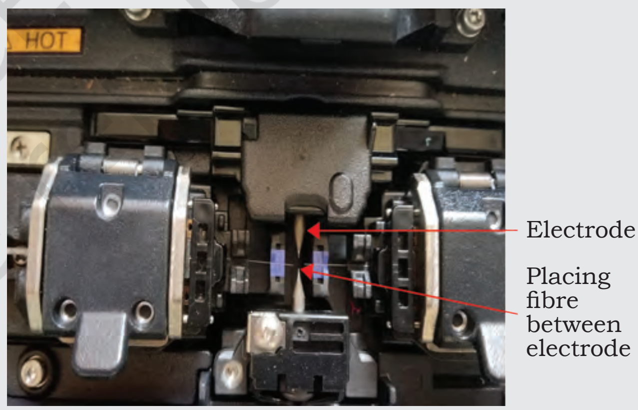
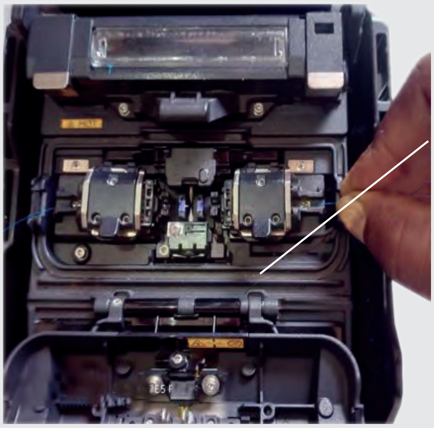


Fig. 5.29: Placing fibre between the electrodes

Note: While placing the fibre, the distance between the electrode and cable placed should be equal.

5. Hold fibres with fingers and close the sheath of left clamp (shown in the Fig. 5.30) so that it does not move. Make sure that the fibre is placed at the bottom of the V-groove. If the fibre is not placed properly then reload the fibre.

6. Prepare the second fibre to be joined then repeat the steps of placing the fibre inside the machine. Lift the right clamp and place the fibre end inside it and finally close the clamp as shown in the Fig. 5.31.



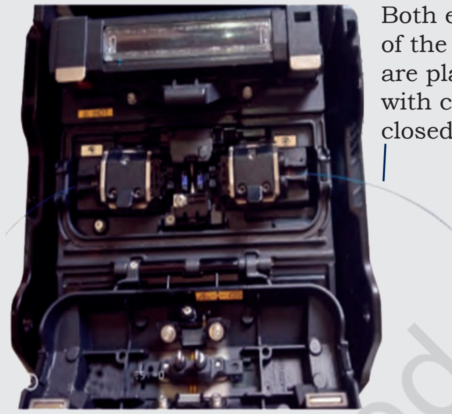


Fig. 5.31: Fixing the fibre inside the machine by closing right clamp

7. Finally Fig. 5.32 shows that both ends of the fibres are placed and both left and right clamps are closed.

8. After the two ends of the fibre are fixed inside clamps, close the wind protector as shown in the Fig. 5.33.

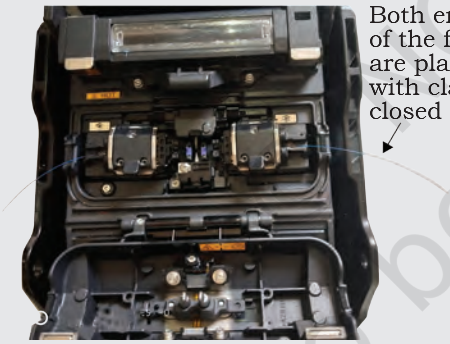


Fig. 5.32: Both ends of the fibre are placed and both left and right clamps are closed

Fig. 5.33: Closing the machine with fibre ends locked inside it

9. To assure good splicing (with minimum attenuation loss), operation taking place inside the wind protector can be seen on the LCD screen. Visual inspection with monitor is very important for good splicing.

10. After the fibre ends are locked inside the wind protector, press the **SET** button on the keypad. Core-to-core alignment is done. This can be visualised on the LCD screen shown in Fig. 5.34(a). If abnormal splice is detected as fat, thin, or with a bubble an error is displayed. If no error is displayed but the splice looks poor visually then repeat the whole step of

placing fibre inside the machine. Now press the **ARC** button after fibre is aligned properly to perform fusion shown in Fig. 5.34.

Fig. 5.34(a): Pressing the set button

Fig. 5.34(b): Core-to-core alignment of fibre

Fig. 5.34(c): Core aligned perfectly

Fig. 5.34(d): Fusion splicing of fibre

Note: After the fibre is spliced the amount of attenuation loss is calculated on the screen showing the level of accuracy of the splicing. If attenuation is 0.00 dB, it means splicing is perfect with no loss. Attenuation from 0.00 dB to 0.02 dB is acceptable. If attenuation value the about 0.002 dB the splicing operation needs to be repeated.

11. The result is saved in splicing memory.

Step 9: Protecting the fibre

12. Open the wind protector. After splicing, open the left sheath clamp and the right clamp together to remove the spliced fibre (shown in the Fig. 5.35).

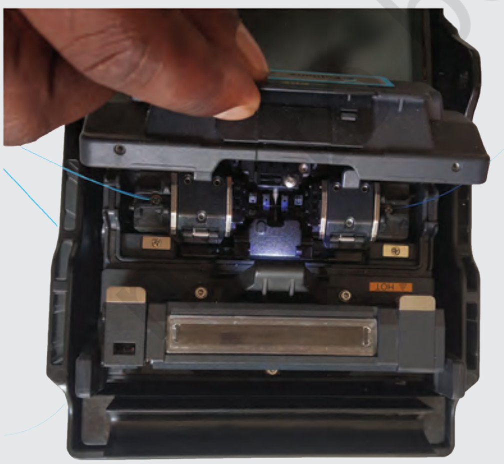


Fig. 5.35(a): Opening the lid of the machine

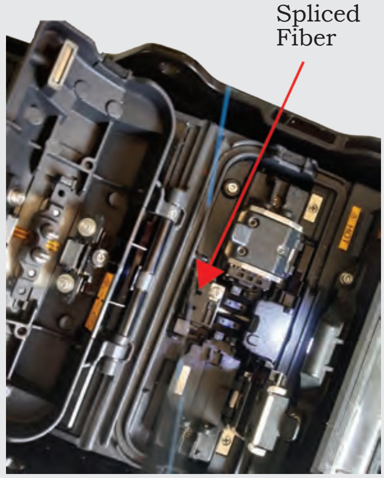


Fig. 5.35(b): Removing spliced fibre from the machine

13. Now slide the protection sleeve (of step 5) to the centre of the splice joint as shown in Fig. 5.36.

Heating the protection sleeve

14. Open the tube heater lid. Place the joined fibre with protection sleeve inside the tube heater as shown in Fig. 5.37.

15. Now transfer the fibre with protection sleeve from the splicer to the tube heater and close the lid of tube heater shown in the Fig. 5.38.

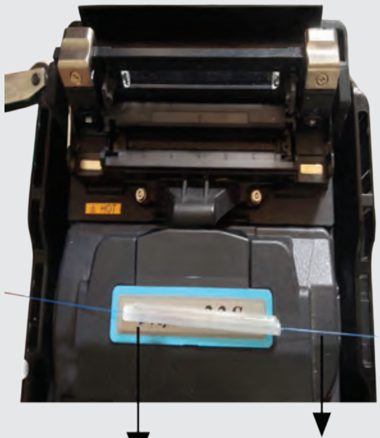


Fig. 5.36: Placing the protection sleeve above the spliced fibre

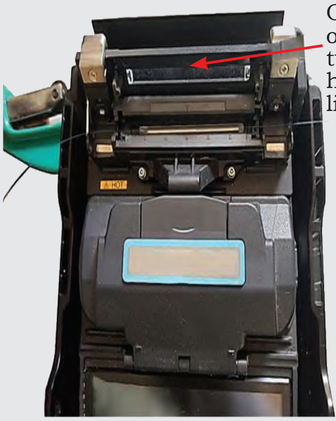


Fig. 5.37: Placing the spliced fibre with protection sleeve inside the tube heater

Fig. 5.38: Locking protection sleeve with spliced fibre inside the tube heater

Note: Make sure that the splice point is located in the centre of the protection sleeve.

16. The heat shrink activity starts by pressing the key [**HEAT**] while closing the tube heater. A buzzer beeps for 1–2 seconds indicating the completion of the process.

17. Open the lid of the tube heater and remove the protected sleeve from inside, as shown in the Fig. 5.40. Apply some tension to the fibre while removing it from the tube heater.

Fig. 5.39: Pressing heat button

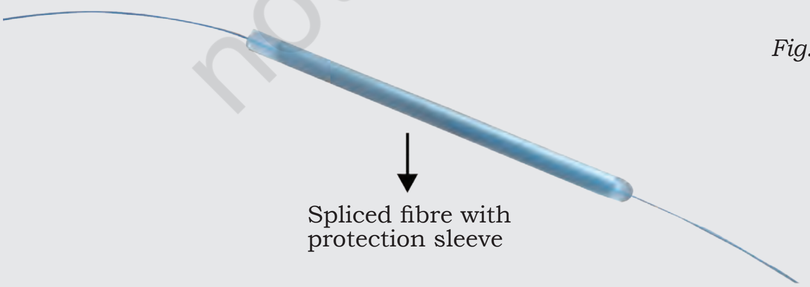


Fig. 5.40: Spliced fibre with protection sleeves

Note

- Visually inspect the shrinked finished sleeve to verify the quantity of bubbles or dust in the sleeve.
- Protection sleeve may stick to bottom plate of the heater. Use cotton swab to remove the residue.

In this way all the fibre to be joined are prepared by performing the splicing operation and organised together.

Step 10: Testing

Finally, the fibres are tested and its performance is measured using OTDR. The readings of OTDR confirm that of all fibre, attenuation is within specified limits. Testing determines that fibres were not subjected to excessive stress during the organising process.

Practical Activity 2: Perform mechanical splicing

Material required

- Optical fibre ends to be spliced
- Optical fibre mechanical splicer connector
- Fibre optic cleaver
- Tissue paper
- Alcohol
- Protection sleeves
- Round tube cutter
- Fibre cutter/stripper
- OTDR (Optical time domain reflectometer)

Fig. 5.41(a): Mechanical connector

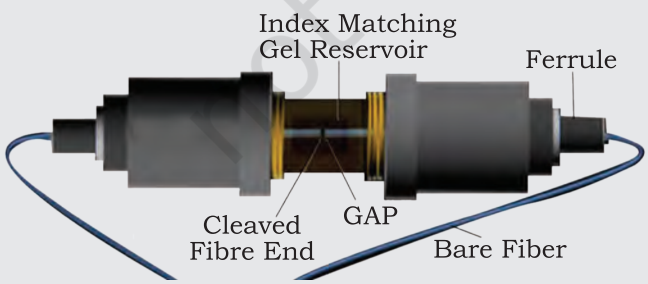


Fig. 5.41(b): Mechanical connector

Procedure to be followed

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

Note: Heat or electric arc is not used in fusion splicing. Instead in mechanical splicing the fibre is simply connected together by the following steps—

1. The fibre parts are placed in a ferrule.
2. A ferrule is a capillary glass tube under compression with the help of a spring.
3. Inside the ferrule the fibre is properly inserted into the sleeve as shown in Fig. 5.41.
4. This type of splicing is done in multimode fibres.
5. The index matching gel is placed inside the mechanical splice apparatus.
6. This gel helps to couple the light from one fibre end to the other.

Testing of splicing

Mechanisms of light loss at optical fibre joint

When joining optical fibres, the opposed cores must be properly aligned. Optical fibre connector/splice loss occurs mostly due to the following—

Poor concentricity

Poor concentricity of joined optical fibres causes a connector/splice loss. In case of general-purpose single-mode fibres, the value of connector/splice loss is calculated roughly as the square of the amount of misalignment multiplied by 0.2. For example, if the light source wavelength is 1310 nm, misalignment by 1 μm results in approximately 0.2 dB of loss.

Fig. 5.42: Splice loss due to poor connectivity

Axial run-out

A connector/splice loss occurs due to an axial run-out between the light axes of optical fibres to be joined. For example, it is necessary to avoid an increased angle at fibre cut end when using an optical fibre cleaver before fusion splicing, since such an angle can result in splicing of optical fibres with run-out.

Fig. 5.43: Splice loss due to axial run-out

Gap

An end gap between optical fibres causes a connector/splice loss. For example, if optical fibre end faces are not correctly butt-joined in mechanical splicing then it results in a splice loss.

Fig. 5.44: Splice loss due to gap

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Reflection

An end gap between optical fibres results in 0.6 dB of return loss at the maximum due to the change in refractive index from the optical fibre to the air. Cleaning optical fibre ends is important for optical connectors. In addition, the optical connector ends should be cleaned because loss can also occur due to presence of dirt between.

Factors that are considered to have good splicing

1. Fibre ends must be cut perpendicular to the length of the fibre. Some cleaving devices are there which produce quite clean and ready-to-use fibre cuts.
2. Just after the end preparation, splicing must be done to avoid dust accumulation on the cleaved ends which will cause loss of a part of light energy at the splicing point.
3. Jackets of the fibre are to be cut lengthwise without scoring the fibre, to get the bare fibre.
4. If jackets are cut longitudinally, it will allow them to be pulled back and forth, to expose the buffered fibre.
5. A chemical or a special stripping must be used to remove the buffer. If a chemical is used for the removal of buffer, it should be removed quickly otherwise it may damage the fibre.
6. Follow the splicing instructions provided by the manufacturer of the splicing equipment and fibre.
7. Splicing is visually inspected. During the process of splicing, optical fibres can cause white or black lines in the spliced region which is not considered as faults.
8. Method of fusion splicing provides a high-quality of permanent joint with very less loss of light (in the range of 0.00 dB to 0.02 dB for single-mode fibres).

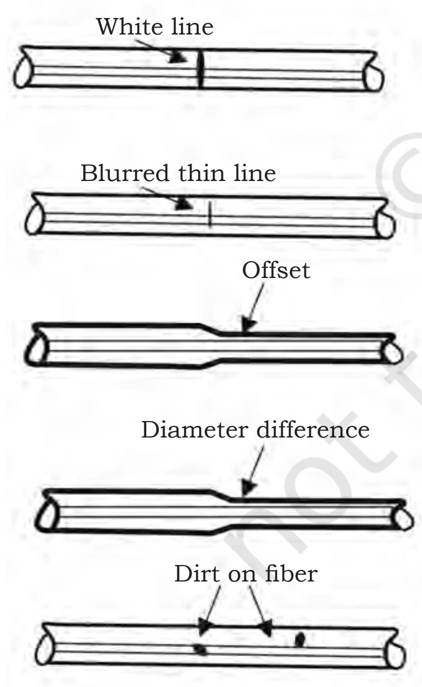


Fig. 5.45: Good splicing

Factors that are considered for bad splicing

During the splicing process, some errors might occur which are not acceptable. This requires the splicing process to be repeated. Sometimes black spots or lines are created in the fibre and can be improved by repeating the whole process of splicing. For large core offsets, bubbles, or bulging-splice, method of splicing is repeated again (Fig. 5.46).

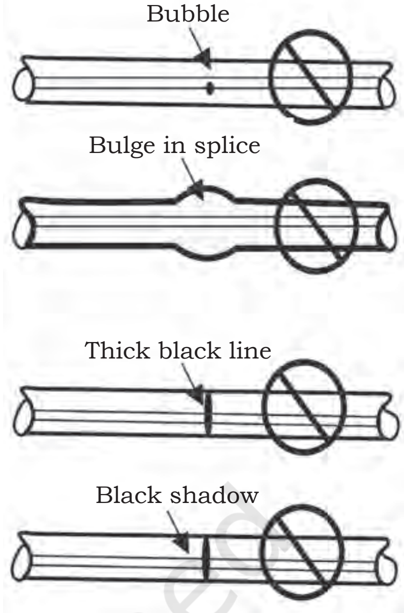
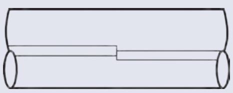
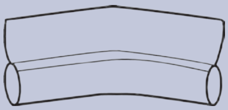
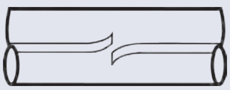
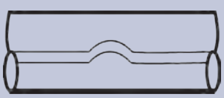
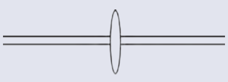


Fig. 5.46: Bad splicing

Troubleshooting Splicing Errors

Here are some common problems and likely causes.

Symptom	Cause	Remedy
Core axial offset 	• Dust on the V-groove or fibre clamp chip.	• Clean V-groove and fibre clamp chip.
Core angle 	• Dust on the V-groove or fibre clamp chip. • Bad fibre end-face-quality.	• Clean V-groove and fibre clamp chip. • Check if fibre cleaving is done properly.
Core step 	• Dust on the V-groove or fibre clamp chip.	• Clean V-groove and fibre clamp chip.
Core curve 	• Bad fibre-end face quality. • Pre-fuse power is too low or pre-fuse time is too-short.	• Check if fibre cleaving is done properly. • Increase pre-fuse power and pre-fuse time.
Bubbles 	• Bad fibre-end face quality. • Pre-fuse power is too low or pre-fuse time is too-short.	• Check if fibre cleaving is done properly. • Increase pre-fuse power and pre-fuse time.
Combustion 	• Bad fibre-end face quality. • Presence of the dust is still there after cleaning fibre or cleaning arc.	• Check if fibre cleaving is done properly. • Cleaning the fibre ends thoroughly or increasing the cleaning arc time.

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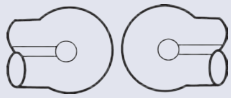
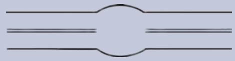
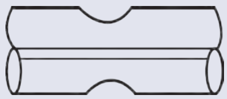
Separation 	• If electrodes are contaminated. • Electrodes and the fusion current are very high.	• Increase pre-fuse power and pre-fuse time.
Fat 	• Auto feed too fast, Incorrect current.	• Increase pre-fuse power and pre-fuse time.
Thin 	• This type of problem is present when current is high and feed rate is very low. Contaminated electrodes, prefusion time span is also too long, prefusion current is too high, gap is too wide.	• Increase pre-fuse power and pre-fuse time.
Line 	• Fusion current is very less- prefusion time is very short.	• Increase pre-fuse power and pre-fuse time.

Check Your Progress

A. Multiple Choice Questions

1. A permanent joint formed between two different optical fibres is known as _______________.
   (a) fibre splicing
   (b) fibre connector
   (c) fibre attenuator
   (d) fibre dispersion
2. Method of fusion splicing is done by _______________.
   (a) electric arc
   (b) heating
   (c) fusion
   (d) All of the above
3. Cleaving means _______________.
   (a) cutting the fibre edges
   (b) polishing the fibre ends
   (c) cleaning the fibre
   (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 ___________ splice.
   (a) V-Groove
   (b) elastic tube
   (c) rotary
   (d) Both a and b
6. Fibre joined using the mechanical splicing are ____________.
   (a) temporary joints
   (b) permanent joints
   (c) loosely joined
   (d) partially joined
7. While 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. Core diameter mismatch loss occurs when _______________.
   (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 lower end of the acceptable size range.
9. Cladding diameter mismatch loss happen when _____________.
   (a) the cladding diameter of the transmitting fibre is larger than the cladding of the receiving fibre.
   (b) the cladding diameter of the transmitting fibre is smaller than the cladding of the receiving fibre.
   (c) the cladding diameters of the fibres do not match.
   (d) the cladding diameters of both fibres are slightly larger than normal.

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10. If the transmitting and receiving cores are offset from their cladding in different directions, the result may be ____________.
    (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. Fibre end must be cut ___________to the end of the fibres.
4. The fusion one provides a lower level of ___________and a higher degree of ___________than mechanical splicing.
5. Full form of OTDR is ___________.
6. Fibre cleaning is done by ___________method.

C. Answer in Brief

1. What is splicing?
2. What is cleaving?
3. How to clean fibre during splicing?
4. Name the tool used for cleaving.
5. Why is diamond 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 the steps involved in splicing.
10. How to repair a broken fibre?
11. What is mechanical splicing?
12. Which solution is used for cleaning fibre?
13. Differentiate between splicing a fibre and joining two copper wires.
14. Which is the best method employed for splicing?
15. List out the applications of splicing.
16. How to test the splicing procedure?
17. What should be done for improper or bad splicing?
18. What are the characteristics of good splicing?

Chapter 6

Optical Fibre Testing

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Optical test equipment are devices used to check light propagation, losses, and splice through the fibre. If there is a fault in the device they locate the fault and help in rectifying them. Once the fault position is located it is rectified.

An ideal test equipment should have the following features—

- Test equipment should be very compact.
- It should be lightweight and portable.
- The results provided by the equipment should be very accurate.
- The equipment should be able to sustain extreme environmental conditions like temperature, humidity, etc.
- The equipment should be connected to the fibre in a very simple way.

Testing is utilised to assess the execution of fibre optic components, cable plants and frameworks. As the components like fibre, connectors, splices, LED or laser sources, locators and receivers are being produced, testing affirms their execution determinations and sees how they will cooperate. Creators of fibre optic cable plants and systems rely upon these particulars to decide whether systems will work for the arranged applications.

Testing fibre optics requires special tools and instruments which must be proper for the components or cable plants being tested.

Standard test procedures

Most test procedures for fibre optic component specifications have been standardised by national and international standard bodies. Several organisations have become involved in standardisation issues relating to optical fibre measurements. The International Telecommunication Union (ITU) recommended several standards for fibre transmission systems and fibre measurements. These are known as Fibre Optical Test Procedures (FOTPs) and optical fibre system test procedures (OFSTPs). These standards are published by the Electronics Industries Alliance (EIA) and telecommunication industries. In order to perform these tests, the basic fibre optic instruments are the power meter and OTDR. Hence, there are generally two types of test equipment generally used.

1. Power meter
2. Optical time domain reflectometer (OTDR)

These and some other specialised instruments are described below.

Optical time domain reflectometer

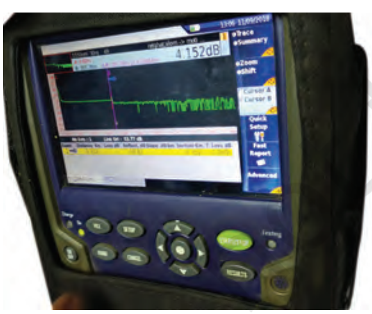

Fig. 6.1: Optical Time Domain Reflectometer

Optical Time Domain Reflectometer (OTDRs) as shown in Fig. 6.1 are useful tools for locating fibre faults. OTDR is typically used for long range (upto several kilometres) measurements. The OTDR is a device that launches a pulse of light into one end of an optical fibre and records the amount of light energy that is reflected back. The high resolution OTDR allows the fibre optic technician to see what is happening in the fibre optic link or cable undergoing the test. With the OTDR, the fibre optic link or cable is no longer a black box. The fibre optic technician can see how light passes through every segment of the fibre optic link. Light reflecting back in an optical fibre is the result of reflection or backscatter. Light is scattered along the length of the optical fibre. The light that travels back toward the OTDR, is considered as backscatter. The OTDR is typically a battery-powered device, which is quite useful when no electrical power is not available. Always keep the spare battery charged, while performing test. Light being reflected back from the fibre is actually of two types. The first type is a constant low-level reflection that is created by the fibre. This is called "Rayleigh backscattering". Rayleigh backscattering originates from the natural reflection and absorption of contaminations inside optical fibre. Whenever hit, a few particles of glass divert the light in various ways, creating both signal attenuation and backscattering.

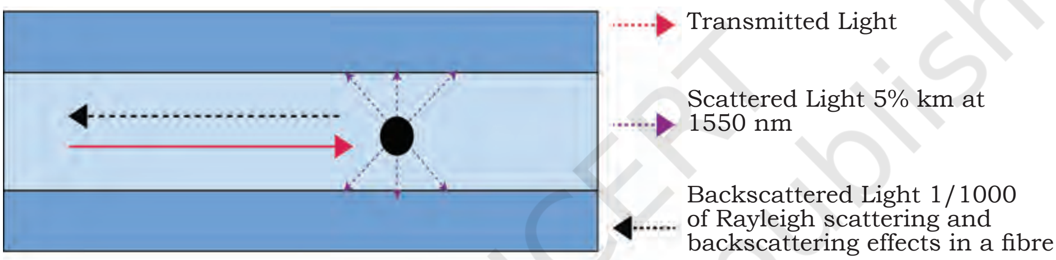

Fig. 6.2: Rayleigh scattering and backscattering in optical fibre

The second type of reflection is called "Fresnel reflection". At the point when the light hits a sudden change in refractive index, for instance, from glass to air at a fibre connector interface, a higher measure of light is reflected back, which can be thousands of times greater than the Rayleigh backscattering. Fresnel reflection can be viewed as spikes in an OTDR trace as shown in the Fig. 6.3. Examples of such reflections are those created due to connectors, mechanical splices, bulkheads, fibre breaks or opened connectors.

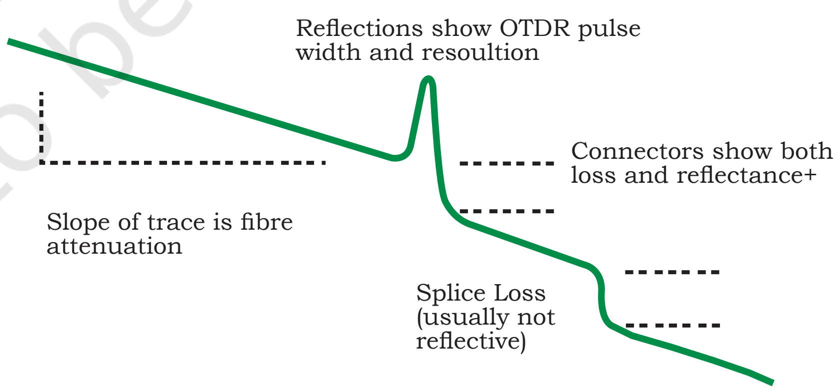

Fig. 6.3: Trace of signal in OTDR

Notes

OTDR measures optical distance between—

- elements (splices, connectors, splitters, multiplexers)
- faults
- end of Fibre

OTDR also measures—

- loss of splices and connectors
- ORL (optical return loss) of link or section
- reflectance of connectors
- total Fibre attenuation

The use of OTDR is usually defined by a two-step process—

1. Acquisition: OTDR takes the input data and displays the results either numerically or graphically.
2. Measurement: Technicians analyse the data and based on the result print, or store the data or work with the next fibre acquisition.

Acquisition

OTDRs automatically select the acquisition parameters for a particular fibre by sending out test pulses in a process known as auto-configuration. Using the auto-configuration feature, technicians select the wavelengths to test the acquisition (or averaging) time and the fibre parameters (for example refractive index). Two major approaches used when configuring an OTDR are—

1. technicians simply allow the OTDR to auto-configure and accept the acquisition parameters the OTDR selects.
2. more experienced technicians allow the OTDR to auto-configure then analyse the results briefly and change one or more acquisition parameters to optimise the configuration for the particular test requirements.

Measurement

Most modern OTDRs perform fully automatic measurements with very little input from technicians. In general, there are two types of events which occur—reflective and non-reflective.

Reflective Events: These events occur where there is discontinuity in the fibre causing an abrupt change in the refractive index. It can occur at breaks, connector junctions, mechanical splices, or the indeterminate end of the fibre. For reflective events, mechanical splices undergo loss which typically ranges from 0.1 to 0.2 dB (Fig. 6.4).

If two reflective events occur very close together, the OTDR may have problems measuring the loss of each event. In this case, it displays the loss of the combined events, which typically occurs when measuring a short fibre length (Fig. 6.5).

Non-reflective Events: These events occur where discontinuities are absent in the fibre and are generally produced by fusion splices or bending losses, such as macro bends. Typical loss values range from 0.02 to 0.1 dB, depending on the splicing equipment and operator (Fig. 6.6).

Elements of OTDR

The basic elements of an OTDR are shown in Fig. 6.7.

- The light source (LASER) which produces focussed beam of light is used to generate light pulse.

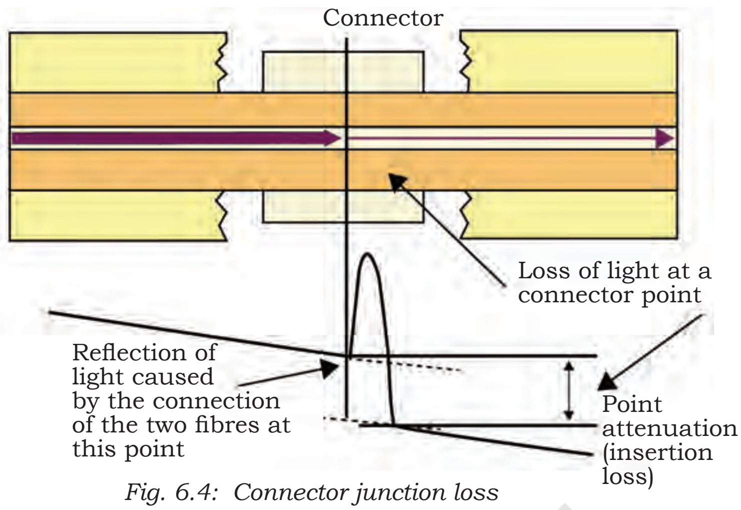

Fig. 6.4: Connector junction loss

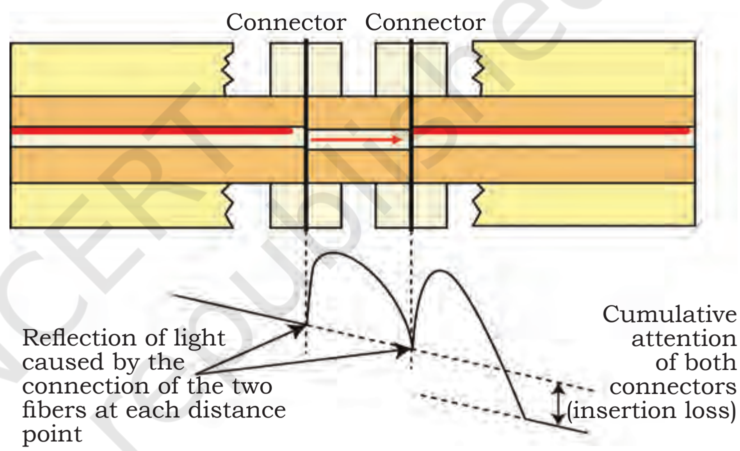

Fig. 6.5: Reflective index when junctions are located close to each other

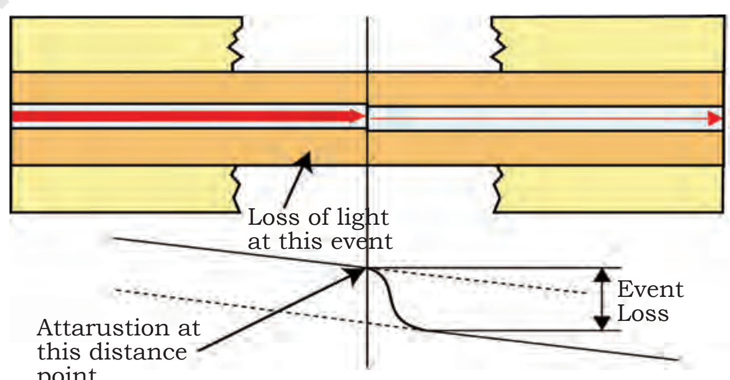

Fig. 6.6: Non-reflective events

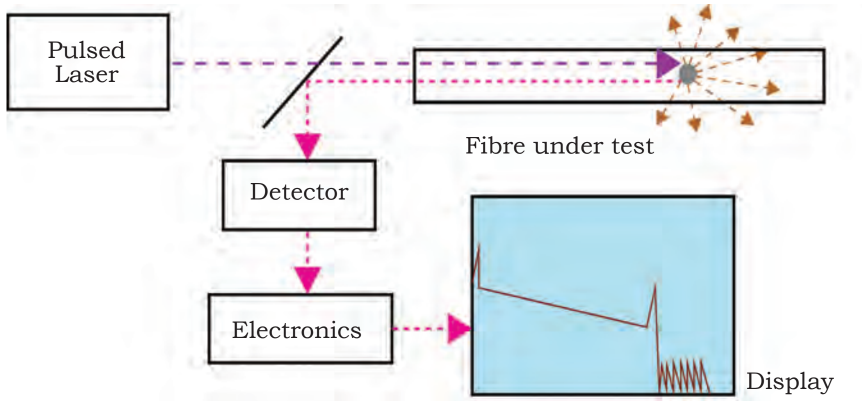

Fig. 6.7: Elements of OTDR

- This light pulse is coupled into the optical fibre which is used for the testing.
- At the point when the light is reflected from the fibre, it is passed through the detector. This detector changes the light signal into electrical signal, which is then enhanced and recorded in the display of OTDR.

In the market three types of OTDRs are generally available. For example, laboratory OTDRs are generally used in test labs. They have an extremely wide range with many options.

Mini OTDRs: These OTDRs are portable and designed for field testing. They have built-in screens to see the data. They also provide data storage as traces which are collected in the field.

PC-based OTDRs: As the name suggests, OTDRs can be connected to personal computers. These computers can work with Windows operating systems. They allow saving traces produced by the fibre on a disk on the computer, and then transfer saved data between computers.

OTDR test set-up: OTDRs are generally used for testing the signal with a launch cable and hence use a receiver cable. It allows the launch cable to settle down after the test pulse is sent into the fibre to determine its loss. It provides a reference connector for the first connector on the cable under test. On the far end, a receiver cable may be used to allow measurements of the connector on the end of the cable under test.

Practical Activity : To study trace of OTDR

Material required

- OTDR

Steps to follow

The OTDR displays time or distance on the horizontal axis and amplitude on the vertical axis, as shown in Fig. 6.8.

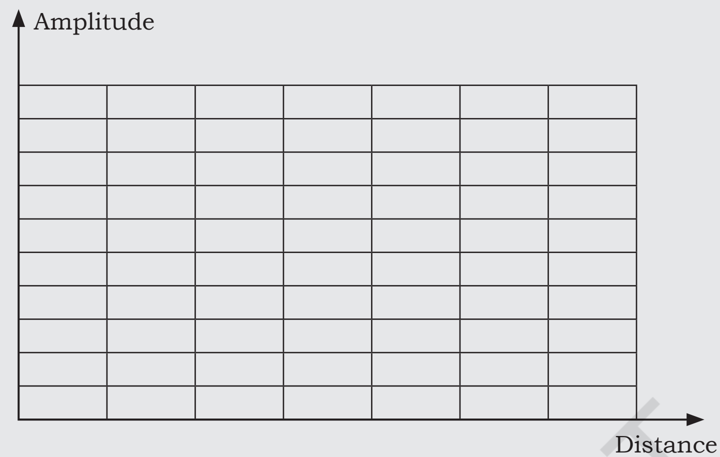

Fig. 6.8: OTDR displays

Step 1: The horizontal axis can typically be programmed to display distance in feet, meters, or kilometres.

The vertical axis is not programmable. The vertical axis displays relative power in dB.

Step 2: OTDR creates a trace like the one shown in Fig. 6.9. The trace shows event loss, event reflectance, and optical fibre attenuation rate. The OTDR can horizontally and vertically zoom in on any section of the trace. This permits a more detailed inspection of the optical fibre or event.

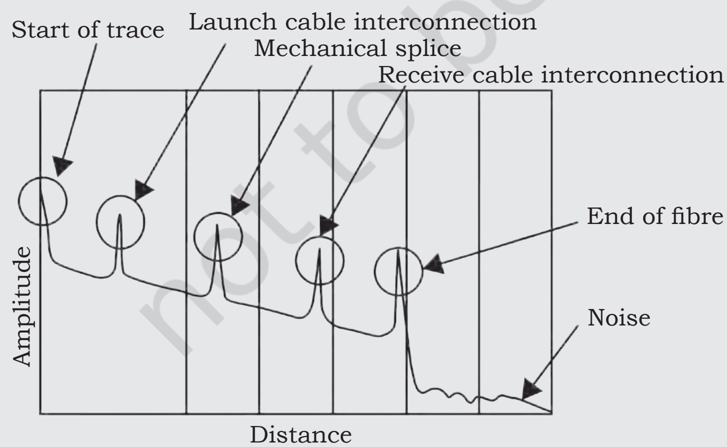

Fig. 6.9: Study of the trace of OTDR

Step 3: The slope of the fibre trace shows the attenuation coefficient of the fibre and is calibrated in dB/km.

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Step 4: Select the type of mode (single mode or multimode) and wavelength in nanometer (nm) in which you want to test the performance (eg., 1310 nm or 1550 nm) using the tab buttons.

Step 5: You can also select length of the system and power of the signal to be measured on the system. You can also select acquisition time.

Step 6: Clean your connector before connecting to the fibre cable of the test box.

Step 7: Click on the start button of OTDR.

Step 8: It shows the performance of the fibre upto 300 meters.

Step 9: The first spike shows that neither reflection nor attenuation is due to the first connector and is regarded as dead zone.

Step 10: The rest of the spike shows the reflections through connector. If one fibre is connected to another fibre by splicing then OTDR shows a spike value in dB.

OTDR specification

OTDR (Optical Time Domain Reflectometer) is a fibre test instrument for technicians or installers to characterise an optical fibre. The OTDR needs to be setup correctly prior to testing, to provide accurate readings. When setting up the OTDR, you need to select the correct fibre type, wavelength, dynamic-range and pulse width. This process takes only a couple of minutes and ensures the most accurate results possible. It is important to understand the specifications which may affect the performance of the OTDR which can help users get maximum performance from their OTDRs.

Fibre type

Each light source or light source module in an OTDR is designed for one or several specific optical fibre types. A multimode module should not be used to test a single-mode optical fibre, and vice versa. Before heading for the test site, ensure that your OTDR has the correct module for the optical fibre to be tested.

Wavelength

The wavelength that your OTDR can test depends on the light source module or modules in your OTDR. Some light source modules contain a single laser while others contain two different wavelength lasers. A light source with two lasers allows testing of the optical fibre at two wave-lengths without disconnecting the cable under test. This simplifies testing and reduces testing time.

Dynamic range

The dynamic range is an important characteristic since it determines how far the OTDR can measure. It is specified by OTDR vendors is achieved at the longest pulse width and is expressed in decibels (dB). The distance range or display range sometimes specified is usually misleading as this represents the maximum distance the OTDR can display, not what it can measure.

Dead zone

The OTDR dead zone refers to the distance (or time) where the OTDR cannot detect or precisely localise any event on the fibre link.

When a strong reflection occurs, the power received by the photo diode can be more than 4,000 times higher than the backscattered power. This causes detector inside the OTDR to become saturated with reflected light. Thus, it needs time to recover from its saturated condition. During the recovering time, it cannot detect the backscattered signal accurately which results in corresponding dead zone on OTDR trace. This is like when your eyes need to recover from looking at the bright sun or the flash of a camera. In general, higher the reflectance, longer the dead zone is. Additionally, dead zone is also influenced by the pulse width.

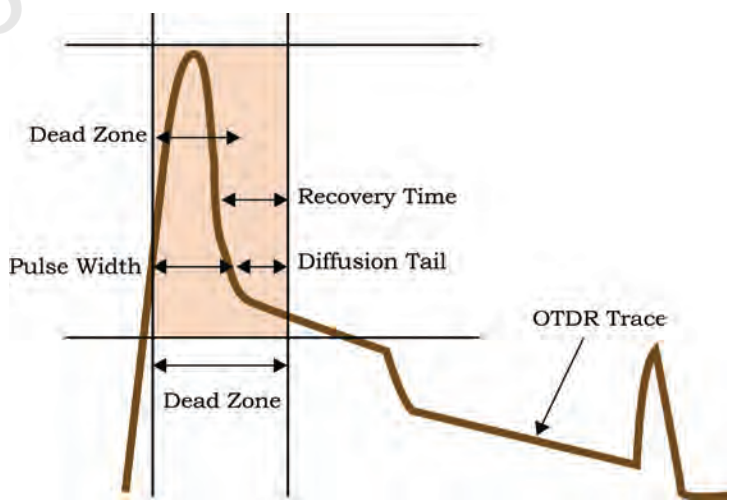

Fig. 6.10: Dead zone and pulse width

Pulse width

Pulse width determines the size of the dead zone and the maximum length optical fibre that can be tested. A short pulse width produces a small dead zone. However, a short pulse width reduces the length of optical fibre that can be tested. The pulse width should be selected so that the trace never disappears into the noise floor.

If the pulse width is set properly, the trace will stay smooth until the end of the fibre optic link. If the pulse is set too wide, events may be lost in the dead zone.

Fig. 6.11: Power meter

Fibre optic power meters

Power in a fibre optic system is like voltage in an electrical circuit. The term usually refers to a device for testing power of optical signal in fibre optic systems. Measuring power requires only a power meter as shown in Fig. 6.11. It's important to have enough power, but not too much. Level of power should not be very less otherwise the receiver may not be able to distinguish the signal from the noise. Also, too much power overloads the receiver. Power meters are calibrated in dBm and the proper wavelengths matching the source should be used. The measured optical power and set wavelength is displayed on the display unit.

When combined with a light source, the instrument is usually called an Optical Loss Test Set (OLTS). A number of portable, battery operated power meter are commercially available. Some of these instruments are of small dimension and therefore designed to be handheld, while other which provide greater accuracy and stability are larger in size. Such devices usually measure power in dBm.

Fig. 6.12: Light source

Light source

A light source is a device that provides source of energy for attenuation measurements. It includes a source, either an LED or a laser. LEDs are typically used for multimode fibre. On the other hand, lasers are used for single mode fibre applications.

Insertion loss tests

In order to know how effectively your fibre optic cables are transmitting, you'll need to test each one for optical loss. The term 'optical loss' also called insertion loss, describes the difference between the amount of light sent into the transmitting end of a fibre optic cable, and the amount of light that successfully makes it to the cable's receiving end. Hence, in order to certify optical fibre cable you must measure optical loss using an optical power meter and proper optical light.

Practical Activity: To test insertion loss in optical fibre

Material required: Power meter device, test cable, light meter

Steps to be followed

Step 1: Connect the optical light source to the transmitting end of the test cable as shown in Fig. 6.13.

Step 2: Connect the power meter to the receiving end of the test cable.

Step 3: Turn on the light source and select the wavelength you want for the loss test.

Step 4: Turn on the meter, select the "dBm" or "dB" range and select the wavelength you want for the loss test.

Step 5: Measure the power loss at the meter. Record the optical power displayed on the optical power meter. This number is the reference power measurement in dBm. This number is typically around (–)20 dBm with a 62.5/125 µm multimode optical fibre and (–)23 dBm with a 50/125 µm multimode optical fibre.

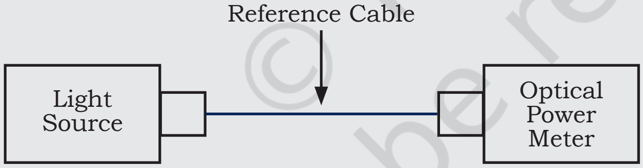

Fig. 6.13: Connection with power meter

Note: A typical OPM measures accurately under most conditions from about 0 dBm (1 milliwatt) to about –50 dBm (10 nano-watt), although the display range may be larger. Above 0 dBm is considered 'high power', and specially adapted units may measure up to nearly +30 dBm (1 watt). Below –50 dBm is 'low power', and specially adapted units may measure as low as -110 dBm.
To calculate dBm from power meter output:
The linear to dBm calculation method is:
dBm = 10 log (P1/P2)
where P1 = measured power level (e.g., in milliwatt)
P2 = reference power level, which is 1 milliwatt
Remember: Typically, OPM can be operated in the wavelength of 850 nm, 1300 nm, 1490 nm, and 1550 nm. Power meter is

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calibrated from the range of 850 nm to 1650 nm. The way you operate calculator in the same way using keys or tabs set the required wavelength.

Terms to Understand

Patch Cord

An optical fibre patch cord is a two-fibre cable. It uses the same connector type and optical fibre type as the optical fibre cabling that it is connected to. The optical fibre patch cord is used at cross-connects to connect optical fibre links**.** They are also used to connect telecommunications equipment. The patch cord must meet the cable transmission performance requirements and physical cable specifications Position A goes to position B on each optical fibre. The connector that plugs into the receiver is position A and the connector that plugs into the transmitter is position B.

Fig. 6.14: Optical fibre patch cord terminal configuration

Test Jumper

The terms 'patch cord' and 'jumper' are often interchanged. A patch cord is a two-fibre cable. However, the term 'patch cord' is often used to describe a single-fibre cable. IEEE standard 802.3 defines a jumper used for bidirectional transmission and reception of information. A test jumper can be a single-fibre cable or a multi-fibre cable. In the fibre optic industry, the test jumper has several names. The test jumper connected to the light source is typically called the transmit jumper. The test jumper connected to the optical power meter is typically called the receiver jumper. Test jumpers must have a core diameter and numerical aperture nominally equal to the optical fibre being tested. A jumper shall be no less than one meter in length and no greater than 5 meters in length. Test jumpers should be cleaned and inspected prior to making measurements. The end face of each connector should be evaluated under a microscope. This means that there can be no scratches, notches, or chips in the end face of the optical fibre.

Check Your Progress

A. Multiple Choice Questions

1. Test equipment means devices meant for _____________.
   (a) testing a device
   (b) measuring a device
   (c) testing fibre
   (d) measuring fibre

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) power meter
   (b) OTDR
   (c) test fibre box
   (d) optical Coupler
4. There are three types of OTDR generally used. They are _____________.
   (a) mini OTDRs
   (b) PC-based OTDRs
   (c) OTDR test set up
   (d) None of the above
5. An OTDR screen has X axis and Y axis. Which one of the following is true?
   (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. OPM can be operated in the wavelength of _____________.
   (a) 850 nm
   (b) 1300 nm
   (c) 1490 nm
   (d) 1550 nm
7. The slope of the fibre trace shows _____________.
   (a) the attenuation coefficient of the fibre and is calibrated in db/km.
   (b) the attenuation of the fibre and is calibrated in db/km.
   (c) the attenuation coefficient of the fibre and is calibrated in db.
   (d) the reflection coefficient of the fibre and is calibrated in db/km.
8. LASER produces _____________.
   (a) focussed beam of light
   (b) unfocussed beam of light
   (c) focussed beam of rays

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9. Fresnel reflections cause a vital OTDR specification referred to as ____________.
   (a) dead zones
   (b) live zone
   (c) test zone
   (d) None of the above

B. State whether 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. 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 fibre trace shows the attenuation coefficient of the fibre and is calibrated in dB.
6. OCWR stands for Optical Continuous Wave Reflectometer.
7. Rayleigh backscattering originates from the natural reflection and absorption of contaminations inside optical fibre.
8. Rayleigh backscattering causes a vital OTDRs specification referred to as dead zones.
9. OTDR equipment is not able to sustain extreme environmental conditions like temperature, humidity, etc.
10. A typical optical power meter consists of a measuring amplifier, calibrated sensor, and display.

C. Answer in Brief

1. What do you mean by test equipment?
2. What is OTDR?
3. What is power meter?
4. What do you mean by dead zone?
5. What does 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 measure?
10. How faults in cable are detected?
11. What is backscattering?
12. Which solution is used to clean the connector?
13. Name the types of OTDR available in the market?

Chapter 7

Occupational Health and Safety

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Whether you work as a technician or an installer, your work with optical fibre can expose you to several workplace hazards. This includes the hazards ranging from laser light sources to ladders. Optical fibre technicians are responsible for their own safety as well as for the safety of their co-workers. Safety manual is prepared keeping in consideration the health of workers, their job holding efficiency, environment, etc., so that their job can be completed accurately and on time. Knowledge to incorporate safe work practices is necessary. This chapter describes the types of hazards that you will encounter while working with optical fibre. Some of the hazards are unique to optical fibre work, but others are more common. This chapter also discusses the dangers that these hazards create, and inform you of the different methods of working safely around them.

Basic Safety

Whenever you work in a hazardous environment, such as a construction site, a lab, or a production facility, you must always be aware of the potential dangers you face. Two guidelines to follow while working are: personal protective equipment (PPE), and good work habits.

Personal Protective Equipment (PPE)

Personal protective equipment consists of anything that you would wear to protect yourself from hazardous material or situations. They can include protective gloves, clothes and eyewear for cutting and grinding operations, respirators for working with chemicals that take out harmful vapours, and specialised goggles for working with lasers.

Fig. 7.1: Worker with safety equipment

The PPE protects you not only from short-term accidents, such as cuts or flying shards of glass, but also from damage that can accumulate over time. Such damage may include dust from construction operations, such as drywall sanding that can build up over time in your lungs and cause diseases such as silicosis, or exposure to chemicals such as solvents that can have harmful long-term or chronic effects as well as harmful short-term effects. While using the PPE, inspect it carefully to ensure that it is in good condition. Look for cuts, tears, or other signs of damage in protective outerwear such as gloves or aprons.

Workers must wear safety equipment, e.g., safety helmets, glasses, ear and eye protection, protective clothing, high visibility vests, etc., as shown in Fig. 7.1 in designated areas, while working on specific jobs, and as per the directions of the supervisor for a specific purpose. Safety footwear must be worn at the work area. Any persons found not following the rules are asked to leave the site. Before performing any task proper training is provided to the workers. They should not handle any equipment without having complete knowledge of all tools and accessories and proper safety instructions are provided to the workers to complete the task. To work with machinery equipment proper qualification and training is needed.

Safety helmets

Safety helmets as shown in Fig. 7.2 must be worn by all workers at all times in all designated areas. It protects the worker from being hit by any falling material or other objects. Helmets should be replaced after three years from the date of issue if it has been used regularly. The date of issue must be recorded. The date of issue isn't the same as the date of manufacturing.

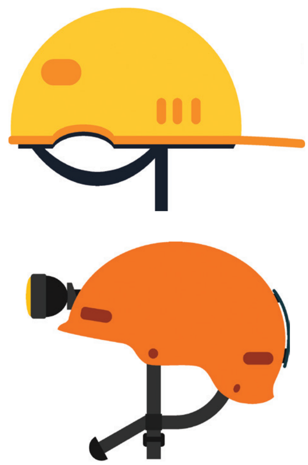

Fig. 7.2: Safety helmet

Eye and face protection

Never look directly at the fibre light, since it will damage the retina of the eyes. LASER light is a focussed beam and will penetrate inside the eyes causing blindness as shown in Fig. 7.3. Hence, it is important to wear goggles/ safety glasses for protecting eyes as shown in Fig. 7.3.

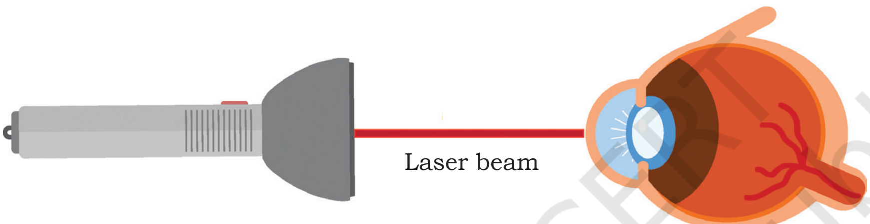

Fig.7.3: Protection of eyes against LASER light

As part of the termination and splicing process, you will be continually exposed to small scraps of bare fibre, cleaved off the ends of the fibres being terminated or spliced. These scraps are very dangerous. If they get into your eyes, they are very hard to flush out and will probably lead to a trip to the emergency room at the hospital. Whenever you are working with fibre, it is necessary to wear safety glasses.

Fig. 7.4: Safety glasses or goggles

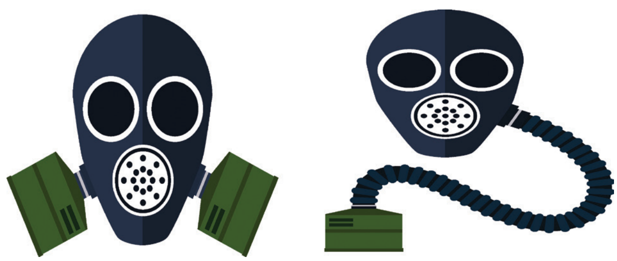

Fig. 7.5: Respiratory or dust masks

Respiratory protection

Respiratory or dust masks as shown in Fig. 7.5 are to be worn when carrying out tasks that create inhalable dust or fumes, while handling certain chemicals or when working in dusty environments.

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Clothing

Do not wear loose clothes as shown in Fig. 7.6. Loose clothes like un-tucked T-shirt, a belt, an unbuttoned jacket or even loose shoelaces, can be caught in the moving machinery. Hence avoid wearing these types of clothes.

Fig. 7.6: Loose clothes

Footwear

Boots must be worn at all times on site as shown in Fig. 7.7. A steel-toe boot (also known as a safety boot, steel-capped boot or safety shoe) is a strong boot or shoe that has a protective strengthening in the toe which protects the foot from falling objects.

Gloves

Safety gloves of appropriate protective material as shown in Fig. 7.8 are to be worn when handling sharp or hot material, chemicals, or dangerous liquids.

Fig. 7.7: Footwear

Fig. 7.8: Hand gloves

Keep all food and beverages out of the work area. If fibre particles are ingested they can cause internal damage to your stomach. Hence, wear laboratory coat as shown in Fig. 7.9 or disposable apron to minimise fibre particles on your clothing. Fibre particles can become lodged in clothing and can later get into food, drinks, and/or be ingested by other means. A coat also ensures that laboratory chemicals do not harm the clothing.

Fig. 7.9: Safety jacket

Good work habits

Good work habits are in some ways the simplest and most effective means to working safely. Good work habits can help you prevent accidents and spot potential problems in time to correct them. Here are some general rules for working safely.

- Keep a clean workspace. Clean up at the end of your work day and store tools properly.
- Observe your surroundings. Look up from what you are doing once in a while to make sure everything around you is the way it should be.
- Use tools for the job they were designed to perform. Misuse of tools is one of the most common causes of accidents in the workplace.
- Do not eat or drink in the work area. In addition to accidentally drinking from the wrong bottle, you could accidentally ingest glass fibre or other dangerous materials that might get mixed with your food.
- Report problems or injuries immediately. Let your facility supervisors know about hazards so they can correct them as soon as possible.
- Know how to reach emergency personnel. Have emergency numbers posted by the nearest telephone so you don't waste time searching through a directory in an emergency.
- Jewellery such as watches, rings, bracelets, earrings and necklaces are not permitted in work areas.

- Do not touch your eyes or mouth while working with fibre optic systems until your hands have been thoroughly washed.
- All tools and equipment not being used must be safely stored. Always use insulated tools while working. The typical insulated tools are shown in Fig. 7.10.
- Put all cut or broken fibre pieces in the dust-bin for disposal. All rubbish and waste should be put in waste bins located on site. Do not drop them on the floor where they will stick on carpets or to shoes and be carried elsewhere.
- Thoroughly clean your work area when you are done. Use adhesive tape to pick up any broken fibre pieces from surfaces to ensure no one rests on them or step onto them.
- Check the weather report. When working outside, make sure that the person works in clear weather conditions as shown in Fig. 7.11. If weather is not favourable, like presence of black clouds in the sky or a thunderstorm then wait for the weather condition to become normal.
- Watch for signs of a coming storm. Regularly monitor the changes in temperature, increase in wind, or darkening of the sky as shown in Fig. 7.12. If it looks like a storm rolling in, cover the panel and stop the work. Look for shelter immediately.

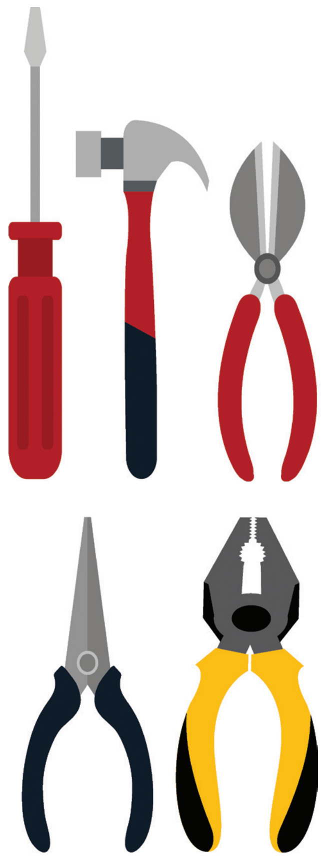

Fig. 7.10: Insulated tools

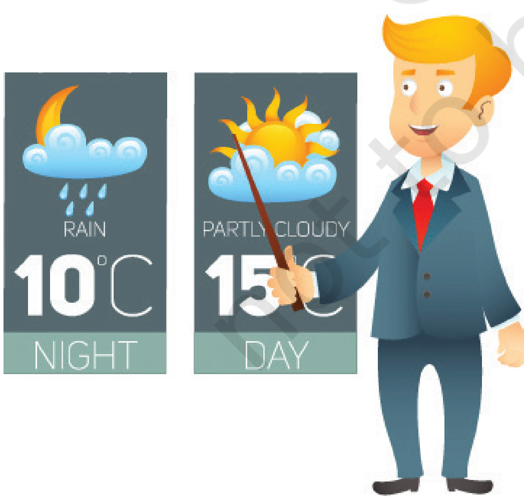

Fig. 7.11: Checking of weather report

Fig. 7.12: Watch for signs of a coming storm

Concepts of LASER light safety

The use of laser light emission by industry and by the academic community continues to increase. A laser can be especially dangerous because it can concentrate a great amount of power into a small beam of coherent light. Many lasers used in optical fibre operate below dangerous levels, but some, such as those used for transmission over long distances, put out enough power to cause damage in a very short time. These should only be used with proper eye protection or measuring devices to prevent eye damage. The hazard evaluation procedure used is based on the ability of the laser beam to cause biological damage to the eye or skin during intended use. It is related to the classification of the laser or laser system from Class 1—considered to be non-hazardous, to Class 4—very hazardous.

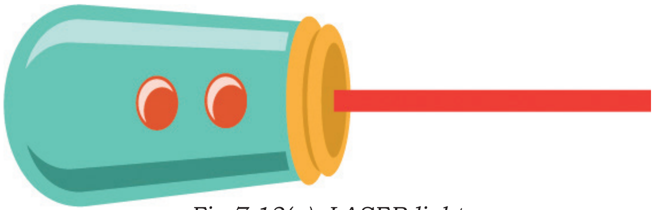

Fig.7.13(a): LASER light

Eye hazards

Certain areas of the eye absorb more light. Absorption of laser radiation above a certain level leads to tissue injury.

Class 1

No hazardous level of optical radiation (exempt lasers) under normal operating conditions must be emitted. Included in this category is laboratory equipment using lasers with all beam paths and reflections, etc.

Class 2

Low-power visible laser device of 1 milliwatt does not have enough output power to injure a person accidentally, but may injure the eye when stared at for a long period. A 'caution' label must be placed on the device. These lasers are used for alignment procedures and optical experiments.

Class 3a

Laser rated between powers of 1 milliwatt to 5 milliwatts cannot injure a normal person when viewed with

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unaided eye, but may cause injury when the collected energy is the eye as with binoculars. Most laser pointers fall into this category. A danger or caution sign must be put on the device, depending on its irradiance.

Class 3b

Laser rated between 5 milliwatts to 500 milliwatts can produce eye injury when viewed without eye protection. This class of laser requires a danger label and could have dangerous reflections. Eye protection is thus required.

Class 4

Lasers rated above 500 milliwatts in power can injure you if viewed directly or by viewing both the specular and diffuse reflections of the beam. A danger sign will label this laser. These lasers can also present a fire hazard. Eye and skin protection are required.

Safety rules while using lasers light

1. Avoid looking directly into any laser beam or at its reflection.
2. Remove all unnecessary specular (shiny) reflecting surfaces from the work area.
3. Operate lasers in well-defined areas to which access can be controlled. The area should be posted with appropriate signs to alert persons passing by the area that a potential hazard exists as shown in Fig. 7.14(b).
4. The laser system should be operated only by or under the direct supervision of a person knowledgeable of the hazards and control methods

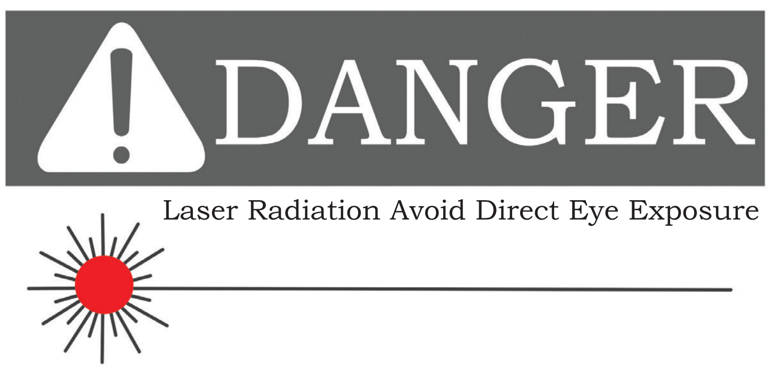

Fig. 7.13(b): Sign and alert from the hazards due to LASERS

for both beam and non-beam conditions. This individual is usually the laser safety officer (LSO) who is designated by the administration of the company, hospital, or educational institution.

5. Any accident should immediately be reported to the responsible medical authority.

Site safety

Many of the locations for fibre 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. Here are some general safety rules to help you.

Electrical

When fibre optic systems run through the same area as electrical wiring or cabinets, use extreme caution with tools and ladders. One wrong move can send enough voltage through your body.

Fire safety

Note that fusion splicers use an electric arc to make splices, so care must be taken to insure no flammable gases are present in the space where fusion splicing is done.

Fire extinguisher

A fire extinguisher is a fire protection device used to stop the fire and burning (Fig. 7.14). It is the basic first aid equipment which can be effectively used for the fire control. It is a cylindrical pressure vessel containing an agent which can be liquidated to stop a fire. Always keep a fire extinguisher ready for the areas where person work with electrical equipment.

All the rooms were fibres are used must have fire and emergency exits in case of emergency use at all times.

Fig. 7.14: Fire extinguisher and its parts

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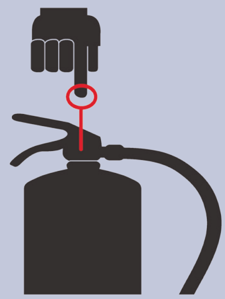
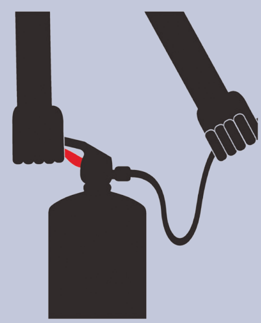
More to know

The following steps demonstrate to operate a fire extinguisher in case of a fire emergency as shown in Fig. 7.15. Steps to open the seal and safety pin.

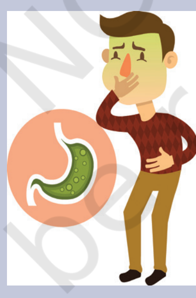
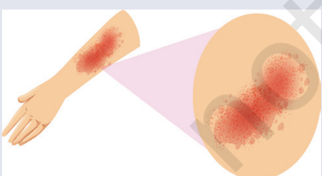
Step 1	Identify the safety pin of the fire extinguisher which is generally present in its handle.	 *Fig. 7.15 (a)*
Step 2	Break the seal and pull the safety pin from the handle.	 *Fig. 7.15 (b)*
Step 3	Use the fire extinguisher by squeezing the lever.	 *Fig. 7.15 (c)*

Safety of materials

Fibre optic splicing and termination use various chemical cleaners and adhesives as part of the process. 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 fibres or cables are presented in Table 7.1.

Table 7.1: Primary Treatments for Isopropyl Exposure

Type of exposure	Isopropyl Effect of exposure	Emergency treatment
Inhalation  *Fig. 7.16: Inhalation*	Irritation of upper respiratory tacks  *Fig. 7.17: Irritation*	Move victim to area containing fresh air. Administer artificial respiration if breathing is irregular.  *Fig. 7.18: Artificial respiration*
Ingestion  *Fig. 7.19: Ingestion*	Nausea, Vomiting  *Fig. 7.20: Vomiting*	Have victim drink water and milk. Seek medical assistance.  *Fig. 7.21: Drinking water*
Contact with skin  *Fig. 7.22: Contact on skin via chemical*	Skin Irritation  *Fig. 7.23: Irritation*	Wipe off the affected area of skin and wash with the soap and water.  *Fig. 7.24: Washing of the hands*

Contact with eyes

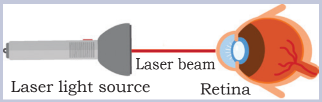


Fig. 7.25: Laser contact with eyes

Eyes Irritation

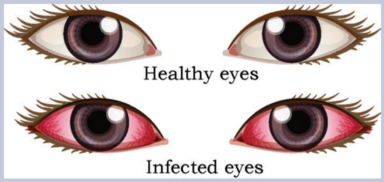


Fig. 7.26: Eye Irritation

Wipe eyes with plenty of water for 15 min.

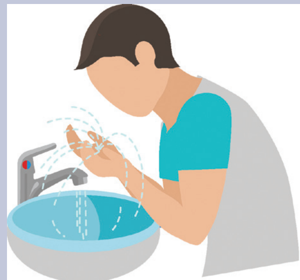


Fig. 7.27: Washing of the eyes

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

Safety from bare fibre

The broken ends of Fibres and scraps of Fibre created during termination and splicing can be extremely dangerous. The ends are extremely sharp and can easily penetrate your skin. They invariably break off and are very hard to find and remove. Sometimes a pair of tweezers and perhaps a magnifying glass will get them out. Be careful when handling fibres to not stick the broken ends into your fingers. Dispose of all scraps properly in a yellow sharps bin. Do not drop Fibre scraps on the floor where they will stick in carpets or shoes and be carried elsewhere like home. Also, do not eat or drink anywhere near the work area. Fibre scraps can get into food or drink and be swallowed.

Documenting the activity assemble

Documenting the activity assemble means to make the document which involves all the task, rules, safety method statements, policies of the government to be followed to come the activity, listing the hazards and necessary prevention steps to be taken against each task. The tasks which are to be carefully handled has to be listed carefully with rules listed step by step.

- Rate the risk in accordance with the risk matrix. Determine the level of risk and its preventions.

- Activity should be supervised, monitored and reviewed from time to time and ensure that it is documented properly.
- Sometimes documentation requires changes, in which case, it should be revised accordingly.
- To proceed with a task, a written record of the process is to be used. It should be signed off by the parties who have responsibility for the tasks, as it is a record that can be used in court.

First Aid

All accidents and equipment damage which occurs at the job must be informed immediately, so that proper safety aid or repairing of machinery is required. First aid is of prime importance in the event of an accident. Hence, everybody should know the basic methods of first aid as shown in Fig. 7.25.

- Bring the affected person at peaceful and airy place, and care should be taken to avoid suffocation.
- Keep all the parts of body of affected person in straight position and should be laid down on an even spot.
- In case of head injury, lay down the affected person in such a way that the head rests in upward position.
- In case of trouble in proper respiration, the person should be kept in sitting position.
- In case of wounds, then take water in one small bucket and add 4 drops of Iodine in it to make it anti-bacterial, and wash the wounds neatly and carefully and dry it. Then apply the iodine on wounds and wrap it by medicated/antibacterial cotton.

Fig. 7.25: Giving basic first aid

The following medicines/items should be kept in first-aid box—

(a) Small dressing cotton

(b) Medium dressing cotton

(c) Large dressing cotton

(d) Yellow or dressing pad for burn injuries
(e) Clean and sterilised cotton pads
(f) Tincture iodine
(g) Potassium permanganate
(h) Sol-violate spirit (for smelling of unconscious person)
(i) Adhesive plaster
(j) Eye drops
(k) Boric powder
(l) Tourniquet
(m) Three angle bandage (in case of broken bone)
(n) Safety pins
(o) Soda Bi-Carbon
(p) 2 or 3 wooden plaques
(q) Aspirin tablets
(r) Bottle of Dettol or Savlon liquid
(s) Bottle of spirit
(t) Scissor, knife, etc.

Bleeding

There can be four types of bleeding through injuries—

1. Minor bleeding
2. Bleeding through artery or main blood circulatory system
3. Bleeding from vein
4. Internal bleeding

Fig. 7.26: Lying unconscious

If bleeding is of (1) or (3) type, then first tightly wrap the part of body below and above the wound in order to stop the bleeding. Internal bleeding, from stomach, brain or lungs, etc., cannot be seen. However, it can be seen in the vomit or spit of injured person. Internal bleeding is more dangerous than external bleeding. In such situations, give the injured person cold water or ice and arrange for immediate medical help. Excessive bleeding after injury may cause death rather than bleeding from wounded spot. Hence, medical help should be arranged without any delay.

Check Your Progress

Notes

A. Multiple Choice Questions

1. Never look directly the fibre light, since it will damage the ____________.
   (a) retina of your eyes
   (b) ears
   (c) skin
   (d) nose
2. LASER light will penetrate inside the eyes retina causing blindness since it is ____________ beam.
   (a) focussed
   (b) unfocussed
   (c) scattered
   (d) transmitted
3. Which of the following is used to heal the burn injury in case of electrocution?
   (a) Burnol
   (b) Soframycin
   (c) Burnol or Soframycin
   (d) None of the above
4. Which of the following is not a type of bleeding?
   (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 ____________.
   (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.
   (b) Break the seal and pull the safety pin from the handle.
   (c) Use the fire extinguisher by squeezing the lever.
   (d) All of the above
7. We use the fire extinguisher in case of ____________.
   (a) flood
   (b) electric shock
   (c) fire
   (d) burn injury

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8. Which of the following is the safety items a technician must not have while working?
   (a) Safety boots
   (b) Gloves
   (c) Helmet
   (d) Belt

B. Fill in the Blanks

1. While working on electricity, the technician must wear _____________ gloves and shoes.
2. Keep stretching your arms, legs, neck and back while working to ensure that they are not _____________.
3. The unconsciousness due to electric shock may cause damage to his/her _____________.
4. If burn injury is due to _____________, it should be cleaned and washed by spirit.
5. Defective or inadequate insulation may result _____________.

C. State whether True or False

1. Fibre optic splicing and termination use various chemical cleaners and adhesives as part of the processes.
2. The broken ends of fibres and scraps of fibre created during termination and splicing can be extremely dangerous.
3. Fire extinguishers used for electrical fires will have a C, BC or ABC on the label.
4. Apply Burnol or Soframycin type of creams to the burnt part of the body of an electrocuted person and wrap the bandage.
5. All the parts of the body of an affected person should be kept in straight position and should be laid down on an 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. The rating and physical condition of the components and cable should be checked.
8. Common injuries that can be caused due to lifting heavy loads include back ache, neck strain, wrist sprain, back sprain, shoulder pain.
9. The aim of first-aid treatment is to cool down the affected area rapidly to minimise 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. Answer in Brief

1. What are the factors that result in a hazard?
2. List out the various remedies to be taken in the 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 a 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.

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Answer Key

Chapter 1. Broadband and Fibre Optics Technology

A. Multiple Choice Questions

1. (a)	2. (b)	3. (a)	4. (d)
5. (a)	6. (a)	7. (b)	8. (a)
9. (a)	10. (a)	11. (a)	12. (b)
13. (c)	14. (c)		

B. Fill in the Blanks

1. Fibre Cables
2. Digital
3. Wireless
4. Analog to digital
5. Fibre optics
6. guided or unguided
7. Serial
8. Cable TV networks and Telephone networks
9. home page
10. amplifier or repeater

C. State whether True or False

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

Chapter 2. Data Communication

A. Multiple Choice Question

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

B. Fill in the Blanks

1. Both direction
2. single
3. guided
4. video transmission
5. unguided media
6. cross talk and electromagnetic
7. reflection and refraction
8. electrical
9. electric and magnetic
10. twisted, coaxial and fibre optics
11. 100 metres
12. total internal reflection
13. glass and plastic
14. crosstalk
15. total internal reflection

C. State whether True or False

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

Chapter 3. Fibre Optic Communication

A. Multiple Choice Question

1. (d)
2. (a)
3. (a)
4. (c)
5. (a)
6. (a)
7. (a)
8. (b)
9. (a)
10. (a)
11. (b)
12. (d)
13. (b)
14. (d)
15. (b)

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B. **Fill in the Blanks**

1. bend
2. seven
3. core
4. total internal reflection
5. parellel
6. smaller
7. hard-plastic coating.
8. tensile strength
9. less
10. more, amplified signal
11. photo detector, signal amplifier and signal restorer
12. Chromatic dispersion
13. incoherent
14. graded index
15. absortion, scaterring and bend loss

C. **State whether True or False**

1. True
2. True
3. False
4. False
5. False
6. True
7. False
8. False
9. False
10. False
11. True
12. False
13. True
14. False

Chapter 4. Tools and Equipment

A. **Multiple Choice Questions**

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

B. Fill in the Blanks

1. clockwise direction
2. anticlockwise direction
3. eight
4. plastic, glass, metal or from any ceramic material
5. faster, cleaner,
6. continuity,cable functionality
7. mechanical splicer
8. carbide or diamond
9. 30mm, 60mm
10. connector

Chapter 5. Splicing

A. Multiple Choice Questions

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

B. Fill in the Blanks

1. 0.3dB
2. 0.1dB/Km
3. Precisely
4. attenuation loss, accuracy
5. optical time domain reflectometer
6. tissue paper and isopropryl alcohol

Chapter 6. Optical Fibre Testing

A. Multiple Choice Questions

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

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B. State whether True or False

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

Chapter 7. Occupational Health and Safety

A. Multiple Choice Questions

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

B. Fill in the Blank

1. Hand
2. injured
3. dealth
4. flammable gasses
5. injury

C. State whether True or False

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

Glossary

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

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

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

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

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

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

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

Brittle: *Easily broken without much bending.*

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

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

Cable: *A cable modem is a hardware device that allows your computer to communicate with an Internet Service Provider (ISP) over a landline connection. To use the broadband internet it changes an analog signal to a digital signal. Transmission speeds are of about 1.5 Mbps. Cable modem service is accessed by the subscriber by simply turning on their computers. Speeds are same to DSL.*

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

Chromatic Dispersion: *This is mainly a problem with LASER systems. Although LASER's emit a single mode they still emit more than one wavelength within that mode. Thus, the chroma or different*

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wavelength will travel at different speeds causing a spreading of the pulse at the distant receiver. With very high speed switching at high data rates this spread becomes critical to error free operation.

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

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

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

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

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

Conduit: *A tube or pipe that may be buried or installed within buildings for providing passage ways into which cables can be pulled.*

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

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

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

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

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

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

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

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

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

DSL (Digital Subscriber Line): *DSL is a medium of communication used to transfer digital signals over standard telephone lines. DSL is a wireline transmission technology that transmits data faster over traditional copper telephone lines already installed to home and business. The transmission speed ranges from hundred Kbps to millions of bits per second (Mbps).*

DTH: *'Direct to Home' The DTH technology enables a broadcasting of digital signal to your TV set through a receiver that is installed in the house.*

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

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

Fibre Optics: *Fibre optic technology converts electrical signals carrying data to light and sends the light through transparent glass fibres about the diameter of a human hair. Fibre transmits data at speeds far exceeding current DSL or cable modem speeds, typically by tens or even hundreds of Mbps. Spelling Fibre or Fiber is acceptable.*

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

FTTH: *Fibre to the home (FTTH), also called "fibre to the premises" (FTTP), is the installation and use of optical fibre from a central point directly to individual buildings such as residences, apartment buildings and businesses to provide unprecedented high-speed Internet access.*

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

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

2G, 3G, 4G: *It is mobile phone technology known as 2,3,4G whereG denotes Generation. the 2G technology was used earlier in our country to transmit and receive voice over mobile phones. Later, the technology got updated to 3G. Hence, in 3G data speeds are high but not very fast. The Indian mobile operators like Airtel, Idea, Vodafone, etc., uses 2G for voice communication and 3G and 4G for data transmission. The Latest mobile operator Jio is a new one who do not have 2G or 3G but uses only 4G. Data transmission speed of 4G is higher than 3G.*

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

Gigabyte per second: *Gigabit per second has symbol Gbit/s or Gb/s, often abbreviated "Gbps". It is a unit of data transfer rate equal to: 1,000 megabits per second. 1,000,000 kilobits per second.*

Graded Index Fibre: *A type of fibre (Multimode) where the refractive index starts at a high value in the center of the core*

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and decreases smoothly with radius toward the cladding.

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

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

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

Incoherent Light: *A random form of light whereby the phase of the light is unpredictable. LED's emit incoherent light.*

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

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

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

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

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

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

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

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

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

Kbps: *Kbps full form is kilobits per second (thousands of bits per second). It is a measure of the amount of data that can flow in a given time on a data transmission medium.*

LAN: *A LAN is a group of personal computers that are linked by cable like in an office building. LAN is abbreviated as 'local area network'.*

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Mechanical splice: *Any splicing method except fusion.*

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

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

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

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

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

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

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

Modem: *Modems is used for both sending and receiving of the digital information between personal computers. The access to the Internet more commonly takes place using high-speed broadband modems*

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

Monomode fibre: *See Singlemode fibre.*

Mbps: *Mbps is used to define the Internet connection speeds. It basically measure capacity and speed of data transfer.*

Multi fibre splice: *Simultaneously splicing more than two fibres.*

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

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

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

Noise: *Any unwanted signal.*

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

Nonmetallic cable: *See dielectric sheath or cable.*

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

Open: *A broken fibre.*

Optical Power: *It is measured in "dBm", or decibels referenced to one mili-watt of power. While loss is a relative reading, optical power is an absolute measurement, referenced to standards. You measure absolute power to test transmitters or receivers and relative power to test loss.*

Optical Loss: *It is defined as the amount of optical power lost as* *light is transmitted through fibre, splices, couplers, etc. This optical is expressed in "dB" which is dimensionless.*

Optical cable assembly: *A cable that is terminated with connectors. Usually the cable has been terminated by a manufacturer and is ready for installation.*

Optical Time Domain Reflectometer (OTDR): *An instrument for characterising a fibre. An optical pulse is sent down a fibre and the resulting backscattered light and reflected light back to the input is displayed as a function of distance on a screen. The instrument is useful for measuring fibre loss, splice loss and determining the location of faults or breaks.*

Optoelectronic: *A device that converts optical signals to electrical signals or vice versa.*

Organiser Splice Tray: *A mechanical assembly consisting of a frame, one or more splice trays and mounting hardware.*

Outside plant: *The portion of a cable network that resides outside of buildings. Outside plant can consist of cable, conduit, utility poles, and enclosures.*

Passive splicing: *Aligning the two ends of a fibre without monitoring its splice loss.*

Photon: *A discrete quantity of light energy.*

Pigtail: *A short length of fibre permanently attached to a component and use to couple light between it and another fibre.*

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

Polarisation: *The property of light relating to the direction of the vibrations. Light from the sun, incandescent lamps and many other sources vibrate in many directions perpendicular to the direction the light ray is traveling and is said to be randomly polarised. For lasers, the vibrations (all in a plane perpendicular to the light ray) are in a definite form that may be a straight line, circle, or ellipse.*

Polarisation maintaining fibre: *A Singlemode fibre that transmits light without changing its state of polarisation. Synonym for polarisation retaining fibre.*

Pole utility: *A tall slender column of wood, fibreglass, concrete, or steel used to support cables.*

Polishing: *Preparing a fibre end by moving the end over an abrasive material (lapping film).*

Preform: *A glass structure that's a magnified version of the fibre to be drawn from it.*

Primary coating: *The first protective coating applied to the surface of a fibre in a dual coat structure.*

Public Switched Telephone Network (PSTN): *The public switched telephone network (PSTN) uses copper wires to carry analog voice data. The public switched telephone network was earlier known as the public telephone network.*

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Pulse spreading: *An increase in the width of an optical pulse as it travels along a fibre.*

Quality assurance test: *A test to verify that a product meets advertised performance specifications.*

Radiation: *Energy and its propagation through matter or space. Radiation may either be "electromagnetic," which is usually considered to travel in the form of waves, or "particles" which is sub atomic particles moving at high speeds.*

Ray: *A geometrical representation of a light path through an optical medium that indicates the direction of energy flow.*

Rayleigh scattering: *Scattering of light caused by index of refraction variations in the submicroscopic structure of the glass.*

Receiver: *An optical and electronic package that takes optical input signals and converts them to electrical output signals.*

Reel, cable: *A large wooden or steel spool on which cable is wound for shipping and storage.*

Reflectance: *The ratio of reflected power to incident power. Synonym for "return loss."*

Reflection: *The abrupt change in direction of light as it travels from one material to a dissimilar material. Some of the reflected power in a fibre gets transmitted back to the source.*

Refraction: *The bending of light as it passes through two dissimilar materials or in a medium whose refractive index varies.*

Refractive index: *See index of refraction.*

Regenerator: *A receiver and transmitter combination used to reconstruct signals for digital transmission. The receiver converts incoming optical pulses to electrical pulses, decides whether the pulses are "1's" or "0's" generates "new" electrical pulses, and then converts them to "new" optical pulses for transmission on the fibre.*

Repeater: *An optoelectronic device that amplifies or boosts a signal. This is an analog technique, no regeneration takes place.*

Restoration, cable: *Locating, repairing and returning service to a damaged cable during an emergency.*

Return loss: *The reflectance measured at a point of reflection and then calculating the loss of that reflectance back to the source. This is important as too much reflectance may cause distortions in the transmitting device.*

Ribbon: *An assemblage of up to 12 fibres laid parallel to one another side by side and fastened together. Several ribbons can then be stacked on top of one another to make a cable.*

Satellite: *Satellite broadband is a type of wireless broadband. It is useful for proving the service to the remote or sparsely populated areas.*

Scattering: *Scattering is the phenomenon by which a beam of light is redirected in many different directions when it interacts with a particle of matter. The intensity of the scattered light depends on the size of the particles and the wavelength of the light.*

Secondary coating: *The protective coating applied over the fibre's primary coating in a dual coat structure.*

Sheath: *The protective outer covering of a cable core. It may consist of plastics, metals and nonmetallic strength members.*

Shield cable: *The metallic components in a cable sheath that drain off the current induced by lightning discharges.*

Short patch: *An emergency cable restoration method in which a short length of cable is used to patch around the damaged region.*

Short wavelength: *Used to refer to light having wavelengths generally less than 1 μm.*

Signal: *It is an electromagnetic representation of data.*

Signalling: *It is the act of propagating a signal over a suitable medium.*

Silica: *The short name for the chemical compound silicon dioxide (SiO2). Silica exists in nature both in free form as in quartz and in combined form as in the silicates.*

Silicate: *A chemical compound of silicon, oxygen and metals.*

Single end pull: *A method for pulling cable into conduit or duct liner from one direction. The cable reel is positioned at a splicing manhole and a truck with a capstan which is located at the pull manhole.*

Singlemode fibre: *A fibre having a small core diameter and in which only one mode (the fundamental mode which may consist of two polarisations) will propagate at the wavelengths of interest.*

Slotted core: *A loose cable construction in which fibres are loosely placed into slots (grooves) molded around the outside surface of a plastic rod. Synonym for open channel and fluted.*

Source: *A device (usually LASER or LED) that emits light energy.*

Spectrum: *The range of electromagnetic radio frequencies used in the transmission of voice, data, etc.*

Spectral width: *A measure of the wavelength content of optical power.*

Splice: *A permanent joint between two Fibres is called splicing. A connection of one or several fibres that in most instances is considered permanent. Splicing can be classified as fusion or mechanical splicing.*

Splice case: *A metal or plastic housing used to enclose and protect fibre splices. Synonym for splice closure.*

Splicing cut ends: *An emergency cable restoration method in which the cut ends are put back together.*

Static fatigue: *The decrease in fibre strength with time when under stress and exposed to humidity, high temperature, alkalinity or ammonia.*

Step index fibre: *A fibre having a uniform refractive index in its core and a sharp decrease in refractive index at the core cladding interface.*

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Strain: *The length by which a wire or fibre deforms divided by its original length.*

Stranding: *The manufacturing process by which fibres are wrapped about some other cable member. Stranding imparts extra length to the fibres.*

Strength member: *Steel aramid yarns, fibreglass epoxy, rods or other material used to increase the tensile strength of a cable.*

Stress: *The force per unit of cross sectional area.*

Stripping: *Removing the coating from a fibre.*

Support strand: *A stranded metallic cable attached to utility poles and used to support aerial cables. The cables are lashed or clipped to the support strand.*

Switch: *A mechanical or electronic device that opens or closes circuits. It also completes or breaks an electrical path or selects paths or circuits.*

Talk set optical: *An instrument for talking over fibres usually when installing and testing the cable.*

Target rod: *A solid cylinder usually made from alumina onto which submicroscopic glass particles are deposited in the OVD process.*

Tensile strength: *The pulling force necessary to break a material.*

Tight construction: *A type of cable construction in which the fibres are tightly coupled to other cable components and move with them.*

Total bandwidth: *The combined modal and chromatic bandwidth.*

Total internal reflection: *Confinement of light within a structure by having the light strike the interface between two optically different materials at an angle of incidence greater than the critical angle.*

Transmitter: *An optical and electronic package that takes electrical input signals and converts them to optical output signals.*

Tray splicing: *Flat rectangular compartments used to secure splices and store excess fibre.*

TRAI: *Telecom Regulatory Authority of India (TRAI) is an independent regulatory body established by the Telecom Regulatory Authority of India Act 1997 to oversee the telecommunications industry in India.*

Telephony: *Word used to describe the science of transmitting voice over a telecommunications network.*

Ultraviolet: *The region of the electromagnetic spectrum containing wavelengths between 0.04 and 0.4 tan.*

Under fill: *A condition for launching light into a fibre in which not all the modes that the fibre can support are excited.*

Underground: *Cable installed in buried conduit. Does not include cables buried directly in the ground.*

Universal closure: *A splice closure suitable for use in aerial, underground or buried plant.*

Waterproof cable: *Cable containing a filling compound in all available spaces in the core to resist the entrance of water.*

Waveguide: *A conducting or dielectric structure able to support and propagate one or more modes.*

Wavelength: *It is a term used to measure light in terms of nm or microns (m). Fibre specifications like attenuation, dispersion are expressed in terms of wavelength. Wavelength is inversely proportional to the frequency of light. It means if frequency increases wavelength decreases and vice-versa.*

Wavelength Division Multiplexing (WDM): *A method to simultaneously transmit two or more optical signals on a fibre by using different wavelengths.*

Web browsing: *A web browser is a software application for accessing information on the World Wide Web. Every individual web page, image, and video is identified by a unique URL (uniform resource locator).*

Wireless: *Wireless broadband the Internet is connected to home or business by radio link. This link is between the customer's location and the service provider's facility. Speeds are generally same to DSL (digital subscriber line) and cable modem.*

Wireless local loop: *Wireless local loop is used for wireless communication links. It deliver plain old telephone services or broadband services to customers. This is best used in areas where cable infrastructure is either expensive or speed is not fast.*

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