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FIBRE OPTIC COMMUNICATION SYSTEM

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Last but not least, we would like to appreciation also goes to our colleagues who have directly or indirectly inspired us in completing this project.

ABSTRACT

The aim of producing this E-book is to fulfil the E-learning key performance indicator (KPI). This E-book was discussed subtopics from the Fiber Optic Communication System. The contained in this E-book include some notes, examples of questions with solutions. This E-book also includes flow chart and steps that can help the reader more easily understand the methods used in fiber optic measurement and testing.

This E-book was defined the introduction of Fiber Optic Characteristic, Component in Fiber Optic System, Optical Measurement and Testing. Fiber Optic Communication System introduces students to the basic concept of fiber optic in communication systems with environmental sustainability. Besides, this E-book also provides knowledge in fiber optic test procedure with safety awareness as well as step by step procedure for testing and measurement.

LIST OF CONTENT

NO	CONTENT	PAGE
1.0	**FIBER OPTIC CHARACTERISTICS**	
1.1	Define Fiber Optic	2
1.2	Fiber Optic Communication System Concepts	4
1.3	Light Propagation	5
1.4	Optical Properties	9
1.5	Transmission Losses In Fiber Optic Cables	11
1.6	Construction Of Fiber Optic Cable	12
1.7	Modes and Index Profiles	13
1.8	Types of Fiber Optic Cable	14
1.9	Example & Exercise	15
2.0	**FIBER OPTIC CHARACTERISTICS**	
2.1	Components In Fiber Optic Communication System	20
2.2	Optical Source	25
2.3	Optical Receiver	32
2.4	Exercise	36
3.0	**OPTICAL MEASUREMENT AND TESTING**	
3.1	Optical Measurement	38
3.2	Fiber Optic Test Equipment	41
3.3	Optical Power Measurement	42
3.4	Fiber Optic Testing	45
3.5	Example & Exercise	57

1 .FIBER OPTIC CHARACTERISTICS

INTRODUCTION

- ❑ Remember fiber optic
- ❑ Understand the fiber optic communication system concepts
- ❑ Remember properties of the light, optical law and the transmission losses in fiber optic cables
- ❑ Apply index of refraction formula
- ❑ Investigate Snell's Law to determine the characteristics of light propagation
- ❑ Investigate the construction of fiber optic cable
- ❑ Understand modes and index profiles
- ❑ Understand type of fiber optic cable

> **In 1870, John Tyndall, using a jet of water that flowed from one container to another and a beam of light, demonstrated that light used internal reflection to follow a specific path**

1.1 DEFINE FIBER OPTIC

Fiber optic is the medium in which communication signals are transmitted from one location to another in the form of light guided through thin fibers of glass or plastic. It also known as an optical fiber where the signals are digital pulses or continuously modulated analog streams of light to representing information. These can be voice information, data information, computer information, video information, or any other type of information. Optical fiber cables can be either aerial, in duct, underwater or buried directly in the ground as shown in Figure 1.1.

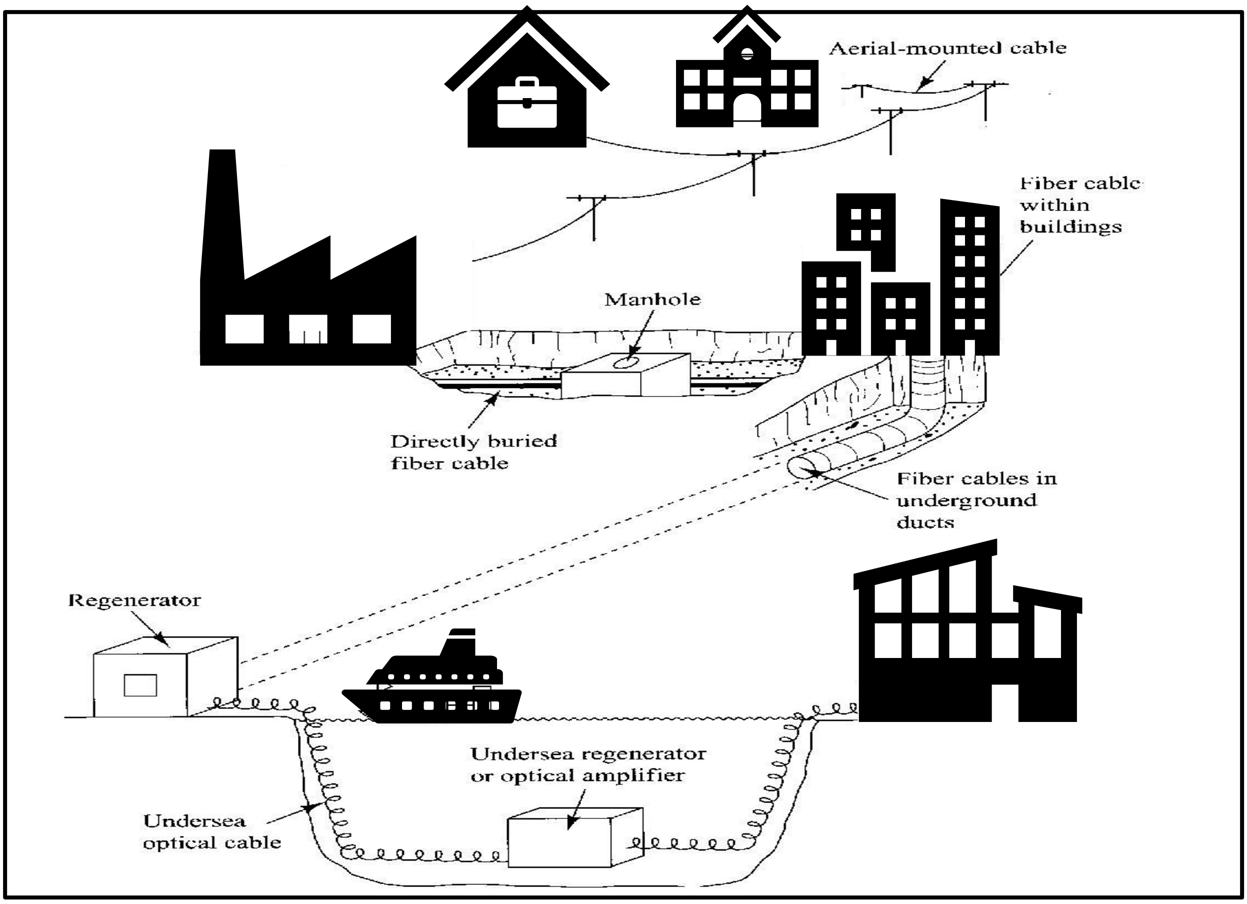
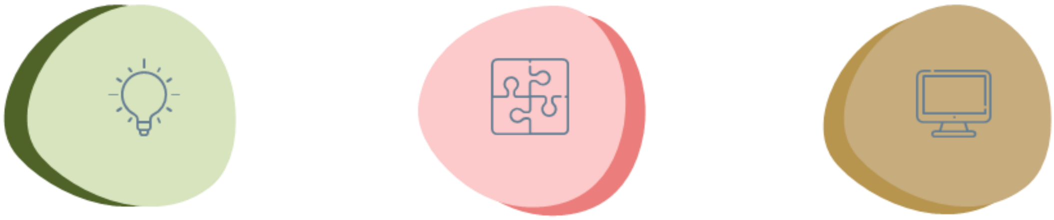


Figure 1.1: Overview of optical fiber cable installation

Fiber optic cables have some environmental benefits because the systems waste less energy than coaxial cable systems. Less energy means less generated heat, therefore fiber optic cables don't need cooling systems to spend excess of energy to cool down the data and keep it at an appropriate temperature. This means that less air conditioning tools are needed, saving equipment and floor space.

> **Coaxial cables consume 3.5 watts to transmit data over 100 meters, while fiber optic systems just use even less than 1 watt to conduct light pulses over 300 meters.**
>
> \- Beyondtech-

Here are three reasons why fiber-optic technology can be considered a “green” technology;



Fiber consumes less energy

Fiber-optic cables require fewer materials

Data centers filled with fiber-optic cables use less energy

Other advantages of optical fibers compared to copper wires is,

1. Long distance transmission
2. Large information capacity
3. Small size and law weight
4. Immunity to electrical interference
5. Enhanced Safety
6. Increased signal security

1.2 FIBER OPTIC COMMUNICATION SYSTEM CONCEPTS

In the Fiber optic technologies, there involve the emission, transmission and detection of light. *Figure 2* is the basic block diagram of optical fiber communication system that consists of transmitter block, fiber optic cable and receiver block.

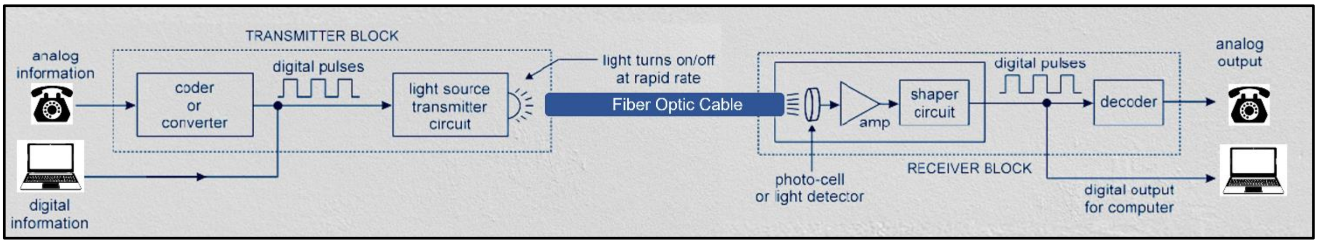


Figure 1.2: Fiber optic block diagram

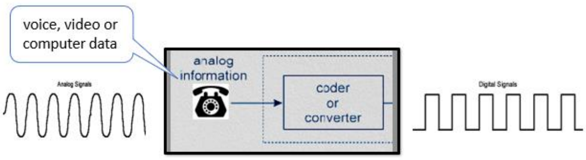
TRANSMITTER BLOCK

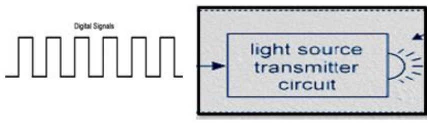
1. CODER/CONVERTER:

- It is a ADC(analog to digital converter).
- At the input ,the Coder converts analog signal (analog information such as voice, video or computer data) into digital signals.
- If the input signals are computer signals, they are directly connected to light source transmitter circuit.

2. LIGHT SOURCE

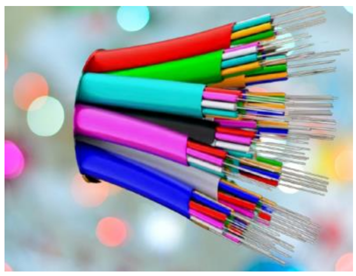
- Is generally a FOCUS type LED (Light Emitting Diode) or low intensity laser beam source (such as Injection Laser Diode-solid state laser) or in some cases an infrared beam of light
- The frequency of digital pulses control the rate, at which light source turns ON/OFF, in other word, this is how the digital signals are converted into equivalent light pulses and focused at one end of fiber-optic cable.





3. FIBER–OPTIC CABLE

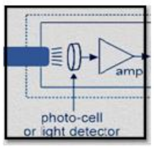
- Fiber optic cable passes the light pulses that are fed to one end of fiber-optic cable on to the other end.
- The cable has VERY LESS attenuation (loss due to absorption of light waves) over a long distance.
- Its bandwidth is large; hence, its information carrying capacity is high.

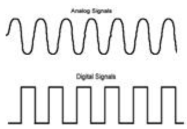


RECEIVER BLOCK

4. LIGHT DETECTOR :

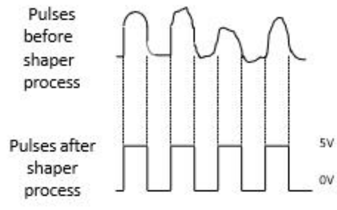
- Also known photodetector is transducer that detect the light pulses and then converts it into proportional electrical signal. signal into analog signals, such as voice, video or computer data.
- The electrical signals are the amplified and reshaped into original digital pulses by the shaper
- If the input signals are computer signals, the signal can be directly taken out from the output of the shaper circuit.

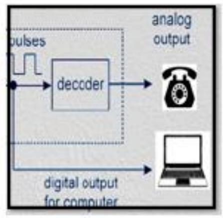




5. DECODER

- It is a ADC (analog to digital converter).
- Converts digital signal into analog signals, such as voice, video or computer data.



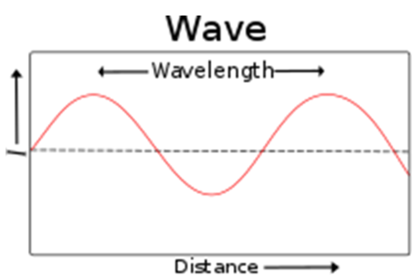


1.3 LIGHT PROPAGATION

Propagation of light refers to an electromagnetic wave transfer energy from one point to another location. Light can travel from a source in three ways. It can move directly from the source through empty space, through various media or after being reflected from a mirror. Inside the optical fibre, light propagates as an electromagnetic wave.

In fiber optics communication systems, the important parameter is wavelength and period.

- ❑ Wavelength is the distance between two identical points (the points having the same phase) of two successive cycles of the wave.
- ❑ Period is the time it takes a wave two identical points (the points having the same phase) to pass, in sequence, the same space location.



The wavelength and the period of the wave are related through wave velocity. The period, T is the time it takes a wave to travel the distance equal to one wavelength, λ, at velocity, C. On the other hand, a wavelength λ, is the distance travelled by a wave per one period, T at velocity, c. Therefore, light velocity is equal to wavelength divided by period, $C = \lambda/T$.

$$\boxed{f = \frac{1}{T}}$$

The number of periods in unit of time is call frequency. Frequency is the number that occur of a repetition event per unit of time.

Light velocity $c = 3x10^8$m/s

Where;

λ = wavelength (m)

f = frequency (Hz)

c = speed of light (m/s)

$$\boxed{c = f\lambda}$$

$$\boxed{f = \frac{c}{\lambda}}$$

$$\boxed{\lambda = \frac{c}{f}}$$

There are several terms to understand light propagation. Index of refraction also called refractive index, measure the bending of a ray of light when passing from one medium into another medium like solids, liquids, and gases. Snell's law is a formula used to describe the relationship between the angles of incidence and refraction, when referring to light or other waves passing through a boundary between two different isotropic media, such as water, glass, or air.

1.3.1 INDEX OF REFRACTION

The index of refraction, n of a material is the ratio of the speed of light, c in a vacuum/air to the speed of light in the material/medium, v.

Where;
n = refraction Index
c = speed of light in vacuum(m/s)
v = speed of light in material(m/s)

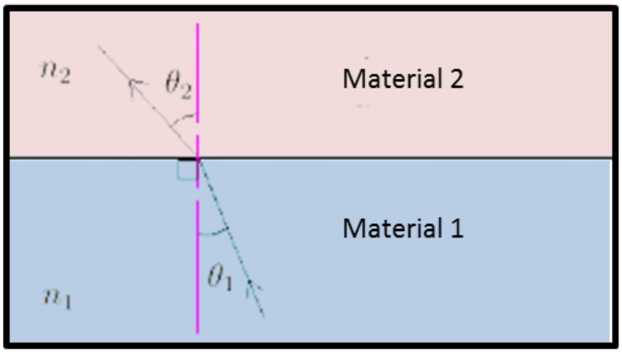
$$\boxed{n = \frac{c}{v}}$$

SUBSTANCE	INDEX OF REFRACTION, n
Solids at 20 °C	
Diamond	2.419
Glass, crown	1.523
Ice (0°C)	1.300
Sodium chloride	1.544
Crystalline	1.544
Fused	1.458

SUBSTANCE	INDEX OF REFRACTION, n
Liquids at 20 °C	
Benzene	1.501
Carbon disulfide	1.632
Carbon tetrachloride	1.461
Ethyl alcohol	1.362
Water	1.333

1.3.2 SNELL'S LAW

When light travels from a material with one index of refraction to a material with a different index of refraction, the angle of incidence is related to the angle of refraction by:



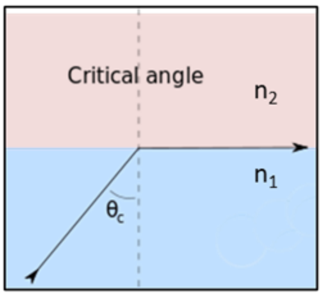
Where;
n_1 = refractive index for material 1
n_2 = refractive index for material 2
θ_1 = angle of incidence
θ_2 = angle of refraction

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

1.3.3 CRITICAL ANGLE

As the angle of incidence in the first material is increased, there will come a time when, eventually, the angle of refraction reaches 90° and the light is refracted along the boundary between the two materials. The angle of incidence which results in this effect is called the Critical Angle.

The value of the critical angle will calculate by assuming the angle of refraction to be 90° and transposing Snell's law,



Where;
n_1 = refractive index for material 1
n_2 = refractive index for material 2
θ_c = critical angle

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

$$\theta_2 = 90^o$$

$$n_1 sin\theta_c = n_2 sin 90$$

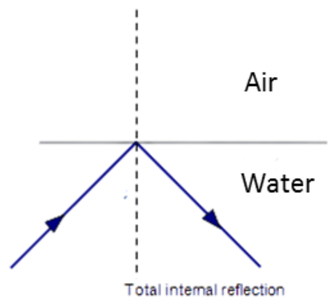
$$n_1 sin\theta_c = n_2(1)$$

$$\theta_c = sin^{-1}\frac{n_2}{n_1}$$

1.3.4 TOTAL INTERNAL REFLACTION

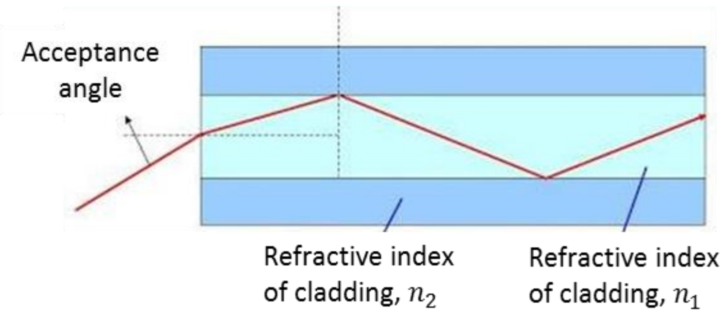
Total internal reflection occurs when light rays are totally reflected at the boundary between two different transparent materials. If the light approaches the boundary at an angle greater than the critical angle, the light is reflected from the boundary region back into the first material. The boundary region simply acts as a mirror.

When the angle of incidence is greater than the critical angle, all the light are reflection.



1.3.5 NUMERICAL APERTURE

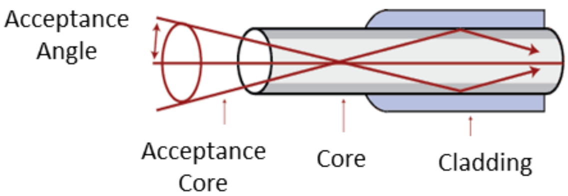
The numerical aperture, NA is a measurement of the ability of an optical fiber to capture light. NA is defined as the maximum acceptance angle to allow and transmit light by an optical fiber.



$$NA = \sqrt{n_{core}{}^2 - n_{clad}{}^2}$$

1.3.6 ACCEPTANCE ANGLE

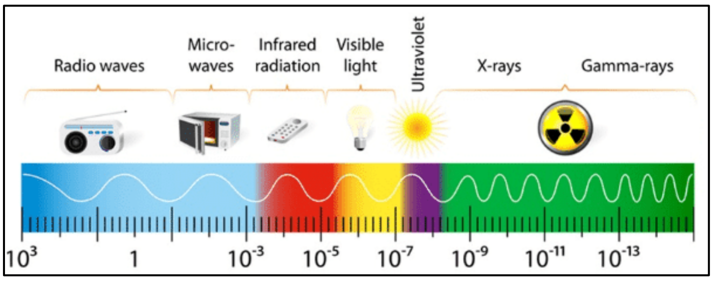
The maximum angle within which light will be accepted by an element, such as a detector or waveguide. It also used to define the acceptance cone of an optical fiber.



$$Acceptance\ angle = sin^{-1}NA$$

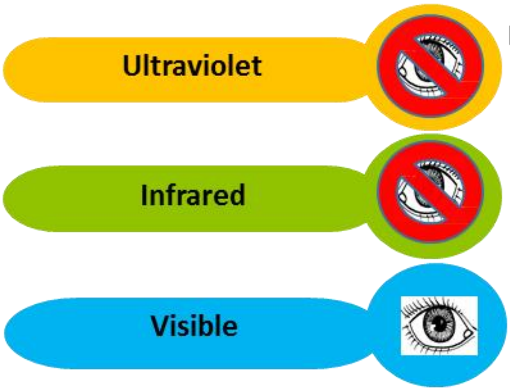
1.4 OPTICAL PROPERTIES

The electromagnetic spectrum is divided into seven regions. There is radio waves, microwaves, infrared (IR), visible light, ultraviolet (UV), X-rays and gamma rays. Wavelengths for optical spectrum is generally defined to encompass electromagnetic radiation in the range from 10 nm to 10^3 µm, or frequencies in the range 300 GHz to 3000 THz.



(Source:http://www.trendshere.com)

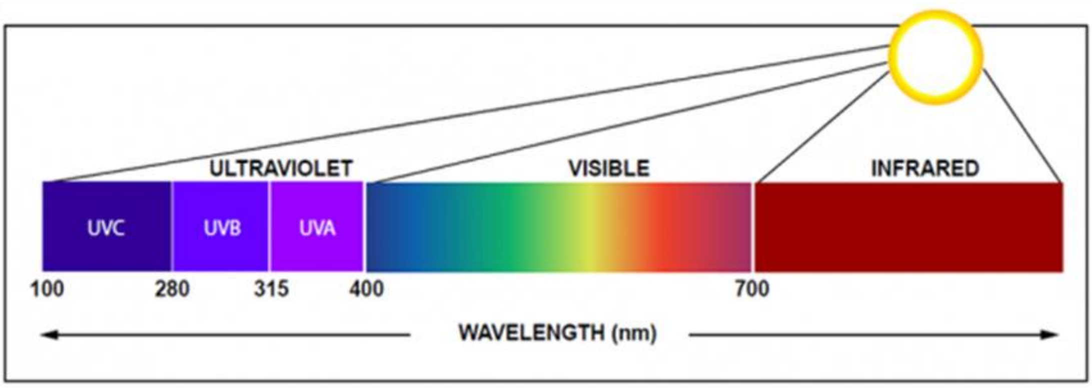
The optical spectrum is divided into three major categories, as follows.



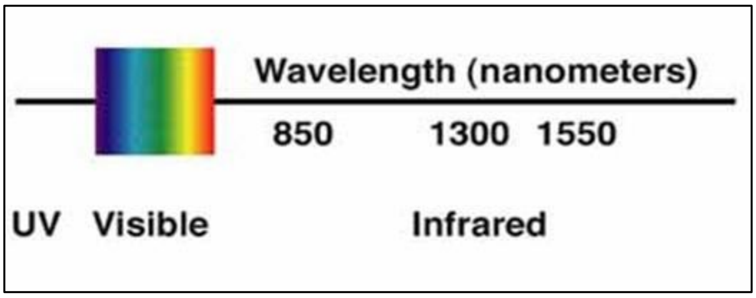
Band of light wavelengths that are too short to be seen by the human eye.

Band of light wavelengths that are too long to be seen by the human eye.

Band of light wavelengths to which the human eye will respond.



(Source: https://eyescreen.cordlifetech.com)



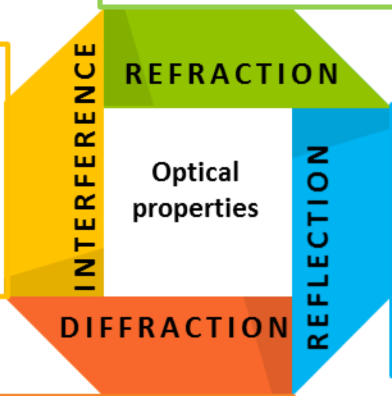
(Source: https://www.thefoa.org)

For fiber optics with glass fibers, the light is in the infrared region which has wavelengths longer than visible light, typically around 850, 1300 and 1550 nm

These properties of wave motion are important because they explain how waves move.

When a light wave passes from one medium into a medium having a different velocity of propagation (the speed waves can travel through a medium), a change in the direction of the wave will occur.

When two light waves are combined, interference can occur. The result is, more light intensity or less light intensity.



Reflection is the change in direction of a signal at an interface between two different media so that the signal returns into the medium from which it originated.

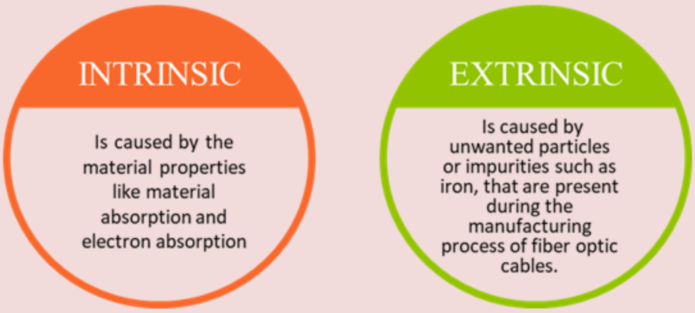
When light waves pass near a barrier, they tend to bend around that barrier and spread at oblique angles.

1.5 TRANSMISSION LOSSES IN FIBER OPTIC CABLES

Optical loss is measured in decibels or dB. Attenuation also known as the reduction of the optical signal intensity over a length of optical fiber or components. There are three losses in fiber optic cable.

Absorption Loss

Absorption loss is defined as portion of attenuation resulting from the conversion of optical power into another energy form such as heat. Absorption can be limited by controlling the amount of impurities during the manufacturing process. There are two types of absorption loss.



Material Scattering Loss

Scattering is a general physical process where light are forced to deviate from a straight line by one or more localized non-uniformities in the medium through which they pass. Scattering caused by the interaction of light with density fluctuations within a fiber.

Dispersion

Spreading of the optical pulse as it travels along the fiber. Two main factors which causes dispersion is, different source wavelengths and modes.

There are 3 type of dispersion.

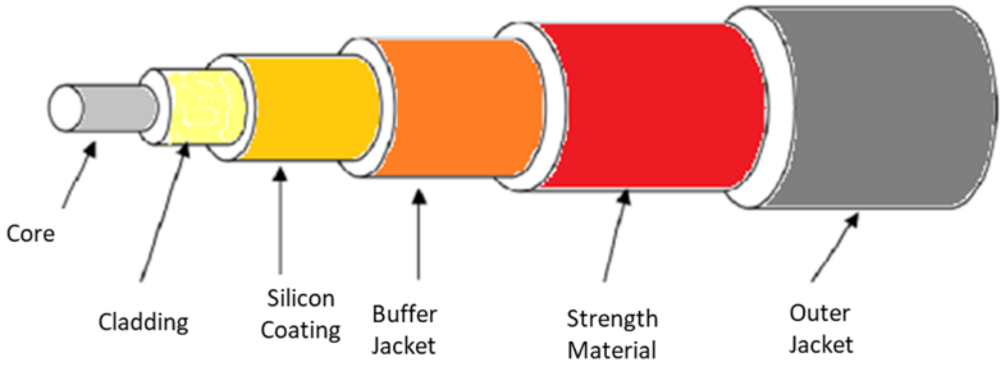
i. Modal Dispersion / Intermodal Dispersion

ii. Chromatic Dispersion / Intramodal Dispersion

iii. Polarization Mode Dispersion

1.6 CONSTRUCTION OF FIBER OPTIC CABLE

The optical fiber mainly consists of six part.



CORE
The light is "guided" down the center of the fiber called the "core". The core is designed to have a higher index of refraction, an optical parameter that is a measure of the speed of light in the material.

CLADDING
Surrounded core to traps the light in the core using an optical technique called 'Total Internal Reflection'

SILICON COATING
It improves the quality of transmission of light.

BUFFER JACKET
Used to help shield the core and cladding from damage.

STRENGTH MATERIAL
Surrounding the buffer, preventing stretch problems when the fiber cable is being pulled.

OUTER JACKET
Is added to protect against abrasion, solvents and other contaminants.

1.7 MODES AND INDEX PROFILES

INDEX PROFILE

Step Index

A step-index profile is a refractive index profile characterized by a uniform refractive index within the core and a sharp decrease in refractive index at the core-cladding interface so that the cladding is of a lower refractive index. Step Index Multimode was the first fiber design. It has higher attenuation and is too slow for many uses, due to the dispersion caused by the different path lengths of the various modes travelling in the core.

Graded Index

Graded Index Multimode fiber uses variations in the composition of the glass in the core to compensate for the different path lengths of the modes. It offers hundreds of times more bandwidth than step index fiber - up to about 2 gigahertz.

MODES

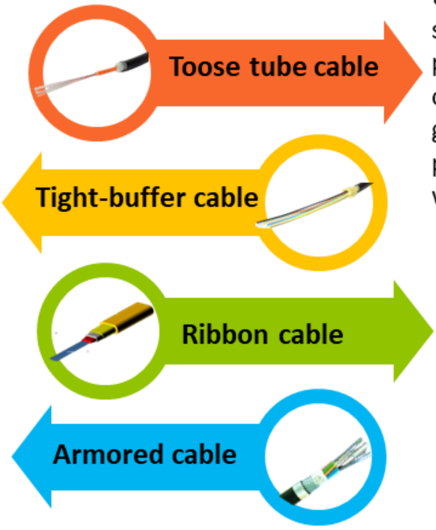
Single Mode

Single Mode fiber optic cable has a small diametral core that allows only one mode of light to propagate. Because of this, the number of light reflections created as the light passes through the core decreases, lowering attenuation and creating the ability for the signal to travel further. This application is typically used in long distance, higher bandwidth runs by Telco's and Colleges and Universities.

Multi Mode

Multimode cable is made of glass fibers Multimode fiber gives high bandwidth at high speeds over medium distances. Light waves are dispersed into numerous paths, or modes, as they travel through the cable's core typically 850 or 1300nm. Typical multimode fiber core diameters are 50, 62.5, and 100 micrometers.

1.8 TYPES OF FIBER OPTIC CABLE



Composed of several fibers inside a small plastic tube, which are in turn wound around a central strength member and jacketed, providing a small, high fiber count cable. The loose tubes filled with gel or water absorbent powder to prevent harm to the fibers from water.

A tight-buffered cable design is better when cable flexibility and ease of termination are a priority. Most inside cables are of the tight-buffered design because of the relatively short distances between devices and distribution racks.

This cable offers the highest packing density, since all the fibers are laid out in rows, typically of 12 fibers, and laid on top of each other. Since it's outside plant cable, it's gel-filled for water blocking.

Cable installed by direct burial in areas where rodents are a problem usually have metal armoring between two jackets to prevent rodent penetration. The cable is conductive.

1.9 EXAMPLE AND EXERCISE

EXAMPLE 1.1

ERA radio station is at 103.3MHz. What is the equivalent wavelength?

SOLUTION

$$f = 1.103x10^6 Hz$$

$$\lambda = \frac{c}{f}$$

$$\lambda = \frac{2.99x10^8}{103.3x10^6}$$

$$\boldsymbol{\lambda = 2.89m}$$

EXAMPLE 1.2

A wavelength for fiber optic operation is 1350nm. What is its equivalent frequency?

SOLUTION

$$\lambda = 1350x10^{-9}m$$

$$f = \frac{2.99x10^8}{1350x10^{-9}}$$

$$\boldsymbol{f = 2.215x10^{14}Hz}$$

EXAMPLE 1.3

Given the index of reflection of diamond is 2.419 and the velocity of light in a vacuum is $2.99x10^8$ m/s. Calculate the velocity of light in the material?

SOLUTION

Index of reflection of diamond,
η=2.419

velocity of light in a vacuum,
c = 2.99 x 10^8 m/s

$$n = \frac{c}{v}$$

$$2.419 = \frac{2.99x10^8}{v}$$

$$v = \frac{2.99x10^8}{2.419}$$

$$\boldsymbol{v = 1.236\,x\,10^8}\textbf{m/s}$$

EXAMPLE 1.4

Given the velocity of light in water is 2.248 x 10^8 m/s, and the velocity of light in a vacuum is $2.99x10^8$ m/s. Calculate the index of refraction of the material?

SOLUTION

velocity of light in ,
v = 2.248 x 10^8 m/s

velocity of light in a vacuum,
c = 2.99 x 10^8 m/s

$$n = \frac{c}{v}$$

$$n = \frac{2.99x10^8}{2.248x10^8}$$

$$\boldsymbol{n = 1.019}$$

EXAMPLE 1.5

Given the index of reflection of benzene 1.501, crystalline is 1.544 and the velocity of light in a vacuum is $2.99x10^8$ m/s. Calculate the velocity of light in all three material?

SOLUTION

$$n = \frac{c}{v}$$

index of reflection of benzene = 1.501

$$1.501 = \frac{2.99x10^8}{v}$$

$$v = \frac{2.99x10^8}{1.501}$$

$$\boldsymbol{v = 1.992\ x\ 10^8}\ \textbf{m/s}$$

index of reflection of crystalline = 1.544

$$1.544 = \frac{2.99x10^8}{v}$$

$$v = \frac{2.99x10^8}{1.544}$$

$$\boldsymbol{v = 1.937\ x\ 10^8}\ \textbf{m/s}$$

EXERCISE 1.1

Calculate angle of refraction at the air/core interface, θ_r critical angle , θ_c incident angle at the core/cladding interface , θ_i . Will this light ray propagate down the fiber?

$\eta_{air} = 1$

$\eta_{core} = 1.46$

$\eta_{cladding} = 1.43$

$\theta_{incident} = 12°$

EXERCISE 1.2

A step index fiber has a core diameter of 100µm and a refractive index of 1.480. The cladding has a refractive index of 1.460.

Calculate the numerical aperture of the fiber and acceptance angle from air.

EXERCISE 1.3

Given an index of reflection of glass is 1.523 and an index of reflection of air is 1.003. Determine the acceptance angle if the light is moving from air towards glass.

EXERCISE 1.4

Describe the relationship of Snell's Law between Critical Angle.

EXERCISE 1.5

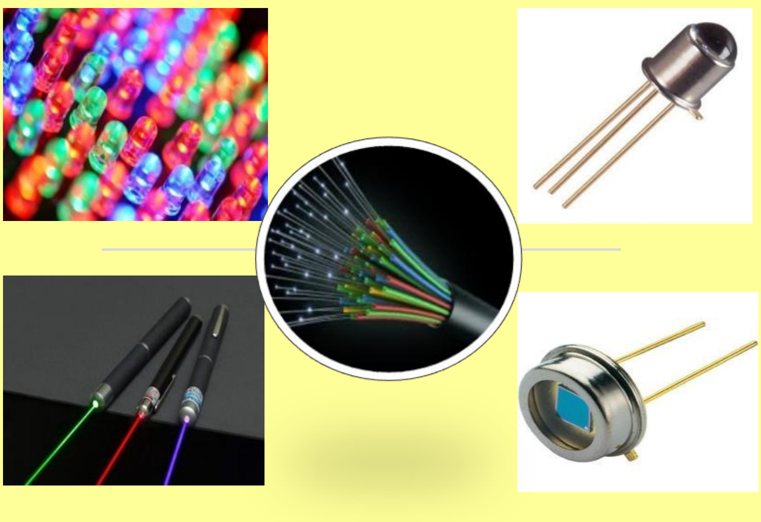
Calculate Angle of Refraction, NA and Acceptance Angle if Material 1 Glass, η = 1.5 and Material 2 Quartz, η = 1.38. Angle of Incidence is 350.

2. COMPONENTS IN FIBER OPTIC SYSTEM

INTRODUCTION

This topic will discuss about components that available in Fiber Optic System. At the end of this topic, students should be able to;

- ❑ understand the main components in the fiber optic communication system.
- ❑ investigate optical sources in fiber optic communication system.
- ❑ investigate optical receivers in fiber optic communication system.



2.1 COMPONENTS IN FIBER OPTIC COMMUNICATION SYSTEM

Fiber optic communication system has three main components that basically need to know which are

i. Light Source (Optical Transmitter)

ii. Fiber Optic Cable (Transmission Medium)

iii. Photo Detector (Optical Receiver)

Figure 2.1 shows three main components of fiber optic communication system. While, Figure 2.2 shows Fiber Optic Communication System.

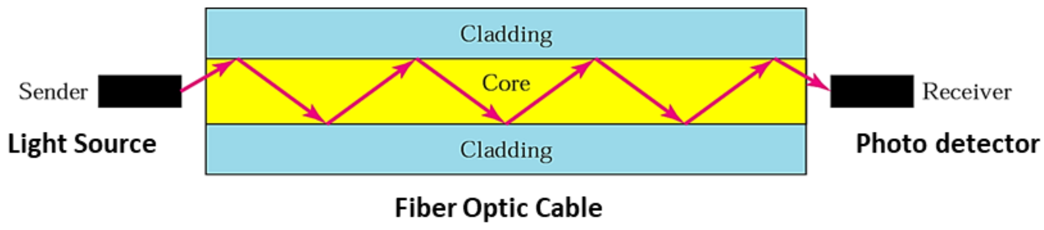


Figure 2.1: Components of Fiber Optic Communication System

Light Source - converts the pulses of electrical current to light pulses. For example, Light Emitting Diode (LED) and Injection Laser Diode (ILD).

Fiber Optic Cable - transmit the light-beam pulses.

Photo detector - converts the received light pulses back to pulses of electrical current. For example, Avalanche Photodiode (APD) and Positive Intrinsic Negative (PIN) Photodiode.

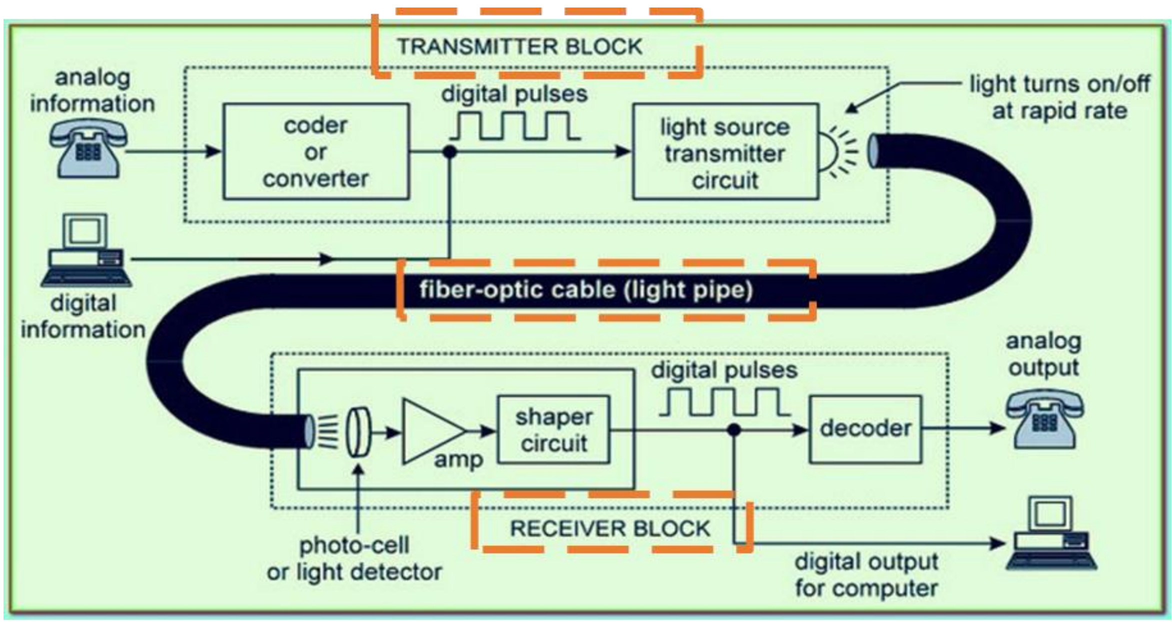
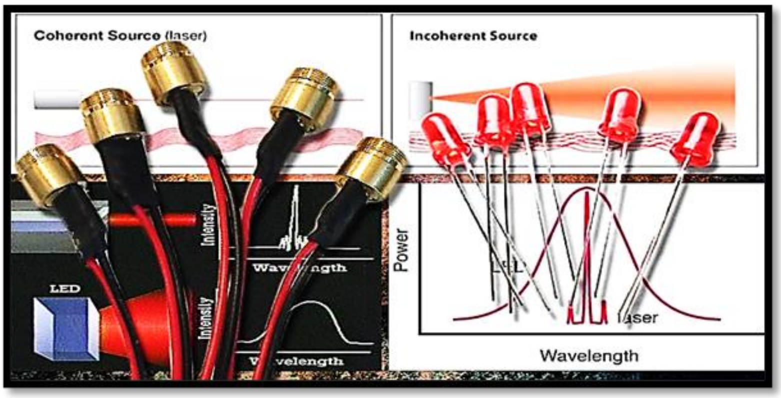


Figure 2.2: Fiber Optic Communication System

OPTICAL SOURCE

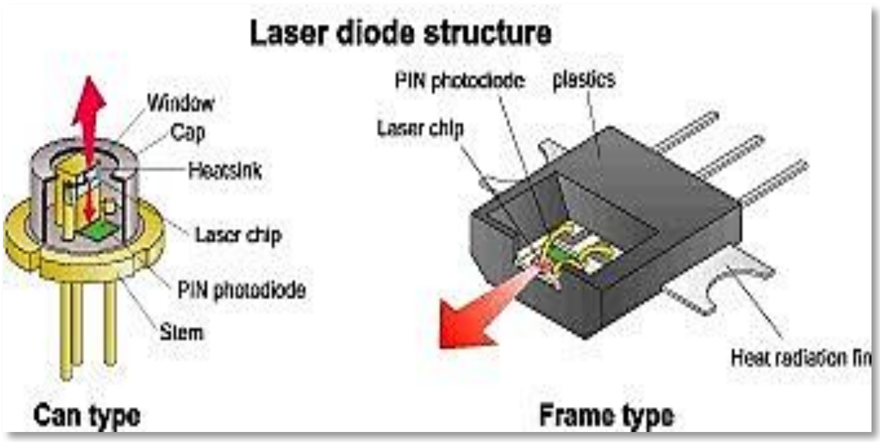
Optical source is an optical transmitter which converts electrical input signal into light signal before transmit them into fiber optic cable. Optical source is the major component in an optical transmitter. The most popular optical sources that usually used are semiconductor Light Emitting Diode and Injection Laser Diodes as shown in Figure 2.3.



(a) (b)

Figure 2.3 (a) Injection Laser Diode (b) Light Emitting Diode

The optical source is often considered as an active component in optical fiber communication system. Its fundamental function is to convert electrical energy into optical energy (light) in an efficient manner which allows the light output to be effectively launched into optical fiber cable. Figure 2.4 shows the Injection Laser Diode internal structure.



(www.hoo-tronik.com)

Figure 2.4 Injection Laser Diode Structure

Characteristics of Optical Sources

LEDs and ILDs are mostly used in fiber optic communication system, because of these two sources fulfill the major requirements of optical emitter which are outlined as below:

01

SIZE & CONFIGURATION

Size and configuration compatible with launching light into an optical fiber. Ideally, the light output should be highly directional.

02

HIGH SENSITIVITY

Have high sensitivity to tracked the electrical input signal accurately to minimize the distortion and noise. Ideally, the source should be linear.

03

CORRECT WAVELNGTH

Should emit light at wavelengths where the fiber has low losses and low dispersion and where the detectors are efficient.

04

CAPABLE MODULATION

Preferably capable of simple signal modulation over a wide bandwidth extending from audio frequencies to beyond the gigahertz range.

05

COUPLED SUFFICIENT POWER

Can couples sufficient optical power to overcome attenuation in the fiber plus additional connector losses and leave adequate power to drive the detector.

06

NARROW BANDWIDTH

Have very narrow spectral bandwidth (linewidth) in order to minimize dispersion in the fiber

07

STABLE OUTPUT

Capable of maintaining a stable optical output which is largely unaffected by changes in ambient conditions (e.g. temperature).

08

CHEAP AND HIGH RELIABILITY

the source is comparatively cheap and highly reliable in order to compete with conventional transmission techniques

FIBER OPTIC CABLE

Light signals which have been converted by optical source will be transmitted into a suitable transmission medium which is Fiber Optic Cable. This fiber optic cable capable to emit signal in the light form. Figure 2.5 shows the fiber optic cable that consists of three sections which are;

i. **Core** - consists a fiber made of glass or plastic or any transparent material. The core is a path for light propagation.

ii. **Cladding** – an insulator made of a glass or plastic or any transparent material that has optical properties different from the core.

iii. **Coating/Jacket** - a non-transparent material which acts as a layer to protect the fiber against moisture, crushing, and other environmental dangers.

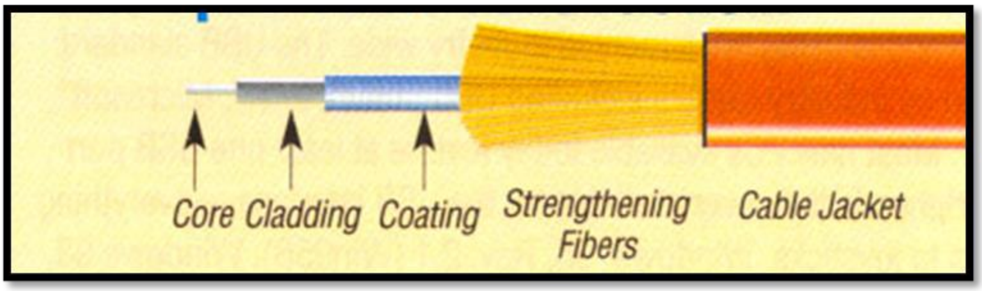


Figure 2.5: Fiber Optic Cable Structure

Advantages of Fiber Optic Cable

There are a number of compelling reasons that lead to the widespread adoption of fiber optic cabling for telecommunications applications which are;

1. Fiber optic cables have lower levels of signal attenuation
2. Fiber optic cables have higher bandwidth to allow more data to be delivered
3. Fiber optic cables are much lighter than the coaxial cables
4. Fiber optic cables don't suffer from stray interference pickup that occurs to coaxial cabling

OPTICAL RECEIVER

Photo-detector is an optical receiver that senses light signal falling on it and converts the variation of optical power to a correspondingly varying electric current. An optical receiver consists of a photodetector and others electronic for amplifying and processing the signal. The most popular photo-detector that usually used are semiconductor Positive Intrinsic Negative (PIN) Photodiode and Avalanche Photodiode (APD) as shown in Figure 2.6.

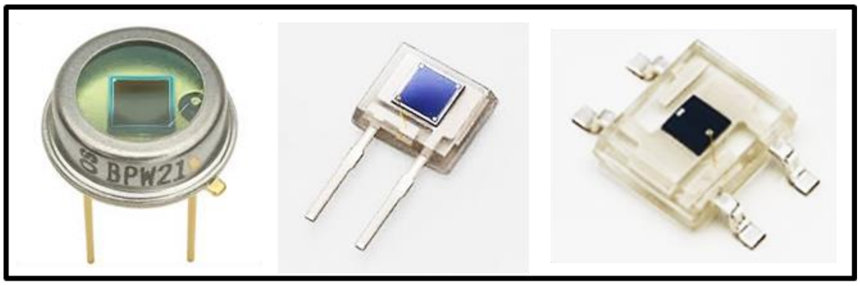
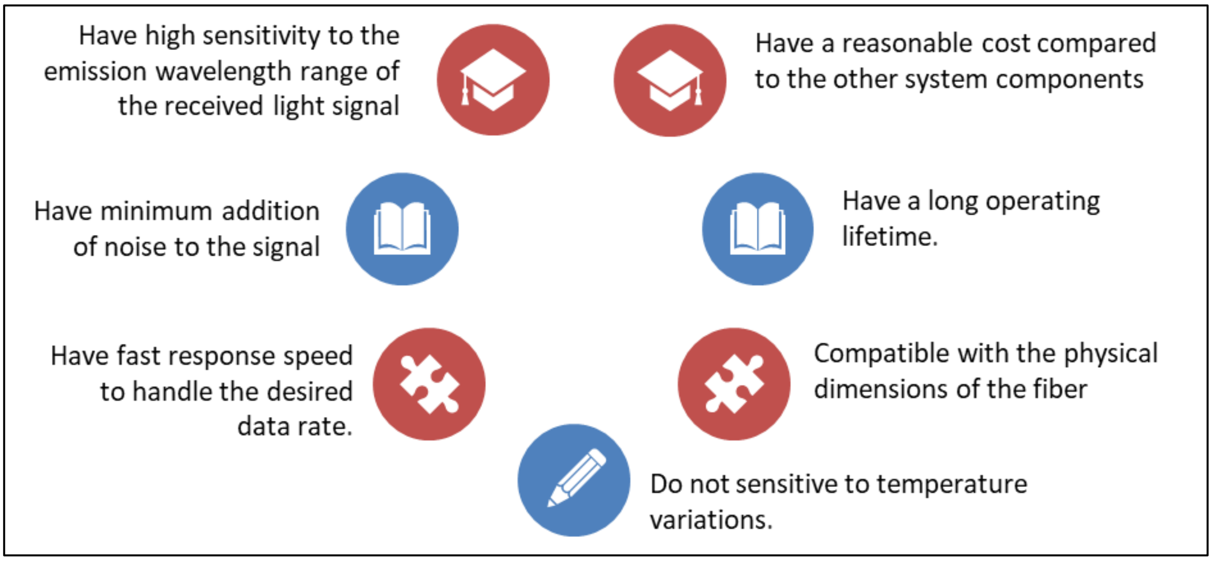


Figure 2.6: PIN and APD Photodiode

Importance Requirements of Photodiode

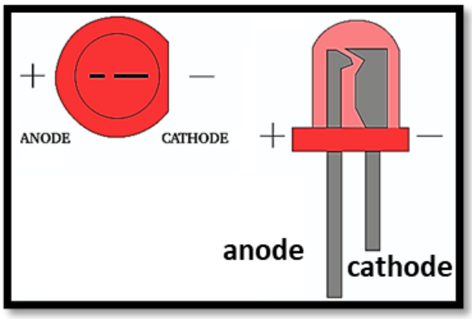
Since the optical signal generally is weakened and distorted when it emerges from the end of fiber optic cable, the photodetector must meet strict performance requirements which are:



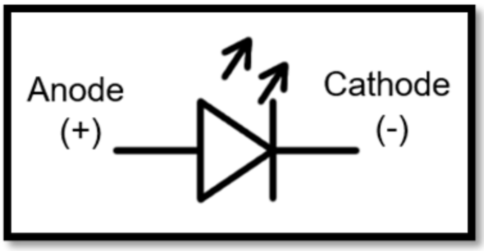
2.2 OPTICAL SOURCE

2.2.1 LIGHT EMITTING DIODE (LED)

An LED is a PN junction diode which made from semiconductor compound gallium arsenide phosphide. LEDs usually are used to emit the infrared radiation at wavelength of 850 nm . Figure 2.7 shows the physical structure and symbol of LED.



(a)

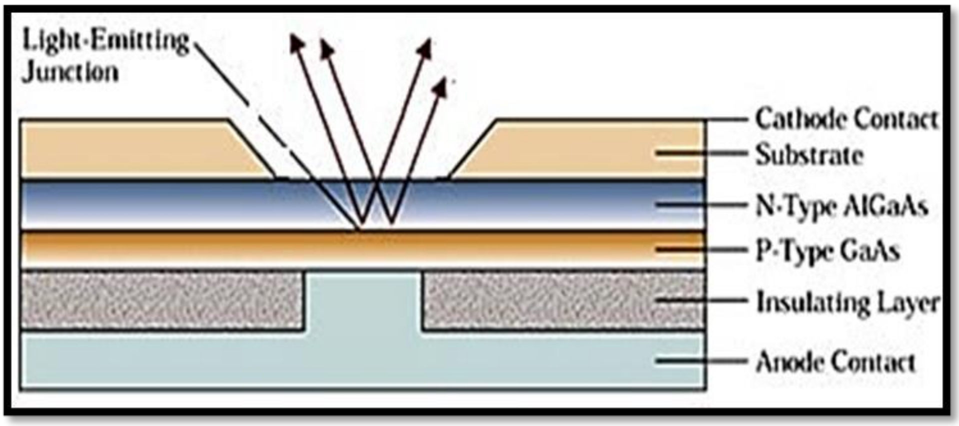


(b)

Figure 2.7 (a) Physical Structure of LED (b) Symbol of LED

Operation and Characteristics of LED

LED is a two-lead semiconductor light source that converts an electrical current into light. It is a P-N junction diode that can emits incoherent light through spontaneous emission when a suitable voltage is applied to leads. LEDs are made from compounds of gallium(Ga), aluminum(Al), arsenic(As) and phosphorus(Ps) where these materials will form a P-type and N-type semiconductor layers as shown in Figure 2.8.

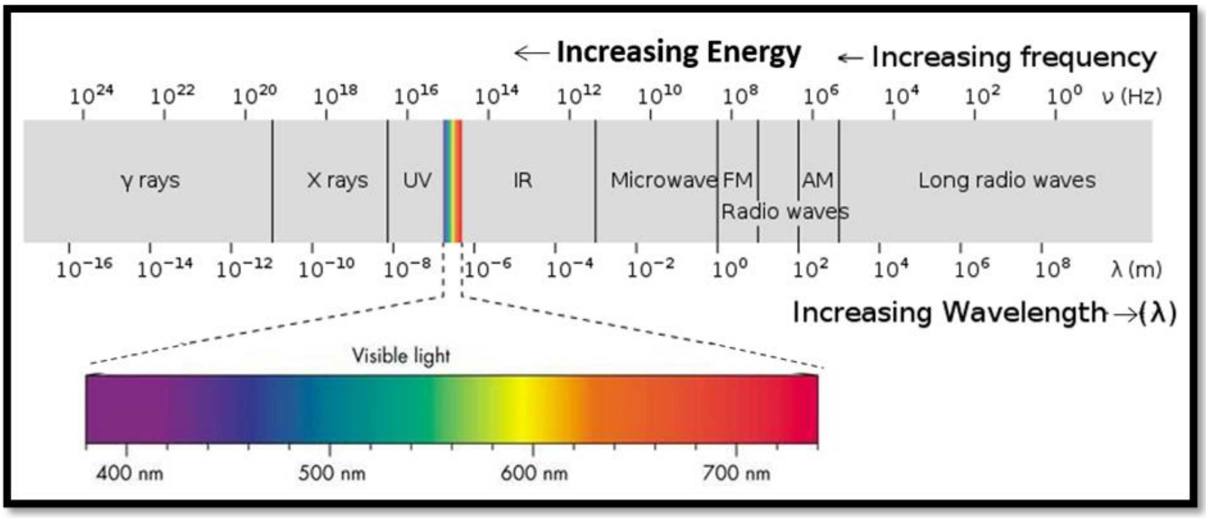


(https://www.elprocus.com)

Figure 2.8: LED Structure

When the LED is connected in a forward bias, the free electrons will move from N-type into holes in P-type semiconductor. As the free electrons recombine with the holes in depletion region, the free electrons will release an energy in the form of light (photons) and this process is called recombination. The higher energy is released, the higher frequency of light is produced where the colors of light are determined by the frequency (or wavelength) of lights.

These LEDs will emit **incoherent** light through **spontaneous emission** as the result of recombination of electrons and holes. The LED may produces a light in the range of frequency from visible light to infrared light spectrum as shown in Figure 2.9.



(https://www.teachengineering.org)

Figure 2.9: Electromagnetic Frequency Spectrum

LED is the most famous optoelectronic device since its price is very cheap and widely used in lighting and fiber optic area. LEDs Are usually used with multimode fibers due to their low output intensity. LEDs are employed in low data rate digital transmission systems up to speed of about 30 Mbps where in spreading of output pulses because of dispersion is not a big problem.

Advantages of LED

- Small size
- Very cheap and convenient
- Emit lots of light in a small area (high radiance).
- Have a very long life, offering high reliability.
- Emitting area is small, comparable to the dimensions of optical fibers.
- Can be modulated (turned off and on) at high speeds

Six Major Characteristics of LED

There are six major characteristics of LED which are;

01

Peak Wavelength (λ_p)

Peak wavelength is a wavelength at which the source emits the most power. It should be matched to the wavelengths that are transmitted with the least attenuation through optical fiber. The most common peak wavelength are 780, 850, and 1310 nm.

02

Spectral width (Δλ)

Ideally, all the light emitted from an LED would be at the peak wavelength, but in practice the light is emitted in a range of wavelengths centered at the peak wavelength. This range is called the spectral width of the source as shown in Figure 2.10.

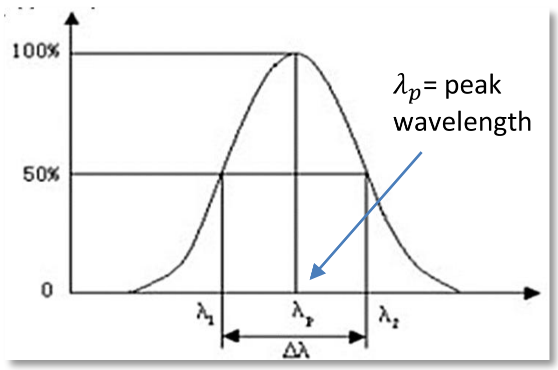


Figure 2.10: Spectral width of LED

03

Emission Pattern

The pattern of emitted light can affect the amount of light that want to be coupled into fiber. Therefore, the size of the emitting region should be similar to the diameter of the fiber core as shown in Figure 2.11

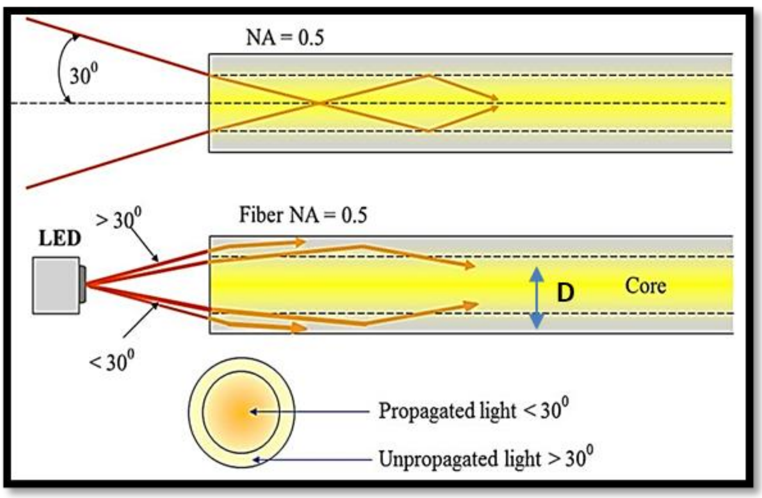


Figure 2.11: Emission (Radiation) Pattern of LED

04

Power

The optimum output power usually achieved by coupling as much as possible the source's power into optical fiber. The output power of the source should be strong enough to provide sufficient power to the detector at the receiving end, considering fiber attenuation, coupling losses and others system constraint. In general, **LEDs are less powerful than lasers.**

05

Speed

A source should turn on and off fast enough to meet the bandwidth limits of the system. The speed is given according to a source's Rise or fall time, the time required to go from 10% to 90% of peak power. **LEDs have slower rise and fall times than lasers**.

06

Linearity

Linearity represents the degree to which the optical output is directly proportional to the electrical current input. Most of light sources give little or no attention to linearity, making them usable only for digital applications. This is because, analog applications require close attention to linearity. Non-linearity in LEDs causes harmonic distortion in the analog signal that is transmitted over an analog fiber optic link.

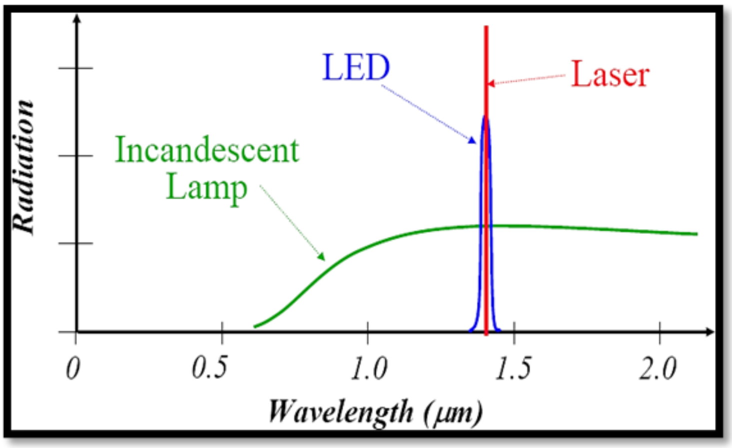
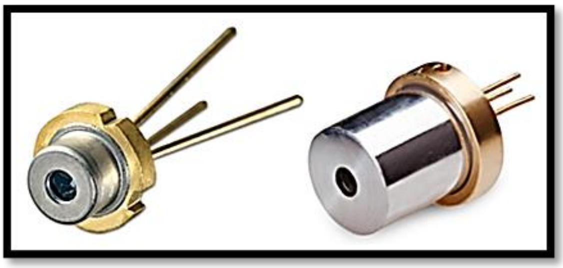


Figure 2.12: Spectral width of various types of light source

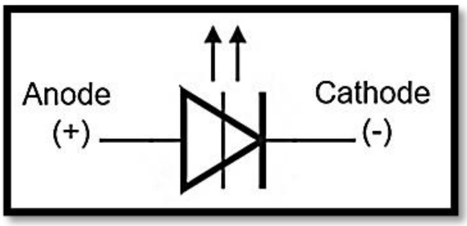
2.2.2 INJECTION LASER DIODE (ILD)

Same as LED, an ILD is also a PN junction diode which made from semiconductor compounds. Figure 2.13 shows the physical structure and symbol of injection laser diode.

> **LASER means "Light Amplification by Stimulated Emission of Radiation"**



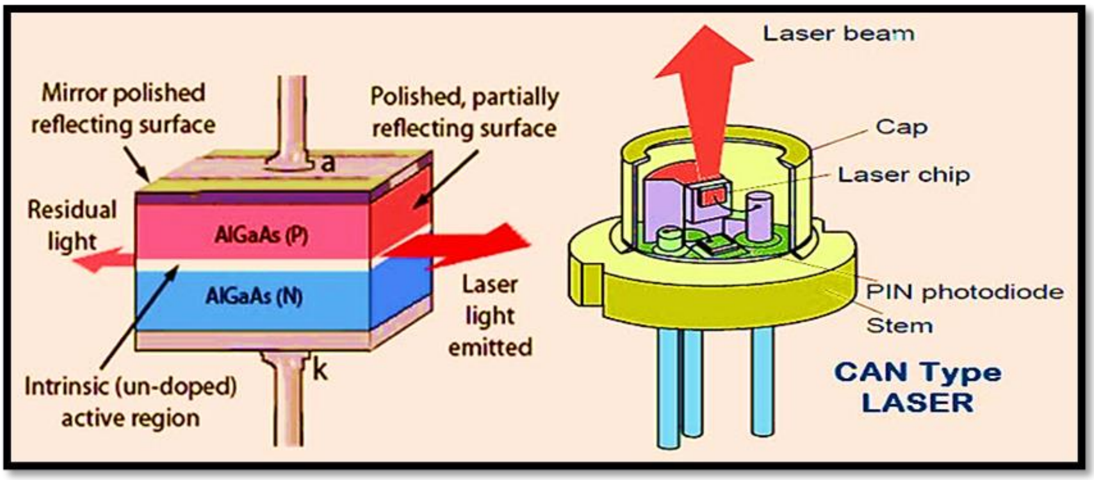
(a)



(b)

Figure 2.13 (a) Physical Structure of ILD (b) Symbol of ILD

A laser produces **coherent** and focused light beams by **stimulated emission**. It emits light spatially coherence which allows a laser to be focused to a tight spot as shown in Figure 2.14. ILD usually is used in optical transmitters for telecommunications and data communications



(https://shefalitayal.com)

Figure 2.14: ILD Structure

Operation and Characteristics of ILD

When the ILD is connected to power supply, the electrons inside special glasses, crystals, or gases atoms will absorb the energy from electrical current and become “excited”. The excited electrons will jump from a lower-energy orbit (or “ground” state) to a higher-energy orbit around atom’s nucleus, leaving many holes as shown in Figure 2.15. Therefore, the atoms are unstable due to “excited” electrons.

To stabilize the atom, the absorbed energy need to be released by “excited” electrons. Therefore, the “excited” electrons will jump back to their origin shell (into hole) and release their energy in a light form. This process is called recombination (electrons release its energy and move back into holes). Each electron that jumped, emits one photon of light. The bigger the jump, the higher the energy, then the higher frequency of light is produced where the colors of light are determined by the frequency (or wavelength) of lights. However, laser lights contains only one wavelength (one specific color) and laser light is directional.

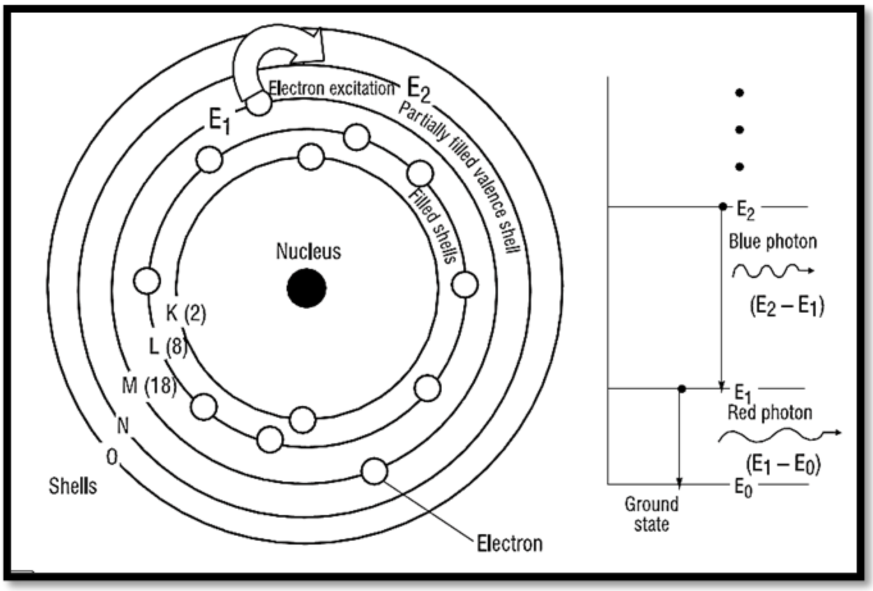


Figure 2.15: Energy Released as a Light

Advantages of ILD

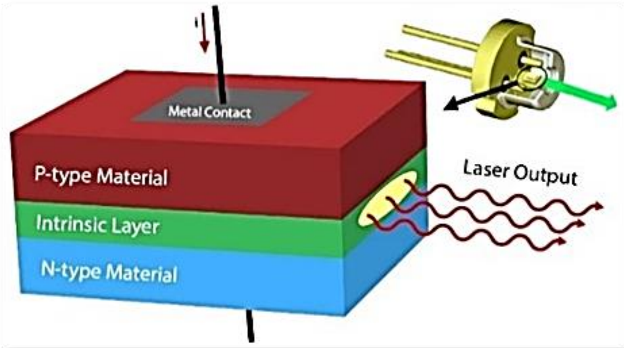
- Small size
- High power (tens of mW)
- High speeds (in the GHz region)
- Narrow spectral width.
- High radiance (emit lots of light in a small area).
- Emitting area is small, comparable to the dimensions of optical fibers.
- Have a very long life, offering high reliability.
- Can be modulated (turned off and on).

Disadvantages of ILD

- Sensitive to temperature variations
- Multimode diode lasers suffer from partition noise. For example, random distribution of the laser power among the modes.
- When combined with chromatic dispersion in the fiber, this leads to random intensity fluctuations and reshaping of the transmitted pulses.

Characteristics of ILD

- Coherence light
- Stimulated Emission
- Narrow beam width (very focused beam)
- Monochromatic : The spectral width of the radiated light is very narrow



(https://spectruminfotech.in)

- Well directed: An ILD radiates narrow, well directed beam that can be easily launched into fiber.
- Highly intense and power efficient: A laser diode can radiate hundreds of milliwatts of output. power. ILD making the current to light conversion 10 times more efficient than LEDs.

Emission Pattern of ILD

The pattern of emitted light affects the amount of light that can be coupled into the optical fiber. The size of the emitting region should be similar to the diameter of the fiber core. ILD has verry narrow beam width as it can focused into the core of optical fiber as shown in Figure 2.16.

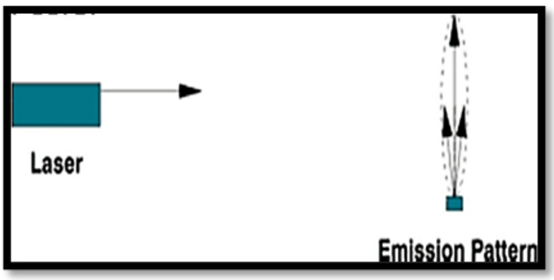


Figure 2.16: Laser Emission Pattern

2.3 OPTICAL RECEIVER

Photo-detector

The main function of the receiver is to convert optical signal into electrical signal. Figure 2.17 shows the optical receiver system where an optical receiver consists of:

i. Photo-detector (semiconductor photo diode) which produces current in response to incident light.
ii. Amplifier
iii. Signal Conditioning Circuitry

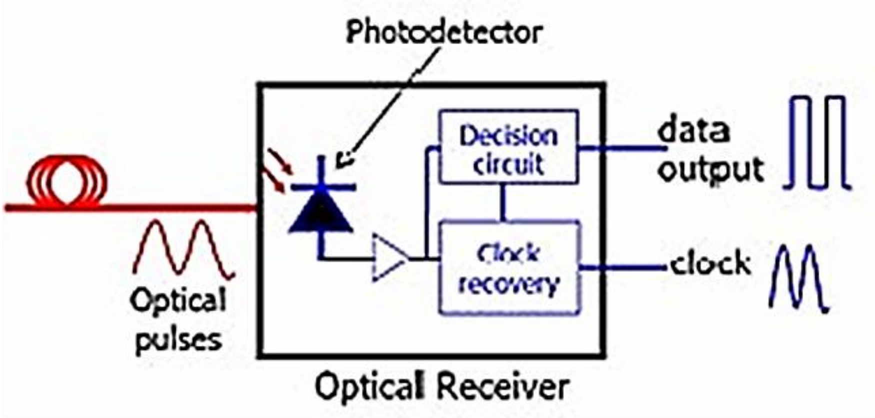


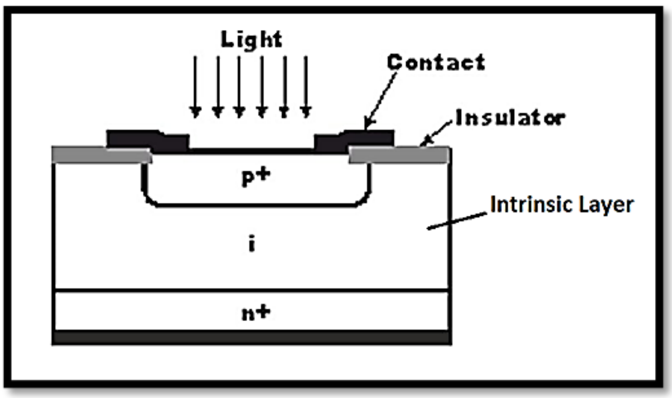
Figure 2.17: Optical Receiver System

Fiber optic receivers use two types of photo diode or photo-detector which are;

i. Positive Intrinsic Negative (PIN) Photodiode
ii. Avalanche Photodiode (APD)

2.3.1 POSITIVE INTRINSIC NEGATIVE (PIN) PHOTODIODE

A PIN photodiodes consist of a **thick doped intrinsic layer** sandwiched between thin p and n regions as shown in Figure 2.18. The major feature of PIN photodiode is that its **intrinsic depletion layer**, where the absorption of photons (light) occurs.



(https://www.researchgate.net)

Figure 2.18: Positive Intrinsic Negative Photodiode

Operation and Characteristics of PIN Photodiode

PIN photodiode is an intrinsic device that behaves similarly to an ordinary signal diode, but it **generates a photocurrent when light is absorbed in the intrinsic depleted region** of the junction semiconductor. A reverse bias potential is applied across the PIN diode to prevent the current from flowing in the absence of light.

The working principle of any types of photodiode either PIN or APD diode, is based on the mechanism of **Photoelectric Effect**. This effect shows that when the photons (light) strike the photodiode, it will produce a couple of electrons-holes (photocurrent) as shown in Figure 2.19.

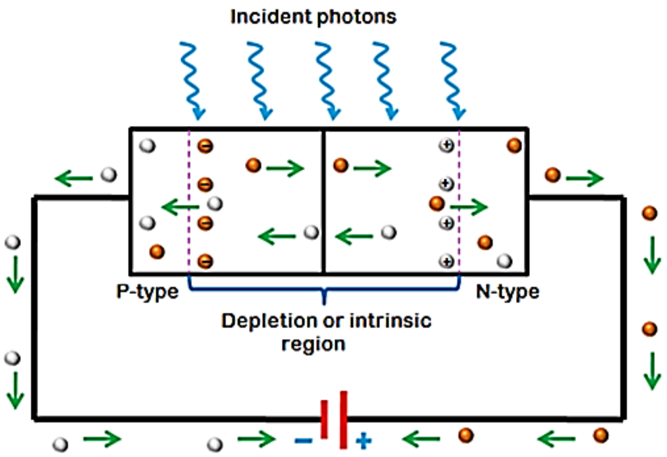


Figure 2.19: Photoelectric Effect to produce Photocurrents

A PIN photodiode is operated by applying a small reverse-bias voltage (usually, 5V) because the thickness of the depletion region is controlled by the thickness of the intrinsic layer, not by reverse bias voltage. When a photon incident upon a semiconductor photodetector device, the energy of the photon will be absorbed by the band gap if photon energy is more than band gap energy. As a result, an electron-hole pair is generated across the band gap.

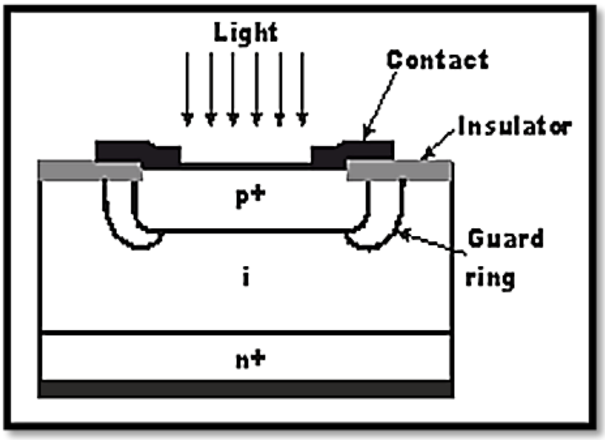
Since the intrinsic layer is naturally thick, most of the incident photons enter this layer and generate electron-hole pairs. Then, holes will move toward the anode and electrons move toward the cathode, and a photocurrent will be generated as shown in Figure 2.19.

Characteristics of PIN Photodiode

- A PIN diode is the most popular method of converting the received light into an electronic signal. Their appearance is almost identical to LEDs and lasers.
- They can be terminated with ST, SC, and a variety of other connectors or a pigtail.
- It uses a semiconductor material, either germanium or silicon.

2.3.2 POSITIVE INTRINSIC NEGATIVE (PIN) PHOTODIODE

The APD photodiode structure is relatively similar to PIN photodiode structure. A guard ring is placed around the perimeter of the diode junction as the avalanche photodiode is **operated under a high level of reverse bias** . This prevents surface breakdown mechanisms. Figure 2.20 shows the structure of APD photodiode.



(https://www.researchgate.net)

Figure 2.20: Avalanche Photodiode (APD) Structure

APD is a photodiode that internally amplifies the photocurrent by an avalanche process. A large reverse-bias voltage (typically over 100 volts) is applied across the active region. This voltage causes the electrons which is initially generated by the incident photons to accelerate as they move through the APD active region .

As these electrons collide with other electrons in the semiconductor material, they cause a fraction of them to become part of the photocurrent. This process is known as avalanche multiplication. Avalanche multiplication continues to occur until the electrons move out of the active area.

Operation and Characteristics of APD Photodiode

The working principle of Avalanche photodiode (APD) is very similar to PIN photodiode, but with only one exception which is the addition to the APD device on a high intensity electric field region. In this region, the primary electron-hole pairs which is generated by the incident photons are able to absorb enough kinetic energy from the strong electric field to collide the atoms present in this region, thus generating more electron-hole pairs.

This process of generating more than one electron-hole pair from one incident photon through the ionization process is referred to as the avalanche effect as shown in Figure 2.21.

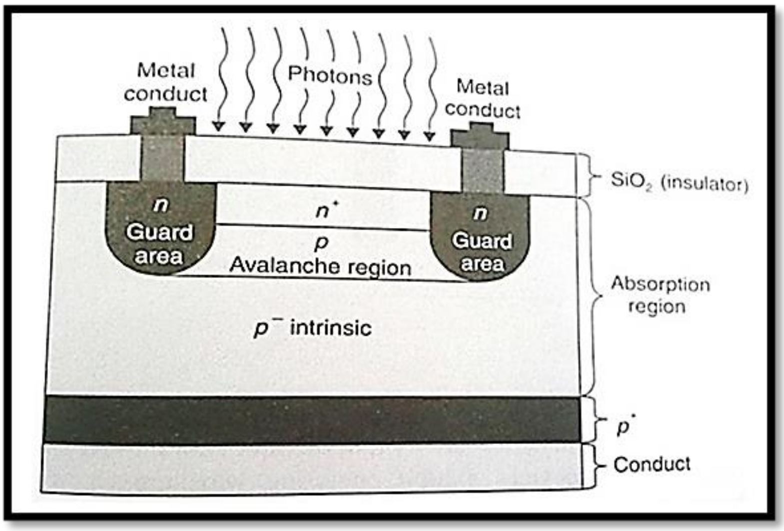


Figure 2.21: Avalanche Photodiode (APD) Operations

Characteristics of APD Photodiode

- Higher output signals can be achieved by an avalanche diode
- It has the advantages of a good output at low light levels and a wide dynamic range. For example, it can handle high and low light levels.
- However there are a number of disadvantages which tend to outweigh the benefits.
- It has higher noise levels, costs more, generally requires higher operating voltages and its gain decreases with an increase in temperature.

2.4 EXERCISE

EXERCISE 2.1

List out THREE (3) main components in Fiber Optic Communication System.

EXERCISE 2.2

Why LED and ILD are mostly used in Fiber Optic Communication System? Explain.

EXERCISE 2.3

What is the advantages of fiber optic cable?

EXERCISE 2.4

What are the importance requirements of a photodiode?

EXERCISE 2.5

Explain the operation of ILD with suitable diagram.

EXERCISE 2.6

Explain the operation of PIN photodiode with suitable diagram.

3. OPTICAL MEASUREMENT AND TESTING

INTRODUCTION

- ❑ Fiber Optic Test Procedure (FOTP)
- ❑ The safety rules when working with fiber
- ❑ Fiber optic test equipment
- ❑ Fiber optic measurement and test procedure

3.1 OPTICAL MEASUREMENT

3.1.1 FIBER OPTIC TEST PROCEDURE (FOTP)

Fiber optic measurements is measuring the power in the light coming out of the end of a fiber. The most basic fiber optic measurement is optical power from the end of a fiber. The measurement may be optical power from a test source, a transmitter or the input of receiver.

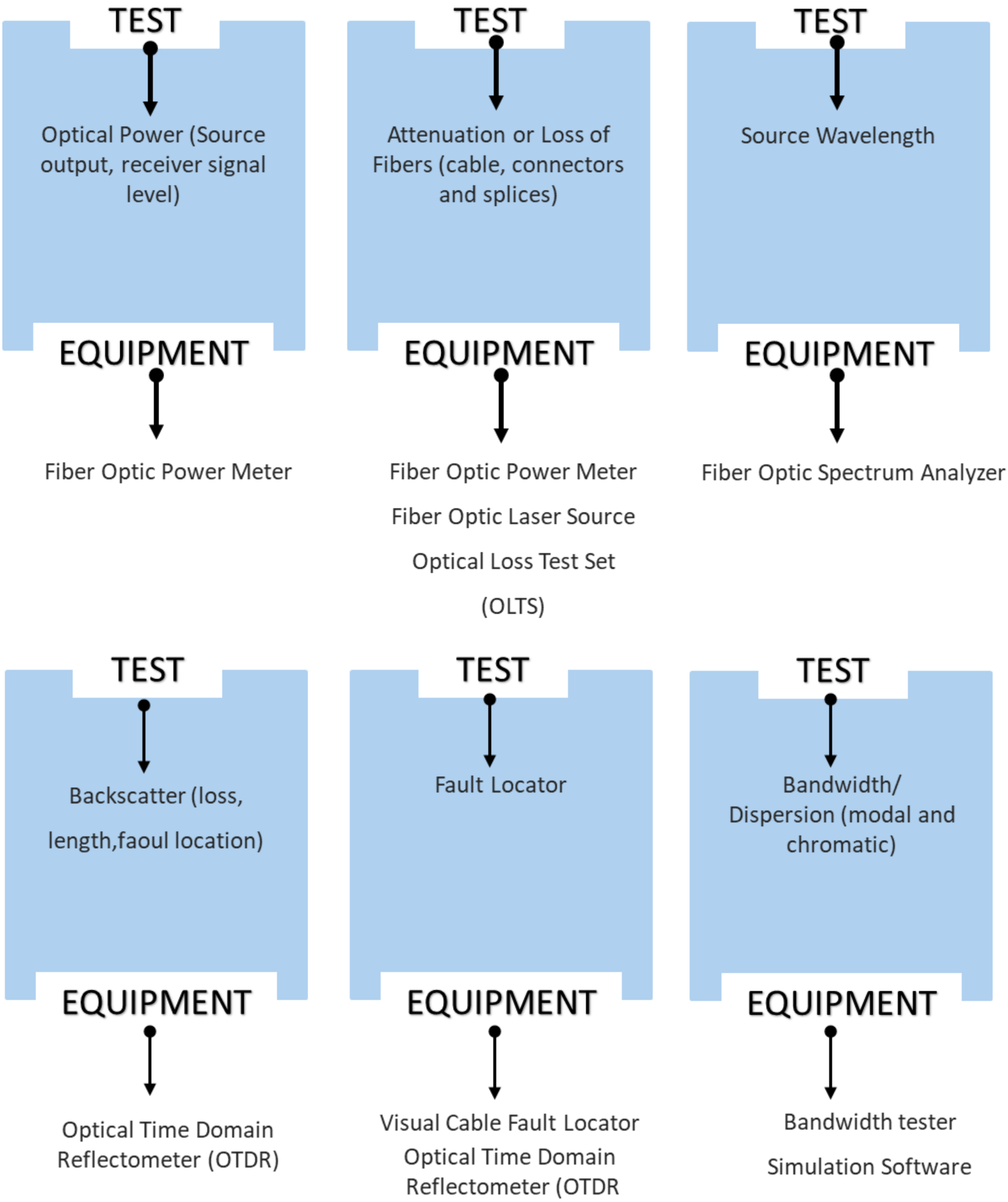
Fiber Optic Testing is used to evaluate the performance of fiber optic components, cable plants and systems. As the components like fiber, connectors, splices, LED or laser sources, detectors and receivers are being developed, testing confirms their performance specifications and helps understand how they will work together. Designers of fiber optic cable plants and networks depend on these specifications to determine if networks will work for the planned applications.

FOTP

How Does It Work?

3.1.2 TYPE OF FIBER OPTIC TEST PROCEDURE (FOTP)

Fiber optic test procedure requires making several measurement with measurement with the most common measurement parameter showed in figure below. For example Optical power, required for measuring source power. The equipment required is fiber optic power meter. Therefore, the picture below describes a summary about the test run performed and the equipment required. A summary below refer to Fiber Optic Testing Requirements from Fiber Optic Association.



3.1.3 IDENTIFY THE SAFETY RULES WHEN WORKING WITH FIBER

According to Safety Rules For Fiber Optic in Fiber Optic Association, they are seven steps about safety rules when working with fiber.

1. Keep all food and beverages out of the work area. If fiber particles are ingested they can cause internal hemorrhaging
2. Always wear safety glasses with side shields to project your eyes from fiber shards or splinters. Treat fiber optic splinters the same as you would treat glass splinters
3. Keep track of all fiber and cable scraps and dispose of them property. If available, work on black work mats and wear disposable lab aprons to minimize fiber particles on your clothing.
4. When finished with the lab, dispose of all scraps properly. Put all fiber scraps in the property marked container for disposal.
5. Do not touch your eyes while working with fiber optic systems until your hands have been thoroughly washed.
6. Contact lens wearers must not handle their lenses until they have thoroughly washed their hands.
7. Never look directly into the end of fiber cables, (especially with a microscope) until you are positive that there is no light source at the other end.

3.2 FIBER OPTIC TEST EQUIPMENT

Optical fiber is one of the communication systems used in Malaysia in applying light sources. After fiber optics cable are installed, they must be tested. Testing procedure is a process to verify component and system specifications in a consistent manner. Therefore, testing fiber optics requires special tools and instruments which must be chosen to be appropriate for the components or cable plants being tested. The following is a list of equipment required for fiber optic testing. Figure below credit to https://www.exfo.com/en/.

Fiber Optic Fault Locator

Optical Fiber Identifier

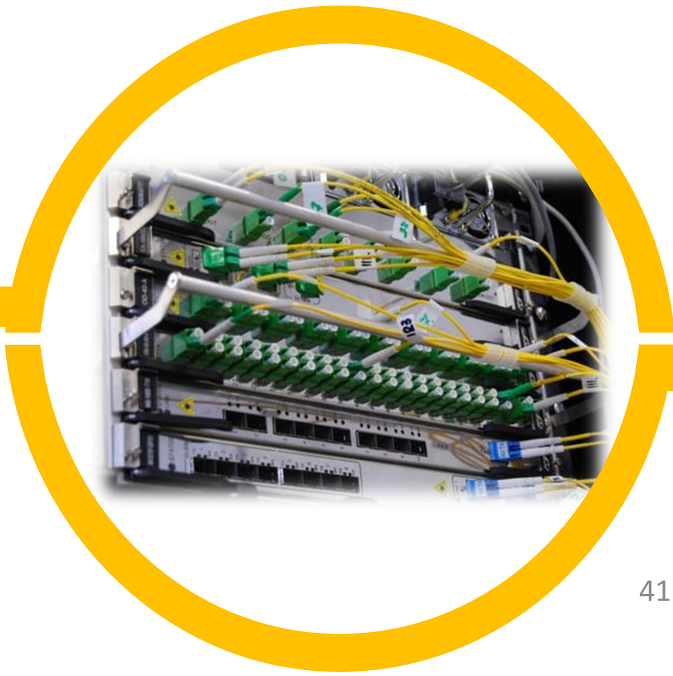
Laser Beam Analyzer

Fiber Optic Power Meter

Fiber Optic Test Source

Optical Spectrum Analyzer

Optical Time Domain Reflectometer



3.3 OPTICAL POWER MEASUREMENT

The most basic fiber optic measurement is optical power from the end to a fiber. This measurement is the basis for loss measurements as well as the power from a source or presented at a receiver. Typically both transmitter and receivers have receptacles for fiber optic connector, so measuring the power of a transmitter is done by attaching a test cable to the source and measuring the power at the other end. At receivers side, one disconnects the cable attached to the receiver receptable and measures the output with the meter. Figure 3.0 show about basic optical power measurement.

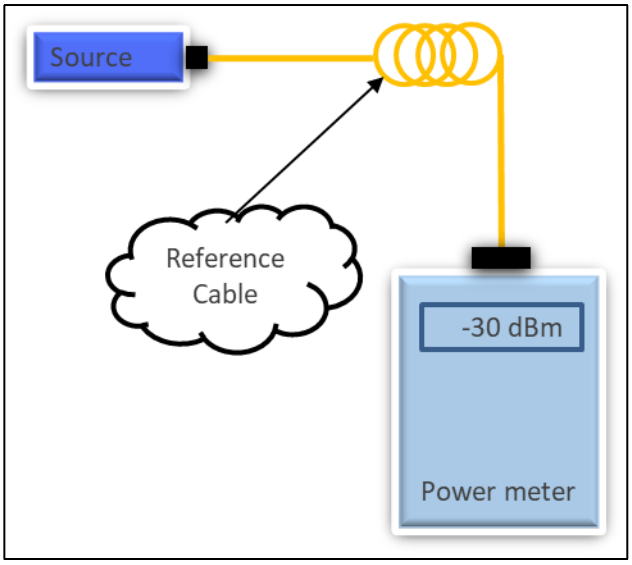


Figure 3.1 : Basic Optical Power Measurement

Measurement of optical power are expressed in units dBm. The “m” in dBm refer to the reference power which is 1 milliwatt. This is Based on the TIA and IEC standards stated in the Fiber Optic Association: Reference Guide dBm is used for power measurement.

$$\text{dBm} = 10 \text{ Log} \left(\frac{Measure\ Power}{1mW}\right)$$

Refer to the standards from Fiber Optic Association FOA 3:Measuraing Optical Power In Fiber Optic Systems, this test will measure the optical power exiting the end of a fiber optic cable. This test is commonly used to measure the coupled power of a fiber optic source in a transmitter, power into a receiver or for setting references for optical loss measurements.

EQUIPMENT NEEDED TO PERFORM MEASURING POWER

1

Calibration

Fiber optic power meter calibrated at the same wavelength as the source output (e.g. multimode: 850 and/or 1300nm, single mode, 1310, 1490 and/or 1550 nm, POF 650 nm) capable of measuring optical power in the power range of the source.

2

Adapter ⟷ Connector

Optical power meter adapters to mate to connector type on cable.

3

Cable Type ⟷ Connector

Optical power meter adapters to mate to connector type on cable.

4

Cleaning supplies

After steps 1, 2 & 3 are set and match then the power supply is given.

TEST PROCEDURE TO MEASURING POWER

1. **ON Meter**
   Turn on meter and allow time to warm-up

2. **Setting to unit dBm**
   Set meter to wavelength of source and “dBm” to measure calibrated optical power.

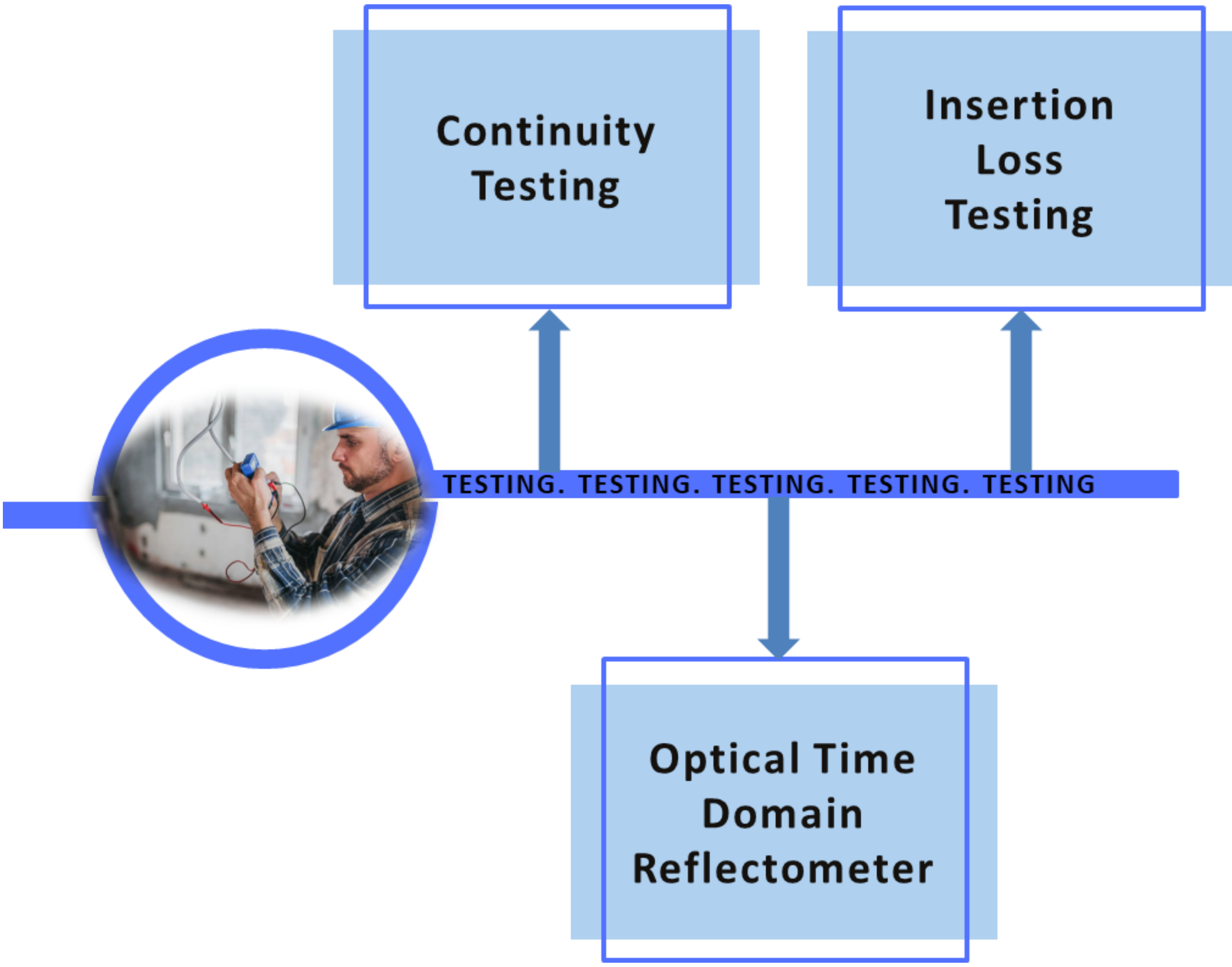
3. **Clean Connector**
   Clean all connectors and mating adapters. Using fiber cleaner.

4. **Reference Cable → Source**
   Attach reference cable to source if testing source power or disconnect cable from receiver.

5. **Power Meter → End Cable**
   Attach power meter to end of cable and read measured power.

3.4 FIBER OPTIC TESTING

Testing of fiber cables installed on the premises is a compulsory procedure to enable the system to work properly. After installation, test each fiber in all fiber optic cables for verification of installation performance and in conformance with applicable standards. According to NECA/FOA 301-2016 Standard for Installing and Testing Fiber Optics several testing procedures can be performed. The procedure is Continuity Testing, Insertion Loss Testing and Optical Time Domain Reflectometer.



3.4.1 Continuity Testing

Data transmission system using fiber optic cable is a rapidly growing system in Malaysia. Before installing the fiber optic cable that will form the network, a test needs to be done to ensure it can transmit data without any attenuation. One such test is Continuity Testing. Refer to NECA/FOA 301-2016 Standard for Installing and Testing Fiber Optics, Continuity Testing is to determine that the fiber routing and/or polarization is correct and documentation is proper. Perform continuity testing of optical fibers using a visual fiber tracer, visual fault locator, Optical Loss Test Set, Power Meter and Source.

CONTINUITY TESTING

Connect equipment to connector

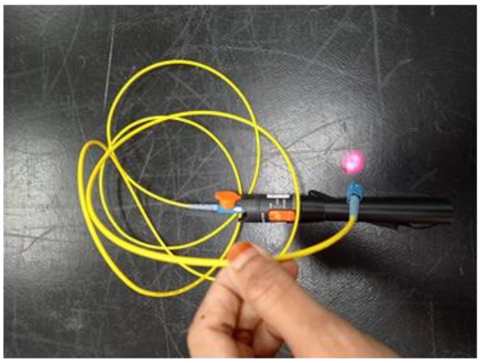
1

Attach your fiber optic tracer or visual fault locator to the connector of the cable being tested.

Send light to cable

2

Send a light signal into the cable. While you're doing this, watch the other end of the cable closely. If light is detectable in the fiber core, this means there are no breaks in the fiber, and that your cable is fit for use.



Fiber Microscope

3

Using the fiber microscope, inspect the connectors' fiber ends to ensure that they are smoothly polished and able to provide effective connection and transmission.

3.4.2 Insertion Loss Testing

Optical loss is a term used in many contexts in fiber optics. It simply means a reduction in optical power for example the loss caused by a component or an entire cable. The component could be a length of fiber, a splice, a connection made between two connectors or a passive component like an attenuator splitter or switch. The cable could be a patch cord or an installed cable plant.

The primary test for these is an insertion loss test, test that uses a test source and optical power meter to measure the difference in power when the component is inserted in the test setup. For a cable plant, the insertion loss test uses a test source and power meter to simulate the transmitter and receiver of a communications link.

Variations of this test are used for practically every loss test in fiber optics. Insertion loss test comes from the fact that one performs the test by inserting the components under test between a test source and power meter. This test will measure the loss of a fiber optic cable single mode or multimode including connector on each end individually as shown in the figure below.

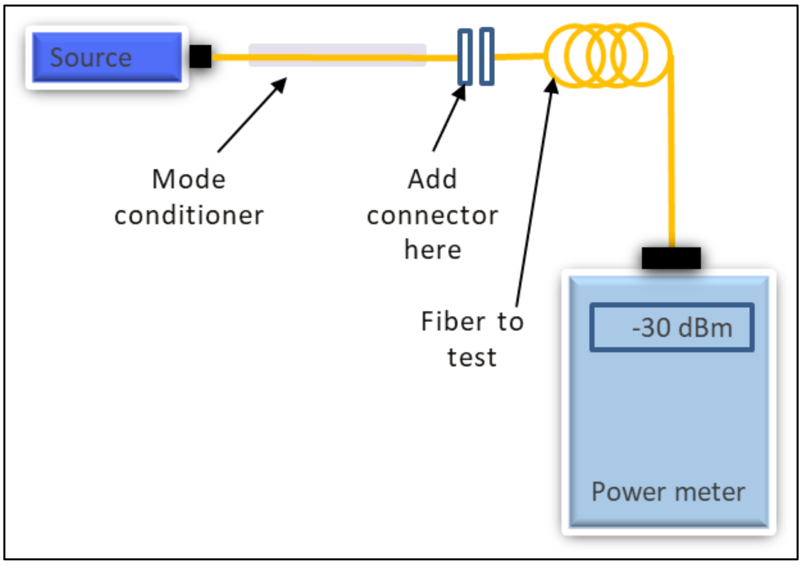


Figure 3.2 : Insertion Loss Test

There are three types of testing under insertion loss testing. The testing is “0”dB reference test, patch cord test (single-ended) and cable plant test (double-ended) . Option for “0” dB reference are set before testing. Figure 3.2 shown about “0”dB reference test.

"0" dB REFERENCE TEST

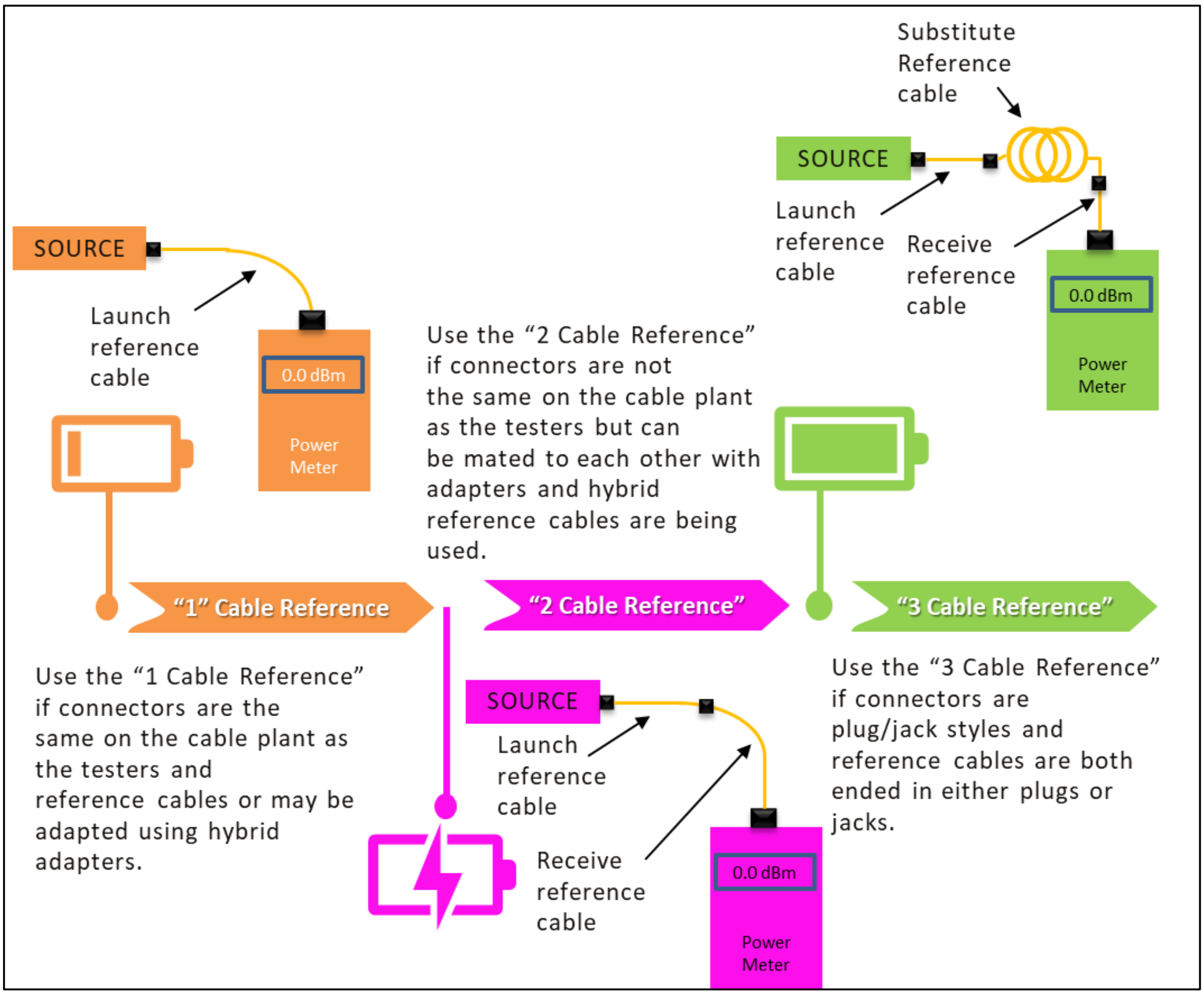
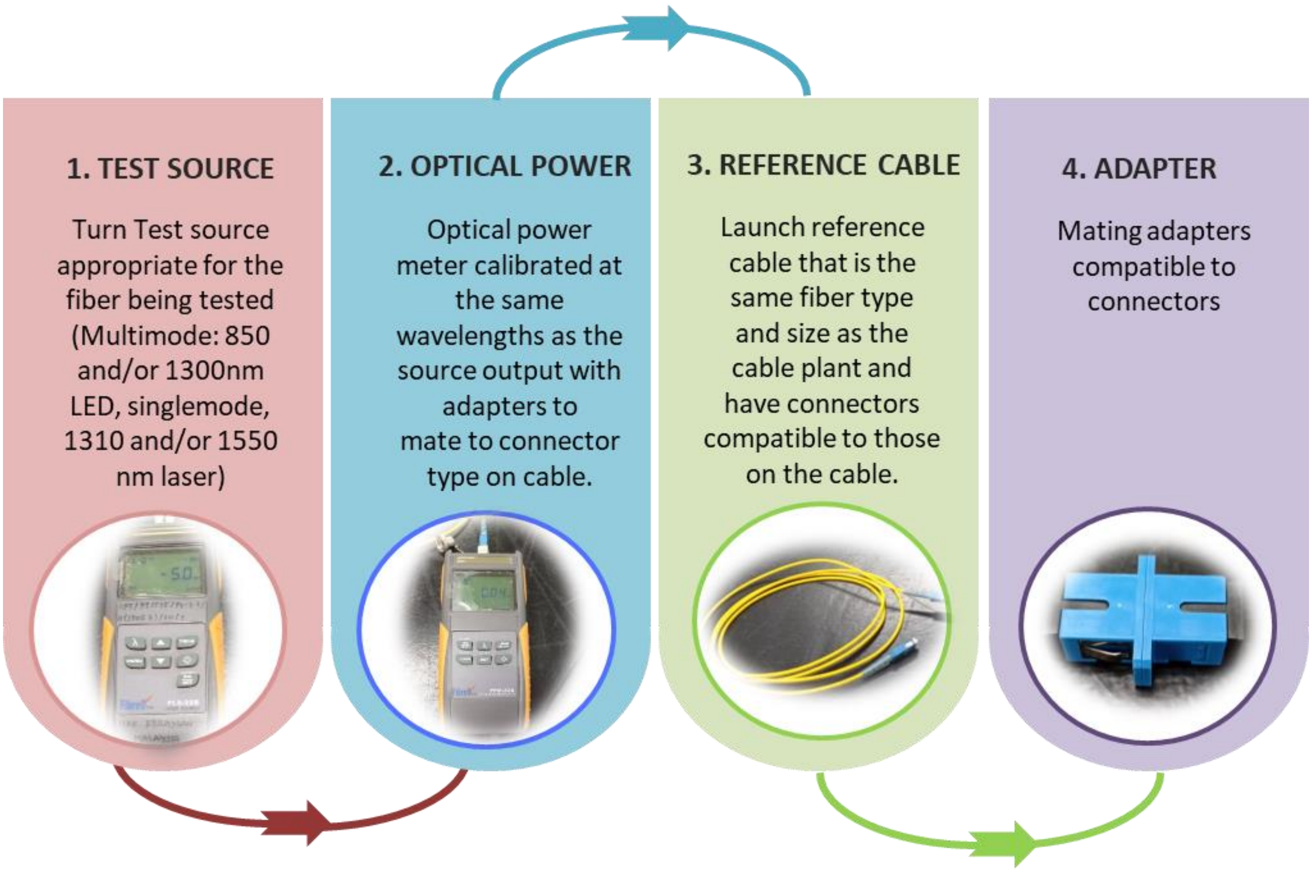


Figure 3.3 : "0" dB Reference Test

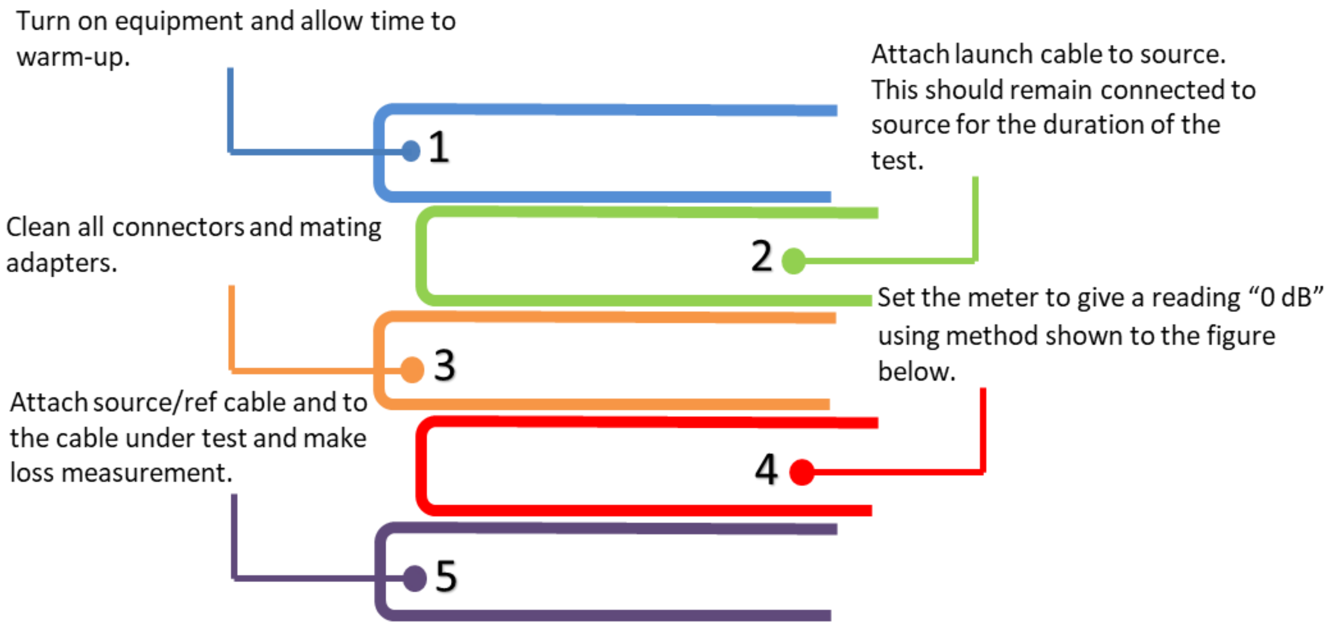
PATCHCORD TEST (SINGLE-ENDED)

This test will measure the loss of a fiber optic cable, single mode or multimode, including connectors on each end individually. Equipment needed to perform this test is test source, power meter, launch reference cable and adapters. After that, set and match then the power supply is given. Refer infographic below.



The infographic described above is based on the FOA-02 standard. Next to describe the test procedure, refer to the infographic on the site for performing a patch cord test (single-ended)

TEST PROCEDURE



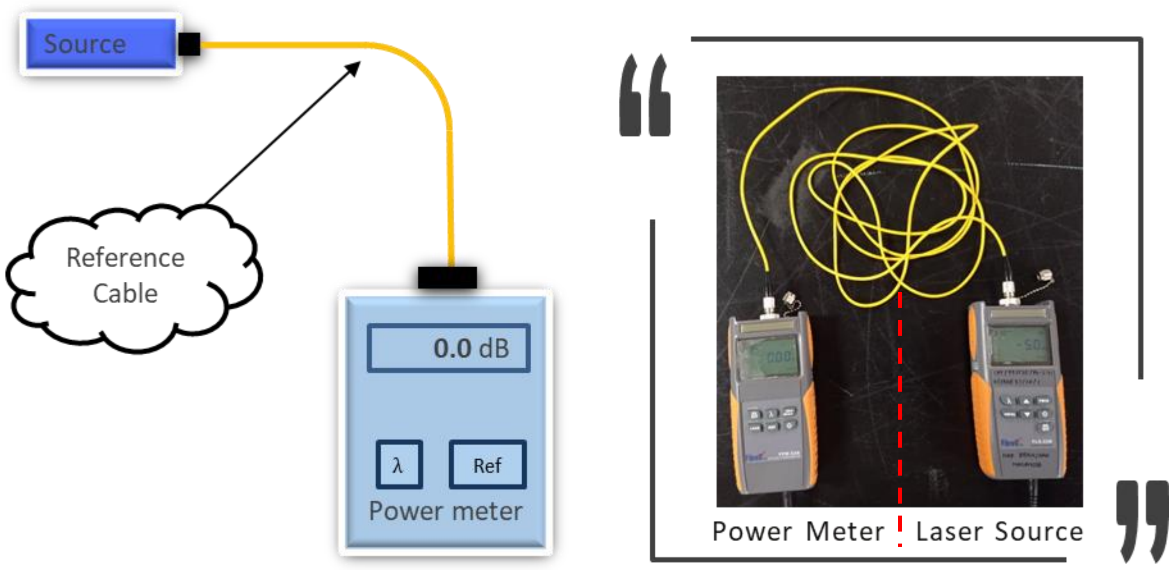


Figure 3.4 : Patchcord Test (Single-Ended)

Tips: To set "0" dB reference on the power meter is to press the 'Reference' or 'Ref' button for two seconds until the buzzer sounds. Then the screen on the power meter will show a reading of "0.0 dB"

CABLE PLANT TEST (DOUBLE-ENDED)

This test will measure the loss of an installed fiber optic cable plant, singlemode or multimode, including the loss of all fiber, splices and connectors. The diagram below shows the installation of equipment and fiber cables if performing double-ended testing. The equipment needed and test procedure is same like patchcord test (single-ended) but there are slight differences in the parts for the “0 dB” reference setting.

For set “0 dB” reference use 1 cable reference, 2 cable references and 3 cable references. This procedure is made before the measurements is performed. The steps to create a “0 dB” reference test are the same as discussed in the insertion loss test section.

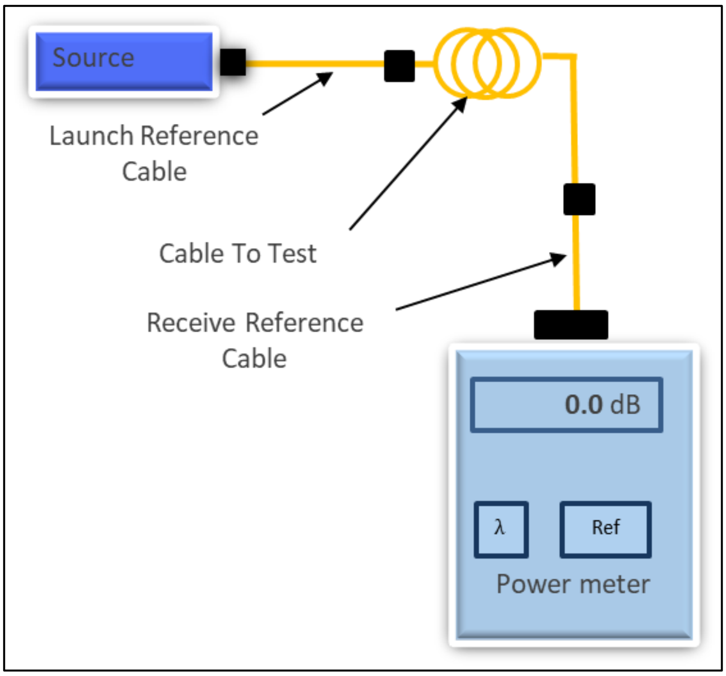


Figure 3.5: Cable Plant (Doudle-Ended)

Options for “0 dB” Reference and SET BEFORE Testing

3.4.3 Optical Time Domain Reflectometer Testing (OTDR)

Optical OTDR testing creates a snapshot of a fiber optic cable. This test is commonly used to verify the quality of the installation and troubleshoot problems. OTDR testing requires interpretation of the data acquired, called the trace or signature, by a skilled operator. OTDR testing uses backscattered light from the optical fiber to create a diagram, called a “trace” or “signature” of the cable plant being tested. The OTDR needs access to only one of the optical fiber to perform testing, but reference cable are needed at both ends of the cable plant to allow testing connectors on each of the cable. The diagram below shows the equipment installation and testing using OTDR.

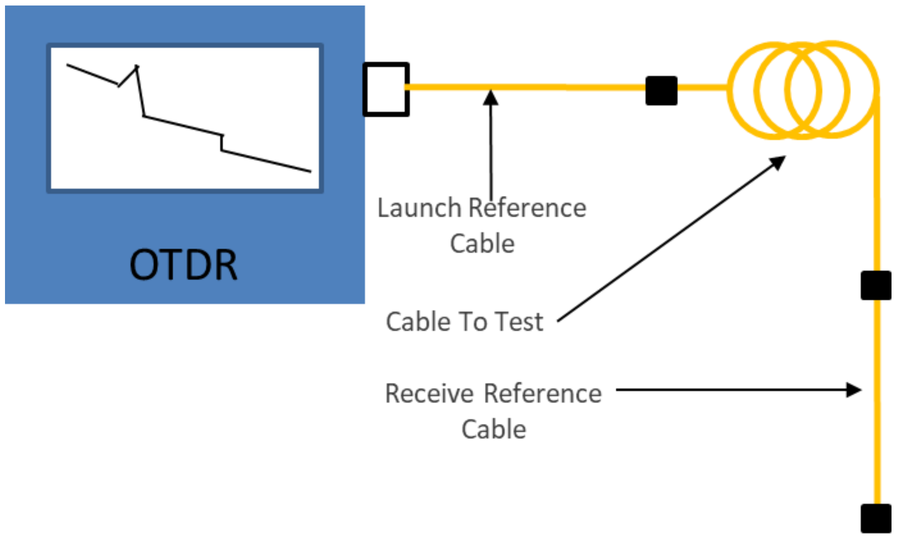
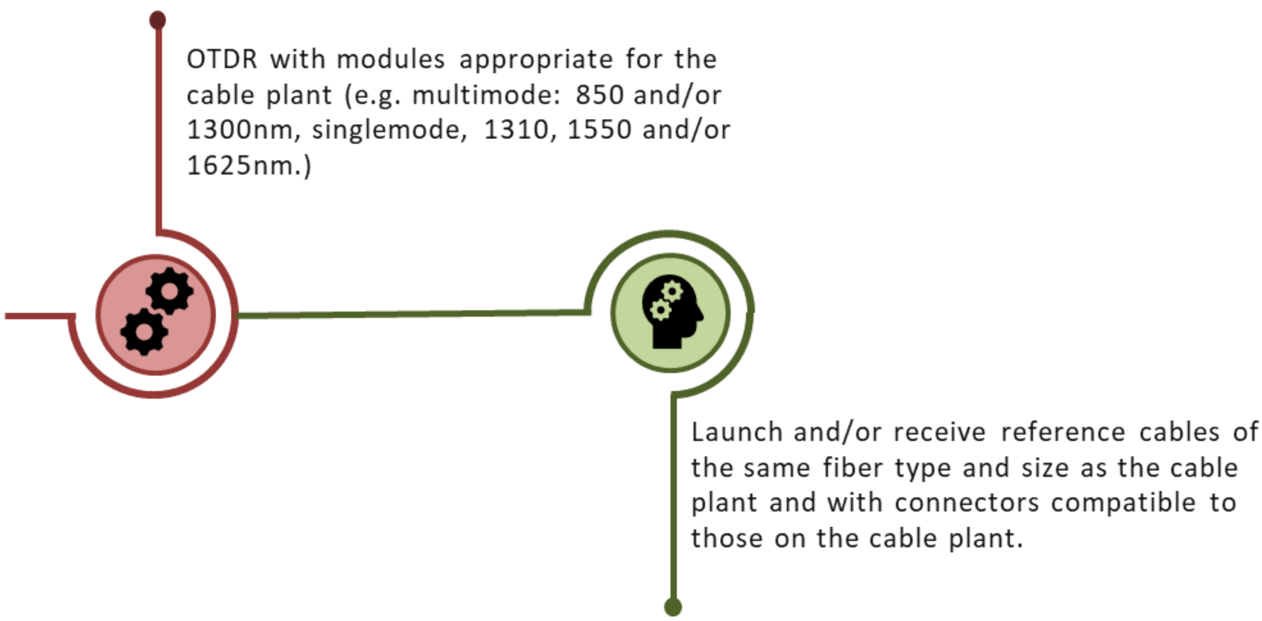
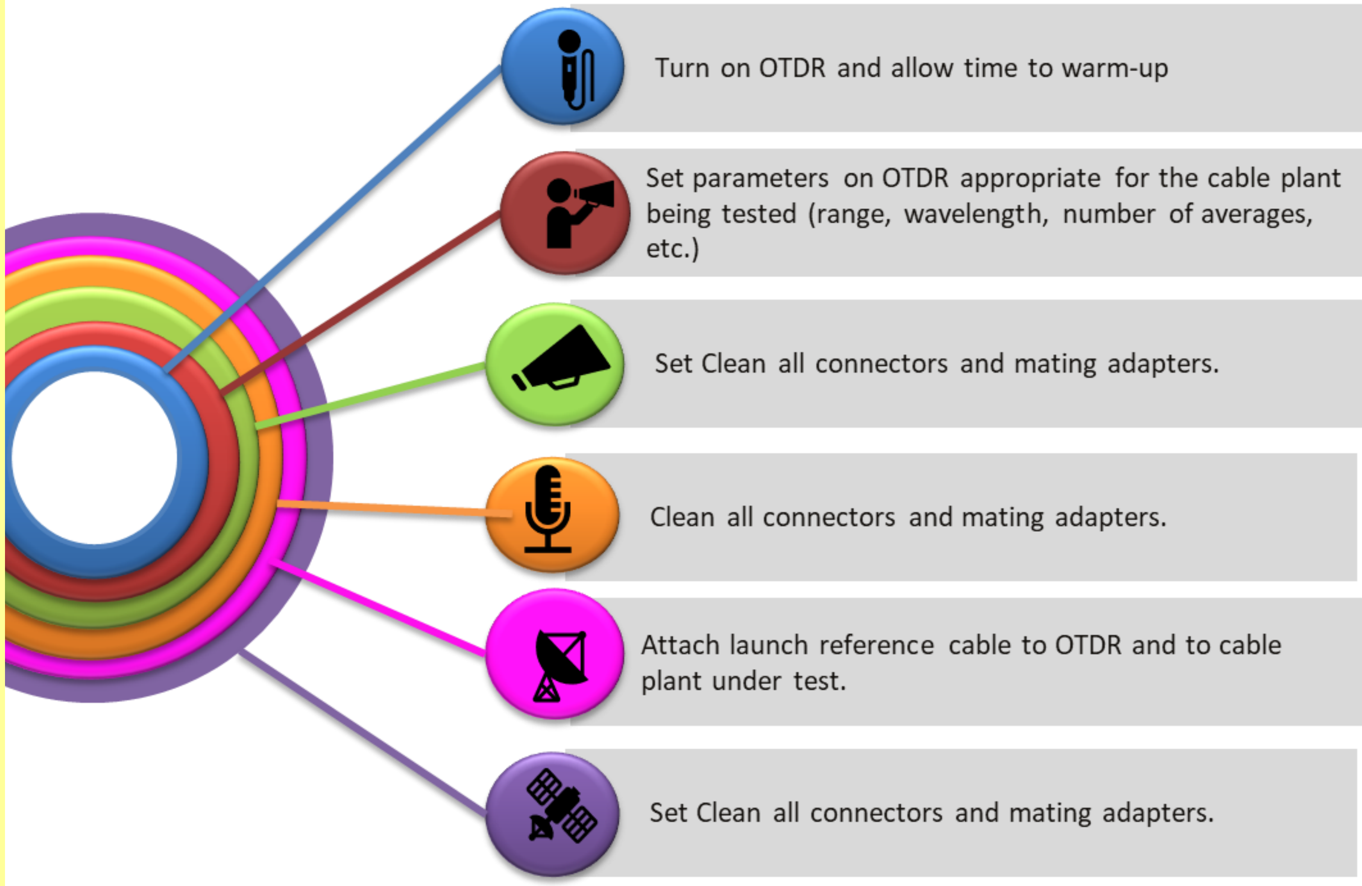


Figure 3.6 : OTDR Connection

The infographic below describes the equipment required for testing using OTDR.



TEST PROCEDURE FOR OTDR TESTING



Options for OTDR Testing :

- Use of the receive reference cable is optional, it is required if the far end connector loss is to be measured and included in total cable plant loss
- Testing at more than one wavelength maybe required. Longer wavelength testing is often used to find stress related to installation problems. Traces may be compared for analysis.

INFORMATION IN OTDR TRACE

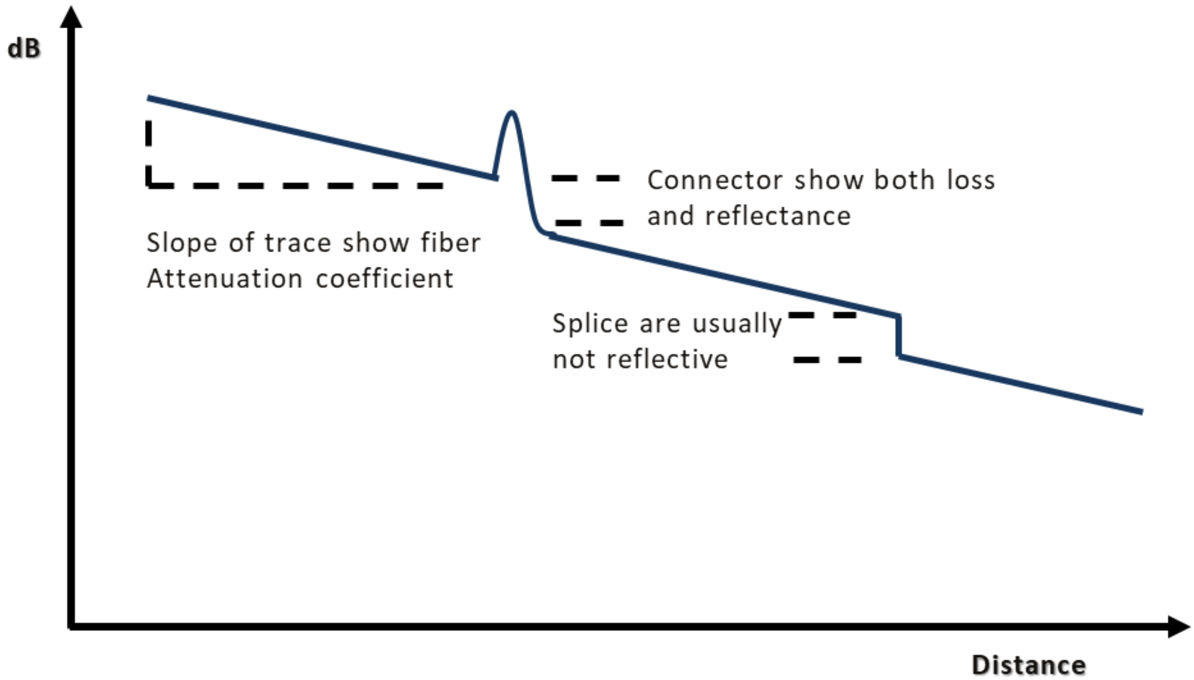


Figure 3.7 : OTDR Trace

- Insertion loss testing of the cable plant is recommended for acceptance testing.
- Not all cable plants are long enough for OTDR testing. Ensure the OTDR has sufficient resolution for the cables being tested.
- Always use a launch cable long enough to allow the OTDR to recover from test pulse overload and permit proper testing of the cable plant.
- Do not use the OTDR automatic cable analysis until a skilled technician analyzes a trace and confirms it is appropriate for the cable plant under test.

OTDR DISPLAY

The OTDR consists of a high power laser transmitter that sends a pulse of light down the fiber. Back-scattered light and reflected light returns to the OTDR through the fiber and is directed to a sensitive receiver through a coupler in an OTDR front end. For each measurement, the OTDR sends out a very high power pulse and measures the light coming back over time. At any point in time, the light an OTDR sees is the light scattered from the pulse passing through a region of the fiber.

Since it is possible to calibrate the speed of the pulse as it passes down the fiber from the index of refraction of the glass in the core of the fiber, the OTDR can correlate what it sees in backscattered light with an actual location in the fiber. Thus it can create a display of the amount of back scattered light at any point in the fiber along its length. The diagram below shows an OTDR display illustrating connector, fusion splice, fibre bend, mechanical splice and the end of connection on an OTDR.

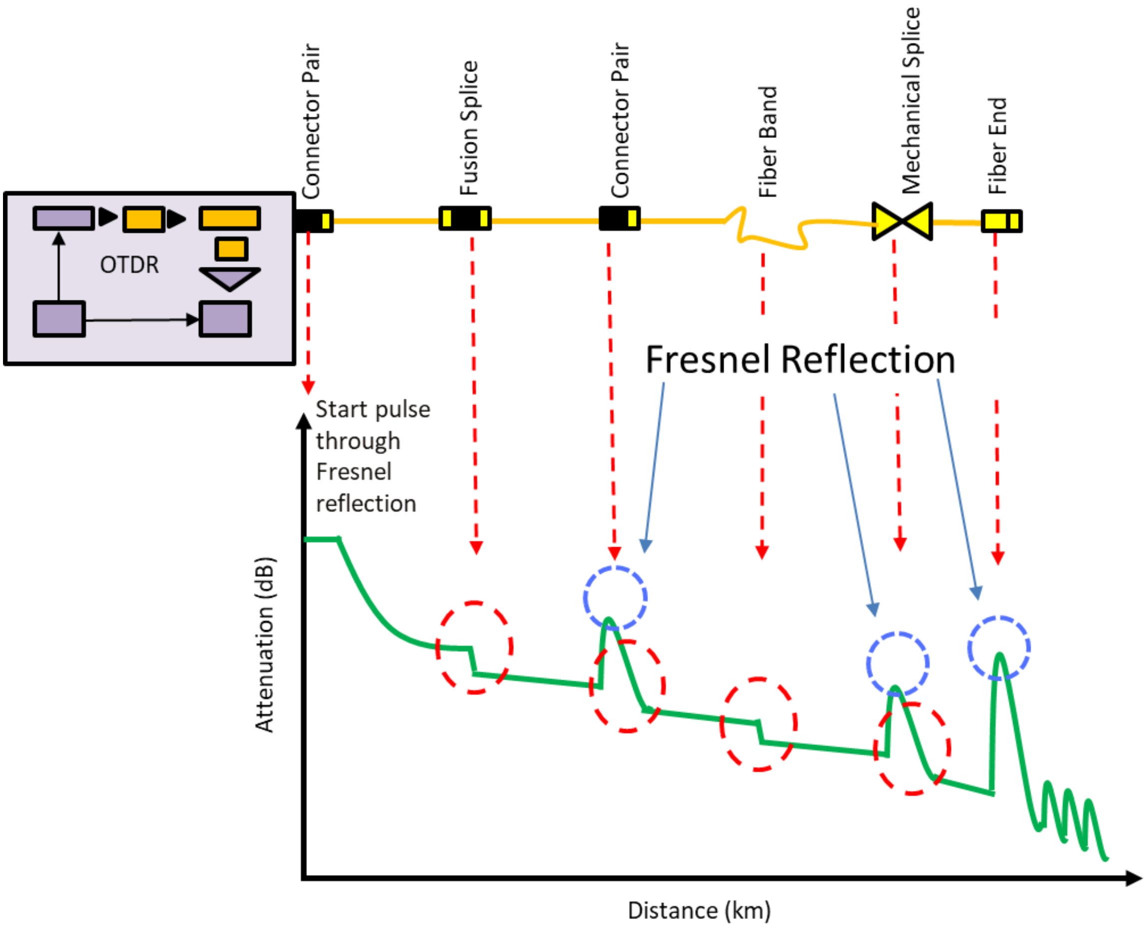


Figure 3.8 : OTDR Display 1

ANOTHER OTDR DISPLAY

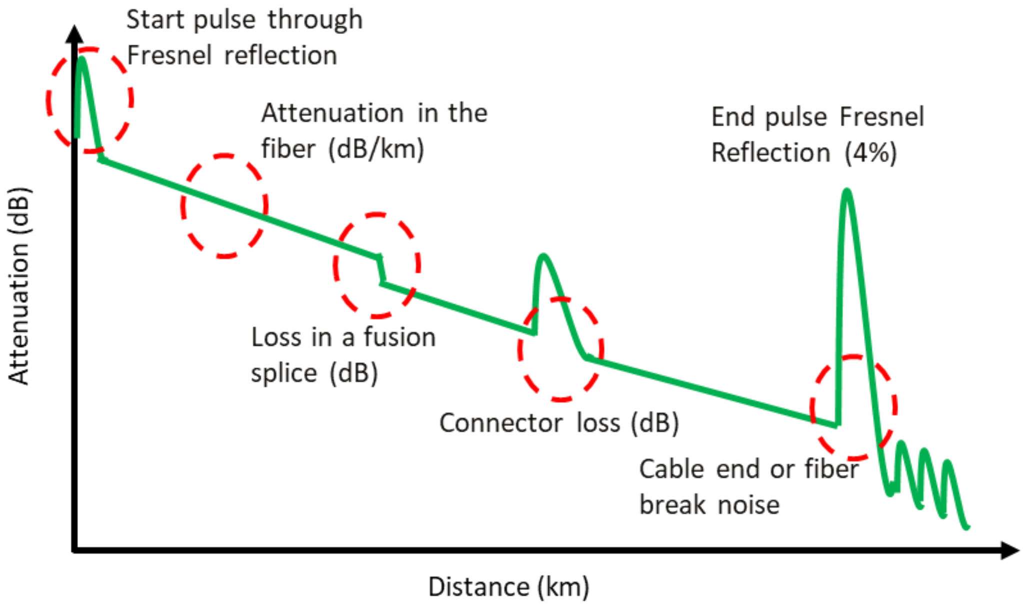


Figure 3.9 : OTDR Display 1

3.5 EXAMPLE AND EXERCISE

EXAMPLE 3.1

List FOUR (4) types of fiber optic test equipment.

SOLUTION

- Fiber Optic Falut Locator
- Fiber Optic Power Meter
- Fiber Optic Test Source
- Laser Beam Analyzer
- Optical Fiber Identifier
- Optical Spectrum Analyzer
- Optical Time Domain Reflectometer (OTDR)

(choose only four answer)

EXAMPLE 3.2

Identify FOUR (4) safety rules when working with fiber optic

SOLUTION

- Keep all food and beverages out of the work area. If fiber particles are ingested they can cause internal hemorrhaging
- Always wear safety glasses with side shields to project your eyes from fiber shards or splinters. Treat fiber optic splinters the same as you would treat glass splinters
- Keep track of all fiber and cable scraps and dispose of them property. If available, work on black work mats and wear disposable lab aprons to minimize fiber particles on your clothing.
- When finished with the lab, dispose of all scraps properly. Put all fiber scraps in the property marked container for disposal.
- Do not touch your eyes while working with fiber optic systems until your hands have been thoroughly washed.
- Contact lens wearers must not handle their lenses until they have thoroughly washed their hands.
- Never look directly into the end of fiber cables, (especially with a microscope) until you are positive that there is no light source at the other end.

(choose only four answer)

EXAMPLE 3.3

The Optical Time Domain Reflectometer (OTDR) used to find bad splices or Optical Return Loss (ORL) problems in connectors and splices in a single mode cable plant. Figure A1, show an Optical Time Domain Reflectometer (OTDR) display for 1 minute duration of a fiber optic system. It is very important to ensure that all fiber optic cables used are in good condition, therefore demonstrate the procedures for Optical Time Domain Reflectometer (OTDR) testing and draw the output graph of Optical Time Domain Reflectometer (OTDR) which indicates all the parameters mentioned.

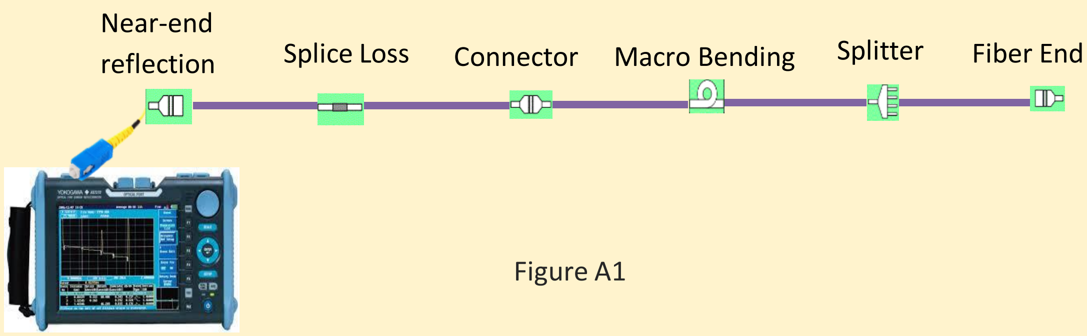
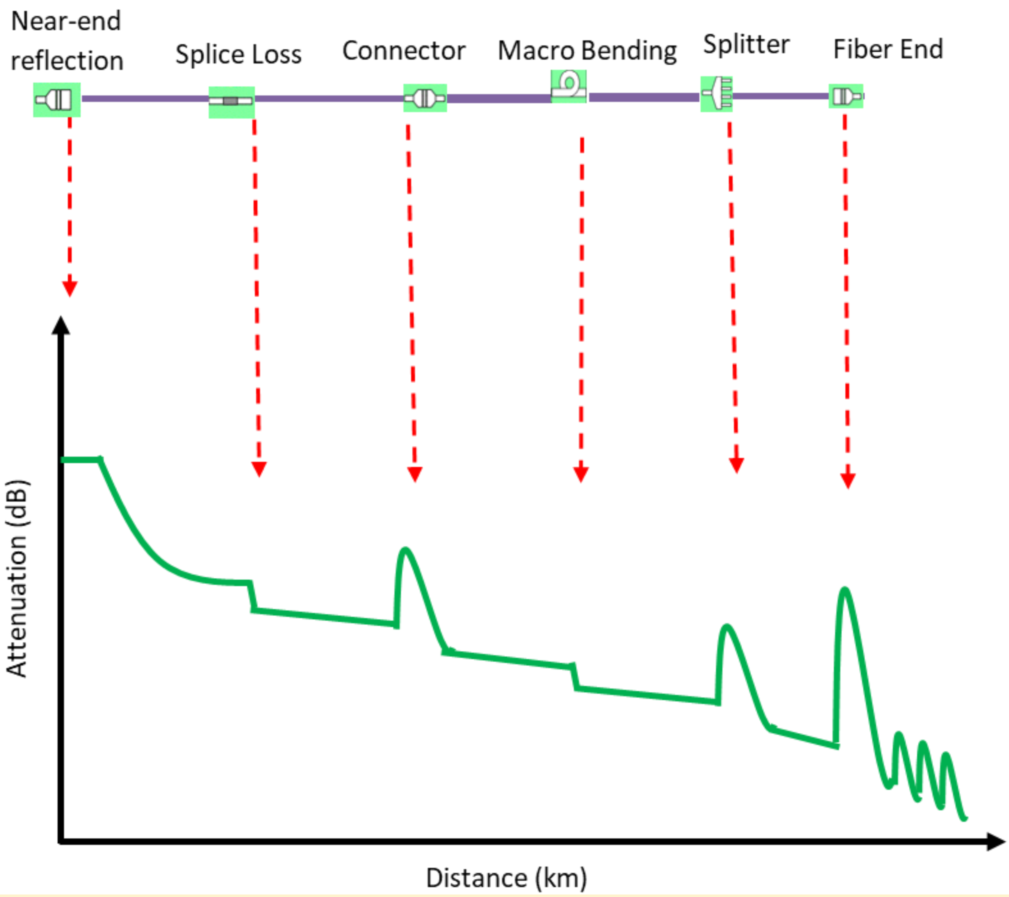


Figure A1

SOLUTION



EXAMPLE 3.4

Demonstrate SIX (6) procedures for Optical Time Domain Reflectometer (OTDR) testing used in fiber optic communication system.

SOLUTION

- Turn on OTDR and allow time to warm-up
- Set parameters on OTDR appropriate for the cable plant being tested (range, wavelength, number of averages, etc.)
- Set Clean all connectors and mating adapters.
- Clean all connectors and mating adapters.
- Attach launch reference cable to OTDR and to cable plant under test.
- Set Clean all connectors and mating adapters.

EXAMPLE 3.5

Figure A2 shows an Optical Time Domain Reflectometer (OTDR) display for fiber optic transmission system. Interpret the diagram to determine the event labelled A,B,C,D and E.

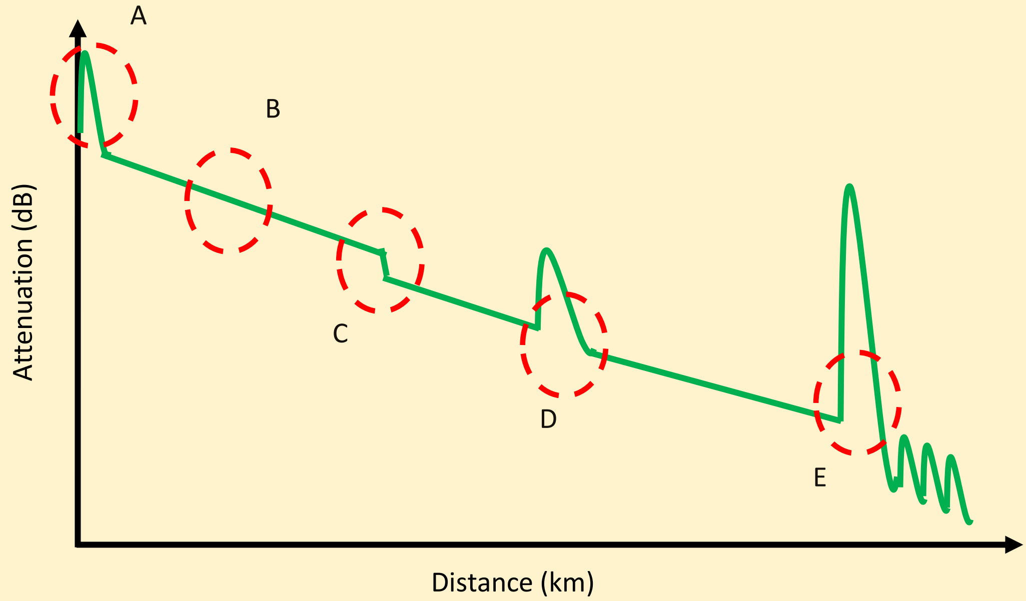


Figure A2

SOLUTION

- **A** Start pulse through Fresnel reflection
- **B** Attenuation in the fiber (dB/km)
- **C** Loss in a fusion splice (dB)
- **D** Connector loss (dB)
- **E** Cable end or fiber break noise

EXERCISE 3.1

Identify THREE (3) types of testing that can be performed on fiber optic system.

EXERCISE 3.2

The testing of fiber optic equipment and cables is generally carried out before and after the system is installed. List step-by-step the continuity test.

EXERCISE 3.3

Carry out the complete step in order to perform Optical Power Measurement.

EXERCISE 3.4

Identify TWO(2) safety rules when working with fiber.

EXERCISE 3.5

Identify THREE (3) equipment or test gears used to perform continuity testing on a fiber optic cable to ensure no breakage or damage along the fiber optic cable.

EXERCISE 3.6

Figure A3 shows the information in the Optical Time Domain Reflectometer (OTDR) Trace. Complete the Information in the OTDR trace which is labelled as A,B,C and D.

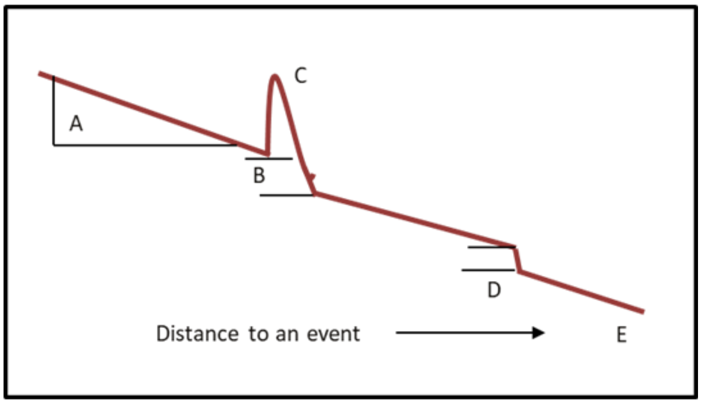


Figure A3

REFERENCES

Basic Elements of a Fiber Optic Communication System. Retrieved August 24, 2021, from https://www.elprocus.com/basic-elements-of-fiber-optic-communication-system-and-its-working/

Downing, James N (2005). Fiber-Optic Communications. Clifton Park, United States: Cengage Learning, Inc

FOA Reference Guide Fiber Optic Measurement Units:"dB" and "dBm". (n.d.). Retrieved August 24, 2021, from The Fiber Optic Association: https://www.foa.org/tech/ref/testing/test/dB.html

FOA Reference Guide. (n.d.). Retrieved August 23, 2021, from The Fiber Optic Association: https://www.thefoa.org/tech/ref/testing/test/visual.html

FOA Standard FOA-01 Testing Loss Of Installed Fiber Optic Cable Plant. (n.d.). Retrieved August 25, 2021, from Fiber Optic Association: https://www.thefoa.org/tech/ref/1pstandards/FOA-1.pdf

FOA Standard FOA-02 Testing Loss Of Fiber Optic Cable, Single-Ended. (n.d.). Retrieved August 25, 2021,from Fiber Optic Association: https://www.thefoa.org/tech/ref/1pstandards/FOA-2.pdf

FOA Standard Foa-3 Measuring Optical Power In Fiber Optic Systems. (n.d.). Retrieved August 25, 2021,from The Fiber Optic Association: https://www.thefoa.org/tech/ref/1pstandards/FOA-3.pdf

FOA Standard FOA-4 OTDR Testing of Fiber Optic Cable Plants. (n.d.). Retrieved August 25, 2021, from TheFIber Optic Association: https://www.thefoa.org/tech/ref/1pstandards/FOA-4.pdf

George Kennedy, Bernard Davis. (2006). Electronics Communication System. 4th Edition. New York,United States: McGraw Hill Education.

Govind P. Agrawal (2010). Fiber-Optic Communication Systems. 4th Edition. Hoboken, United States:John Wiley and Sons Ltd.

Jim Hayes (2010). Fiber Optics. Technician's Manual. 4th Edition. Clifton Park, United States: CengageLearning, Inc.

Joseph C. Palais, (2005). Fiber Optic Communication. 5th Edition. Upper Saddle River, NJ, United States:Pearson Education.

REFERENCES

Keiser Gerd (2013). Optical Communications Essentials. India: McGraw Hill Education.

Laser Beam Analysis. (n.d.). Retrieved August 23, 2021, from Edmund Optics Worldwide:https://www.edmundoptics.com/c/laser-beam-analysis/719/

Optical Time Domain Reflectometer (OTDR). (n.d.). Retrieved August 24, 2021, from The Fiber OpticAssociation: https://www.thefoa.org/tech/ref/testing/OTDR/OTDR.html

Quantum Dots and Colors Worksheet Answers. Retrieved August 24, 2021, from https://www.teachengineering.org/content/uoh/activities/uoh_nano/uoh_nano_lesson02_activity3_worksheetas_v4_tedl_dwc.pdf

Rangkaian Laser pada Alarm Sistem Keamanan. Retrieved August 24, 2021, from www.hoo-tronik.com

Safety Rules For Fiber Optics. (n.d.). Retrieved August 23, 2021, from The Fiber Optic Association: https://www.thefoa.org/SafetyPoster.pdf

Simple Photodiode. Retrieved August 23, 2021, from https://www.researchgate.net/figure/Structure-of-a-Simple-Photodiode_fig3_333647264

*Spectrum (2021). Laser Diode. Retrieved August 24, 2021, from*https://spectruminfotech.in/2021/09/04/laser-diode/

Standard for Installing and Testing Fiber Optic. (2016). National Electrical Contractors Association.Retrieved August 28, 2021, from https://www.thefoa.org/NECA301.html

Sudhir Warier (2017). The ABCs of Fiber Optic Communication. Norwood, United States: Artech House.

Wayne Tomasi. (2004). Electronics Communication System. 5th Edition. United States: Pearson Education.

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