Fiber Optics and Laser Instrumentation (EIC18201) Lab Manual

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Experiment No: 01

Objective: To Observe and characterize Fiber Bragg Grating (FBG) as an optical Filter.

Apparatus Required: -

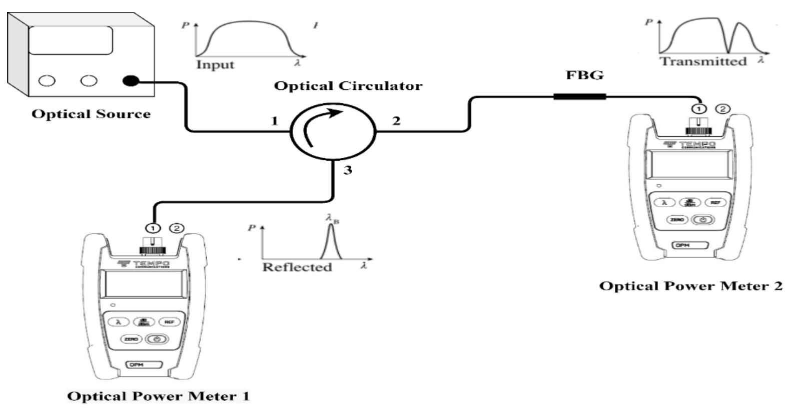
- FBG,
- Broadband light source,
- Optical circulator,
- Optical power meter,
- Connecting optical patch cables.

Theory: - FBGs can be thought of as bandpass or band-reject filter (depending upon the port observed). Whenever a broadband light source passes through a fiber inscribed with Bragg gratings, constructive interference between a forward propagating light and reflected light occurs. The conservation of momentum takes place on a particular frequency that depends upon the grating period. Thus, one of the wavelength reflects from the broadband spectrum and passes all other wavelengths; this can be observed on the optical spectrum analyser. The Bragg wavelength or reflected wavelength (λB) of FBG can be given as:

$$\lambda_B = 2.\, n_{eff}.\, \Lambda$$

Where Λ is the grating period and n_{eff} is the effective refractive index of the waveguide mode.

Block diagram of FBG based optical filter:



Procedure:

- Keep all the switches in OFF position.
- Set the optical power meter wavelength is near to the Bragg wavelength of the FBG.
- Connect Optical Source to circulator port1 through the optical patch cable and then connect the FBG with circulator through port 2 of the circulator.
- Optical power meter 1 through optical patch cable through the port 3 of the circulator for the reflection power of the FBG.
- Optical power meter 2 connect to the other port of the FBG for taking transmission power.
- Press the power switch in ON of the optical source and then enable the source button
- By changing the wavelength of the optical source and take reading of the power (dBm) of the both power meter reading.
- Plot the graph between wavelength vs reflected and transmitted power of the FBG.

Observation Table:

S.No.	Wavelength	Power (dBm)

Result: Plot the transmitting and reflecting power of the FBG with respect to the wavelength.

Experiment No. - 2

Objective: To Observe and characterize Fiber Bragg Grating (FBG) as an optical sensor.

Apparatus Required: - FBG based sensor (strain or temperature), Optical interrogator, Lan cable, System, and connecting optical patch cable.

Theory: - FBGs have demonstrated their remarkable sensing capability as well. They are sensitive to applied strain and temperature variation in its vicinity. The applied strain and temperature variation produce a change in grating period and effective refractive index of fiber Bragg grating, which produces red or blue shift in Bragg wavelength depending upon the nature of strain and temperature. The change in Bragg wavelength (Δλ), due to applied strain (ε) and temperature variation (ΔT) is given as

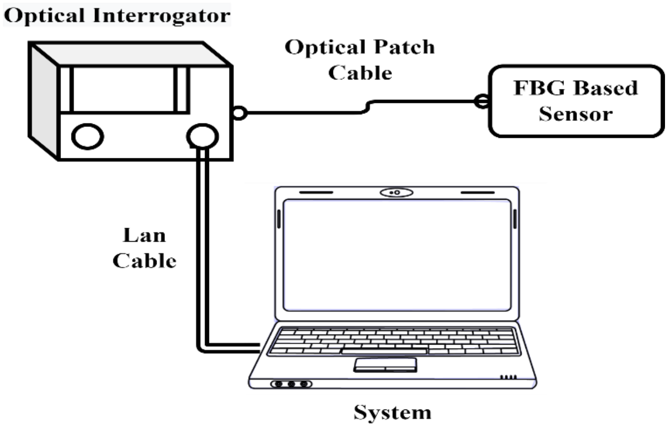
$$\frac{\Delta\lambda_B}{\lambda_B} = (\alpha + \zeta)\Delta T + (1 - P_e)\varepsilon$$

Where, α and ζ are the thermal expansion coefficient (0.55×10-6 $K^{-1}$for silica) and thermo-optic coefficient (8.6×10-6 $K^{-1}$for silica*)*, respectively. and pe is the effective strain-optic coefficient of the fiber.

FBGs can sense both temperature and strain simultaneously. While sensing any one of them (i.e., strain or temperature), it is important to know another parameter from the initial testing phase. For example, while measuring static strain, it is important to have prior knowledge of temperature change during the test to observe the exact wavelength shift due to strain.

1. FBGs are by far the most successful optical sensors due to to some of their principal advantages, such as:
2. They are small, lightweight and able to withstand harsh environmental conditions for long time.
3. These are immune to electromagnetic interferences.
4. They can be inscribed inside the fiber and can send sensing data from tens of kilometres.
5. As FBGs are passive, i.e., no electrical signal is used to operate them, they have proved themselves safe under explosive environments, which is very important for gas and oil pipeline sensing and structural health monitoring of coal mines.

Block diagram of FBG based sensor:



Procedure:

1. Keep all the switches in OFF position.
2. Connect FBG based sensor with optical interrogator using optical path cable
3. Install the Bragg Monitor DI software in the system.
4. Optical interrogator is connected with installed Bragg Monitor DI software system through the Lan cable.
5. After that press power button of the interrogator then showing Ethernet is connected in system.
6. Open Bragg Monitor DI software in the system and go to configuration panel, where seen the FBG is connected at the particular channel with showing its Bragg wavelength and power.
7. After varying the temperature or strain of the sensor and note down corresponding wavelength shift and power.

Observation Table:

S. No.	Strain or Temperature	Wavelength Shift (nm)	Power (dBm)

Result: Observed that wavelength and power of the FBG will shifted with change in temperature or strain and plot the graph between applied strain or temperature corresponding its wavelength and power.

Experiment No.-3

Objective: To study and characterize optical time domain reflectometer.

The objective of this experiment is to understand the basic working principle of OTDR, phenomenon used in OTDR to detect different faults and preparing the OTDR by setting the parameters for fiber under test.

Equipment Required:

- OTDR
- Optical Fiber
- Connectors

Theory:

In telecommunication, Optical Time Domain Reflectometer is a portable optoelectronic instrument used to characterize an installed optical fiber link. OTDR tester are widely used for optical cable testing, maintenance and construction, and it can be used for evaluating the parameters such as fiber cable length, fault in the fiber such as breakage, bending loss, attenuation, etc; losses due to splices and connectors in the system, reflectance level. OTDR technology is designed to provide a single ended test of any fiber cable.

OTDR is fundamentally an optical radar that have significant computing ability and a graphical display, so provide significant test automation.

1. **Basic Operating principle of OTDR**

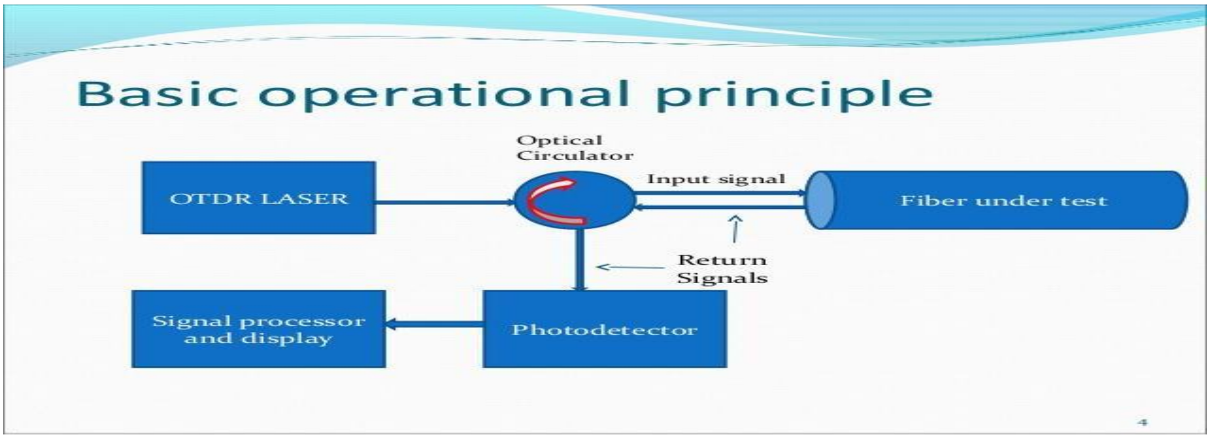


Fig 1. Working principle of OTDR

- The above figure 1. shows the basic operating principle of OTDR.
- During the process of OTDR testing, the instrument periodically launch a narrow laser pulse into a fiber under test from one end of the fiber cable by using either a directional coupler or a circulator.
- When the OTDR sends optical pulse into the fiber, due to the discontinuities such as, connectors, the engagement points, splices, bending or other similar event, there will be a scattering and reflection which return pack to the OTDR.
- Useful information returned will be measured by the OTDR detector, and act as the time or curve segments of fiber at different positions.

- Thus, the properties of the optical fiber link is then determined by analysing the amplitude and temporal characteristics of the waveform of the reflected and back scattered light.
- An typical OTDR consist of :
- Light source and receiver
- Data acquisition and processing modules
- An information storage unit.

2. Phenomenon used in OTDR to detect faults

There are two types of light levels: a constant low level created by the fiber called **"Rayleigh backscattering**" and a high-reflection peak at the connection points called **"Fresnel reflection**" Hence, OTDR use Rayleigh scattering and Fresnel reflection to characterize fibers' under test.

- **Rayleigh Backscattering**
  Rayleigh backscattering is used to calculate the level of attenuation in the fiber as a function of distance (expressed in dB/km), which is shown by a straight slope in an OTDR trace. This phenomenon comes from the natural reflection and absorption of impurities inside optical fiber. When hit, some particles redirect the light in different directions, creating both signal attenuation and backscattering.
- **Fresnel reflection**
  The second type of reflection used by an OTDR—Fresnel reflection—detects physical events along the link. When the light hits an abrupt change in index of refraction (e.g., from glass to air) a higher amount of light is reflected back, creating Fresnel reflection, which can be thousands of times bigger than the Rayleigh backscattering. Fresnel reflection is identifiable by the spikes in an OTDR trace. Examples of such reflections are connectors, mechanical splices, fiber breaks or opened connectors.

3. OTDR display

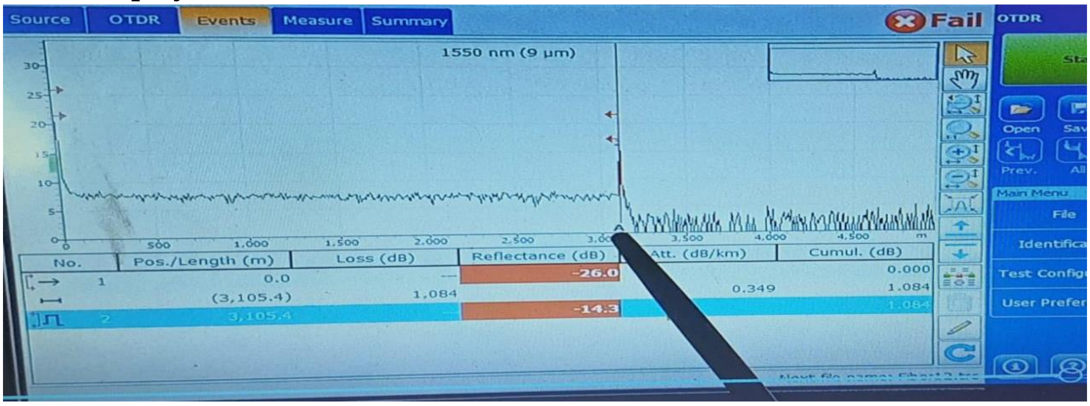


Fig 2. OTDR display

Figure.2 shows typical trace which can be seen on the display screen of an OTDR. The scale of vertical axis is logarithmic and measures the returning (back-reflected) signal in decibels. The horizontal axis gives the deal of distance between the instrument and the measurement point in the fiber.

4. **Optical trace**

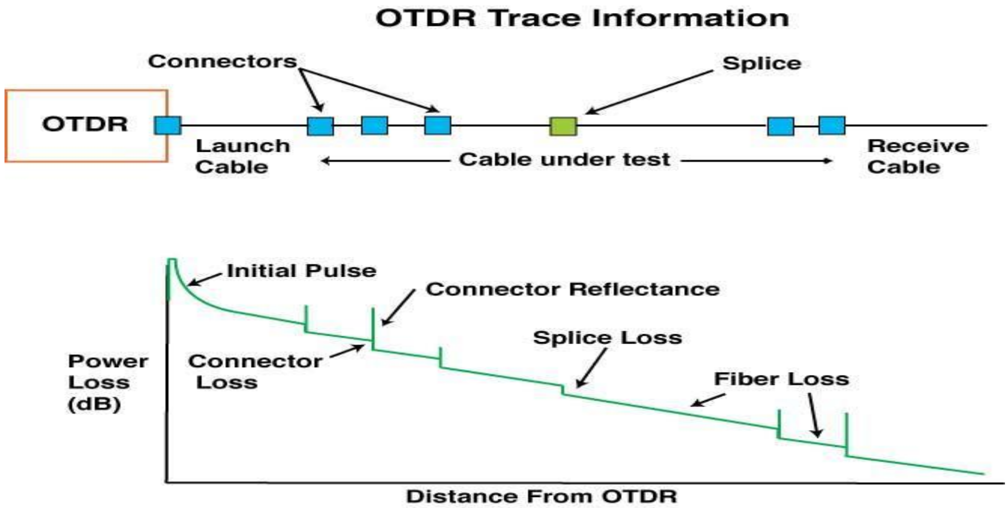


Fig 3. OTDR trace for different types of faults.

The back scattered waveform has four distinct features which can be seen from figure.3:

- A large initial pulse resulting from Fresnel reflection at the input end of the fiber.
- A long decaying tail resulting from Rayleigh scattering in the reverse direction as the input pulse travel along the fiber.
- Abrupt shift in the curve caused by optical loss at the joints or connectors in the fiber.
- Positive spikes arising from Fresnel reflection at the far end of the fiber, at fiber joints, and at fiber imperfection.

5. **Dead zone**

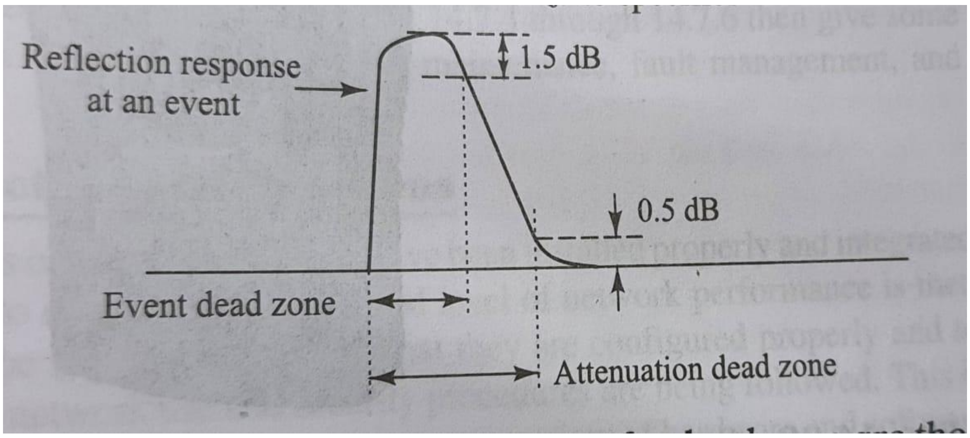


Fig 4. Dead zone

There exist two types of dead zones:

- **Event dead zone:** The importance of having the shortest-possible event dead zone allows the OTDR to detect closely spaced events in the link. If the dead zones are too long, some connectors may be missed and will not be identified by the technicians, which makes it harder to locate a potential problem. Typically vendors specify this event dead zone as the distance between the start of the reflection and -1.5 dB point on the falling edge of the reflection shown in figure.4**.**
- **Attenuation dead zone:** The attenuation dead zone indicates over which distance the photodetector in an OTDR needs to recover following a reflective event before it is again able to detect a splice. This also means that the receiver has to recover to within

0.5 dB backscattered value which can be seen from figure.4.Typical attenuation of dead zone ranges from 10 to 25 m.

Procedure:

➢ **Parameter setting for preparing OTDR to detect faults in fiber under test.**

- **Dynamic Range**: This parameter reveals the maximum optical loss an OTDR can analyze from the backscattering level at the front connector and the noise level peak at the far end of the fiber. It is expressed in decibel.
- **Measurement Range**: It deals with how far away an OTDR can identify event in the link, such as splice point, connection point, or fiber breaks.
- **Pulse Width:** The pulse width is actually the time during which the laser is on.Shorter pulse improves the resolution but longer pulses are required for higher dynamic range of our choice.
- **Acquisition Time :** corresponds to the acquisition duration i.e period during which the result will be averaged.
- **Resolution:** Sampling resolution is defined as "the minimum distance between two consecutive sampling points acquired by the instrument".This parameter is crucial, as it defines the ultimate distance accuracy and fault-finding capability of the OTDR.
- **The index of refraction (IOR)**:(also known as group index) is used to convert time of light to distance. Having the proper IOR is crucial for all OTDR measurement associated with distance.
- **The Rayleigh backscatter coefficient:** is used in the calculation of event loss and reflectance and it can usually be obtained from the cable manufacture.
- **The helix factor :** represent the ratio b/w the length of the fiber inside the cable core, the fiber length is different from the cable length.By setting the helix, the length of the OTDR distance axis is always equivalent to the physical length of the cable.

NOTE *The helix factor value takes into account the difference b/w the length of the cable and the length of the fiber inside the cable; it does not vary with wavelengths. For this reason , you can't define a different helix factor for each wavelengths*.

➢ **Different faults calculation by taking values from OTDR trace.**

- **Attenuation measurement**- Attenuation gives loss over distance.The average attenuation between two points x_1 and x_2 ,where,$x_1 > x_2$

$$\alpha = \frac{10[logP_D(x_2) - logP_D(x_1)]}{2(x_1 - x_2)}$$

- **Fiber fault location** – To locate breaks and imperfection in an optical fiber, the fiber length L (hence, the position of the break or fault) can be calculated from the difference between the pulse reflected from the front of the fiber and the event location donated by t and n_1 that is core refractive index of fiber. Thus, L is given by

$$L = \frac{c * t}{2 * n_1}$$

2 in denominator accounts for the fact that light travels a length L from the source to the break point and then another length L on the return trip.

- **ORL :-** It is define as the percentage of total reverse power in relation total forward power at particular point .The ORL can be expressed as

$$ORL = 10\, log\left(\frac{P_{ref}}{P_{inc}}\right)$$

An OTDR gives precise reflectance values at individual event along fiber transmission path

Observation:

Calculate the following for by anlayzing the OTDR trace

Wavelength (nm)	**Pulse width(s)**	**Fiber fault location**	**ORL (dB)**	**Cumulative Loss (dB)**	**Attenuation Coefficient (dB/km)**
1310					
1550					

Conclusion:

Question:

1. OTDR stands for?
2. Define helix factor?
3. What is dead zone?

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Experiment No.-4

Objective: To study different types of fault detection in fiber using OTDR operating at two different wavelengths.

The objective of this experiment is to measure and analyzing faults results such as event distance and their relative powers, event and section loss, maximum reflectance, optical return loss, attenuation coefficient, etc; in the fiber under test using OTDR.

Equipment Required:

- OTDR
- Optical Fiber
- Connectors

Theory:

In telecommunication, an optical time domain reflectometer (OTDR) is an optoelectronic instrument used to characterize an optical fiber. An OTDR is used for purposes like: fiber optic testing in fiber optic communication systems, measurements like: fiber loss per unit length, fault in the fiber, loss due to splices and connectors in the system, position of breakage of fiber in field, etc. In addition to required specialized optics and electronics, OTDRs have significant computing ability and a graphical display, so they may provide significant test automation. The selection of parameters in the measurement settings screen of the OTDR depends on the requirements. It is given as follows:

- **Range:** By selecting auto in the range display the OTDR itself selects the suitable measurement range for the fiber. Selection can also be made from the predefined ranges or the input range of our choice.
- **Pulse Width:** Short pulse improves the resolution but longer pulses are required for higher dynamic range of our choice.
- **Wavelength**: The available wavelength depends on how our module has been configured. It is meaningful if we have a dual wavelength OTDR module.
- **Meas. Mode**: The measurement mode may be real time for updating the settings while making the measurements or averaging to reduce noise level or to continue averaging the measurement that is stopped.
- **Scatter Coefficient**: It indicates how much light would be scattered back in the fiber which affects the return loss and reflectance measurements.
- **Refractive Index:** It influences the distance scale of OTDR. Generally it is set to any value between 1.0 and 2.0. We can select the refractive indices of selected cable vendors from the dialog box or manually input a desired value.
- **Front Connector Threshold:** The front connector threshold indicates the threshold for reflectance of front connector. If the reflectance is above the threshold then a warning message is displayed.
- **Reflection Threshold:** Events with the reflection above threshold are displayed in the event bar and event table.
- **Non-reflection Threshold:** Events with an insertion loss above this threshold are displayed in the event bar and table.
- **End Threshold:** The first event with an insertion loss greater than or equal to this value is declared as type end and all subsequent events are ignored. It is like setting the fiber end.

The following parameters can be measured between the marker A and marker B. The change in position of markers, change the recorded values.

1) ***2pt.L***: 2-point loss between the markers. This indicates the difference in power level between the two markers.
2) ***2pt.atten:*** 2-point attenuation. This indicates the two point loss per unit length.
3) ***LSA-Attn***: LSA attenuation indicates least square approximation for the fiber loss per unit length between the markers.
4) ***ORL***: optical return loss which indicates the fraction of power reflected to the mini-OTDR.
5) ***Four point event loss***: this uses least square approximation method to determine event loss.
6) ***Max Refl. at A/B:*** the return loss of event close to the marker.
7) ***Cum.L.to A/B:*** the cumulative loss between the initial backscatter values interpolated to the start of fiber and the marker point.

Procedure:

For analyzing the results the markers can be moved or zoom in on or out of any event or trace segment to measure splice loss, fiber section attenuation, reflectance, and optical return loss.

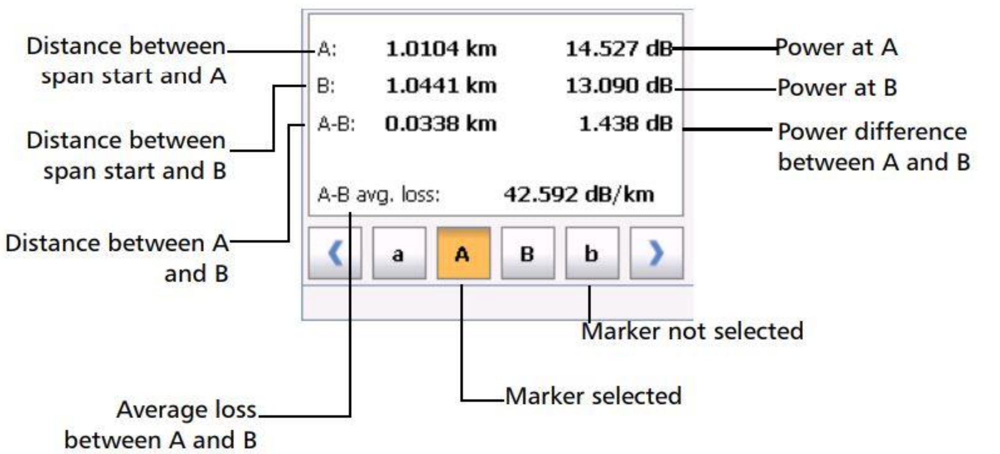
A. Using Markers

- Markers can be used to view the position and relative loss or reflectance of an event. These are available from event tab or measure tab in the main window.

To move a marker directly from the graph:

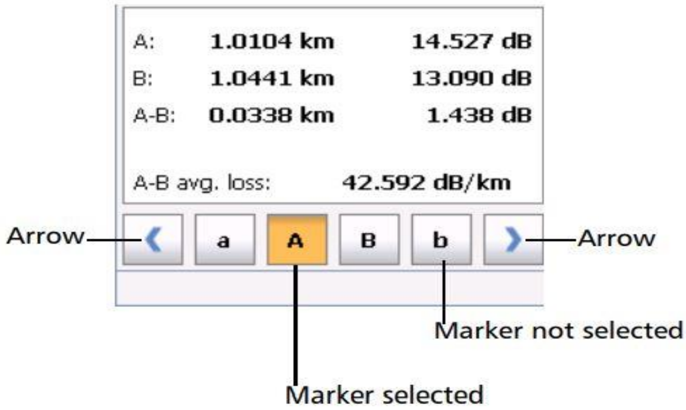
1. Ensure that the button is selected in the zoom button bar.

2. Select the marker directly on the trace display and drag it to the desired position.



To move a marker with the arrow buttons:

1. From the **Measure** tab, tap the marker buttons to select the desired markers.



2. Once the appropriate markers are selected, use the right and left arrow buttons to move the markers along the trace.

B. Getting Event distances and Relative powers

- The OTDR test application automatically calculates the position of an event and displays this distance in the event tab.
- You can retrieve the position of an event as well as distance between event manually. Distance and relative powers correspond to the x- axis and y- axis respectively**.**

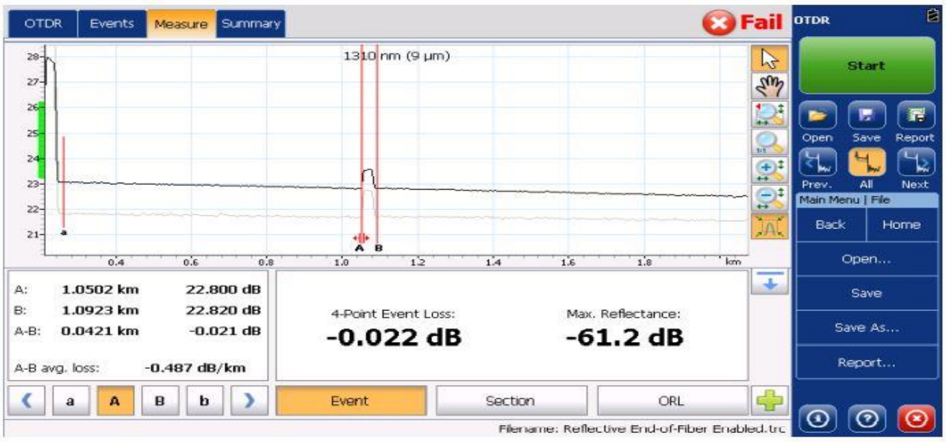
To get the distance to an event and the associated relative power level automatically:

1. From the main window, select the **Measure** tab.

2. Tap  to display all markers. Markers are automatically positioned at the right location.

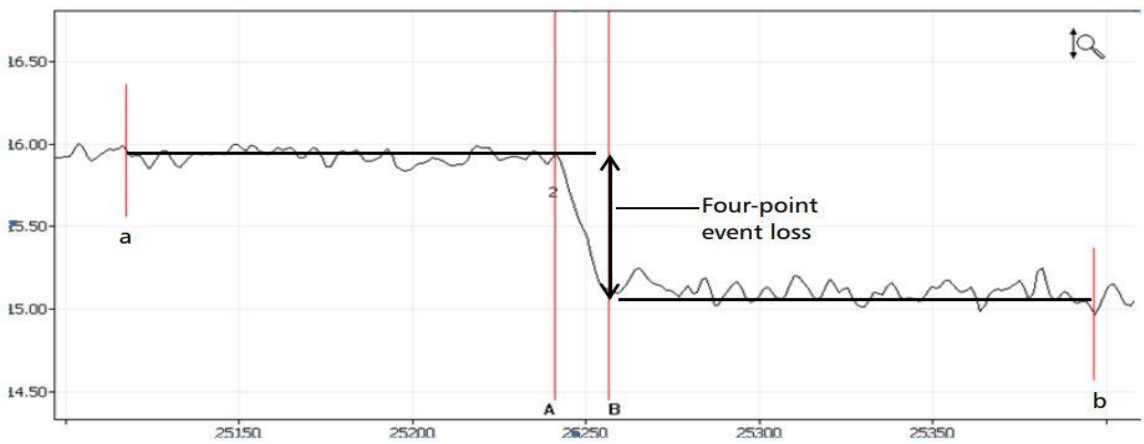
To get the distance to an event and the associated relative power level manually:

1. From the main window, select the **Measure** tab.
2. Move marker **A** to the beginning of the event. For more information about markers, see *Using Markers* on page 87.



C. Getting Event loss and Maximum Reflectance

- Event loss (dB) is calculated by measuring the signal level reduction in Rayleigh backscattering caused by this event. Event loss can result from both reflective and non-reflective events.
- The four-point event loss calculation uses the least-square approximation method to determine the event loss. LSA method is used to fit a straight line to the backscatter data within the two regions defined by markers a, A and b, B that is over the regions to the left and to the right of the event bordered by markers A and B, respectively.
- Reflectance is the ratio of reflected light to input light.

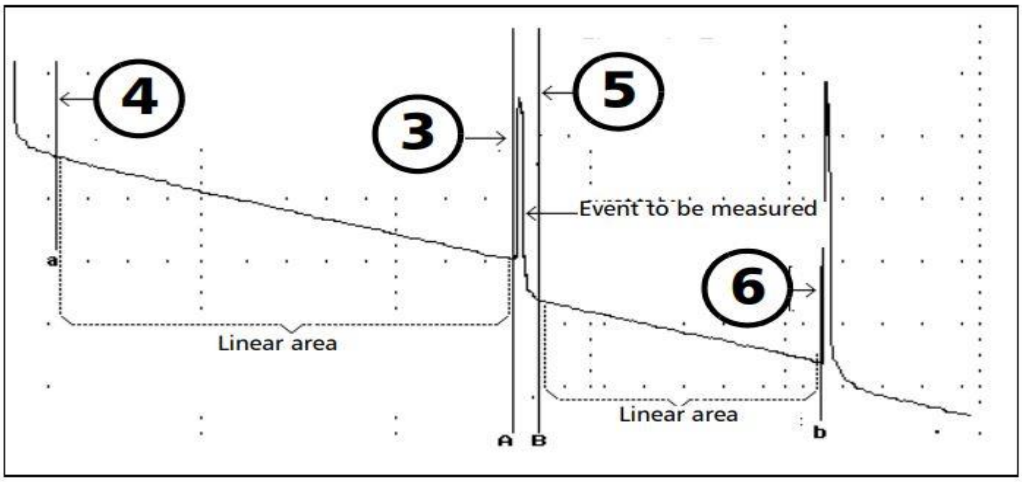


The two fitted lines are then extrapolated toward the center of the event and the loss event is directly read from the drop in power between the two lines.

To get event loss and maximum reflectance:

1. From the main window, select the **Measure** tab.
2. At the bottom of the window, tap **Event**. Markers **a**, **A**, **B** and **b** appear on the graph.
3. Zoom in and position marker **A** at the *end* of the linear area *preceding* the event to be measured. For more information, see *Using Zoom Controls* on page 113 and *Using Markers* on page 87.
4. Position submarker **a** at the *beginning* of the linear area *preceding* the event to be measured (must not include any significant events).

5. Position marker **B** at the *beginning* of the linear area *following* the event to be measured.
6. Position submarker **b** at the *end* of the linear area *following* the event to be measured (must not include any significant events).

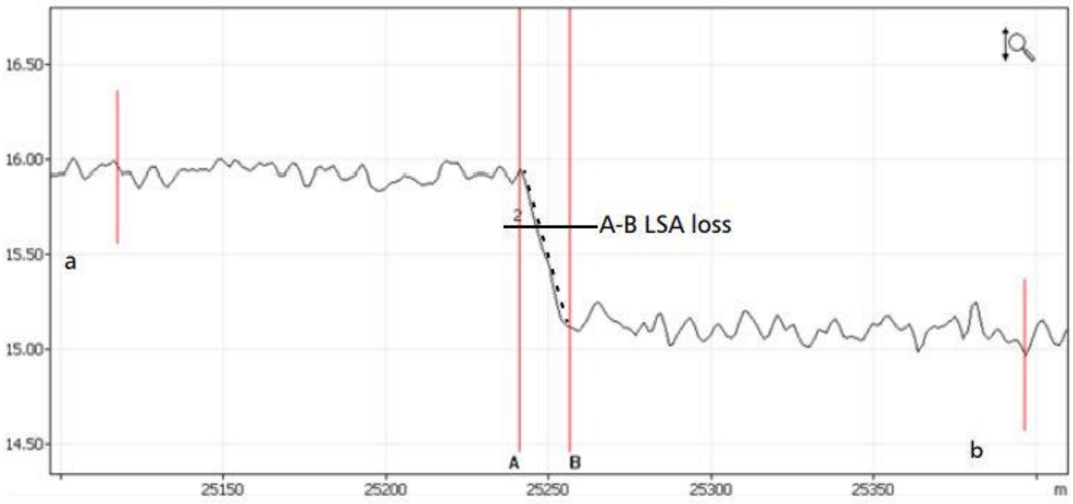


Note: *For non-reflective events, —— will be displayed.*

D. Getting section loss and Attenuation.

- The least square approximation method measures the attenuation loss over distance between two points by fitting a straight line in the backscatter data between markers A and B. The LSA attenuation corresponds to the difference in power over the distance between two points.

- *A-B LSA loss:* the loss of the event bordered by the marker A and B is obtained by fitting a straight line to the backscatter data between these two markers shown below.



To get section loss and attenuation:

1. From the main window, select the **Measure** tab.
2. Tap the **Section** button. Markers **A** and **B** appear on the graph.
3. Place markers **A** and **B** at any two points on the trace. For more information, see *Using Markers* on page 87.
4. Zoom in on the trace and fine-tune the marker positioning if necessary. For more information, see *Using Zoom Controls* on page 113.

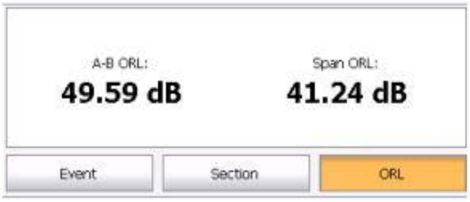
Note: *There should not be any event between markers A and B when performing a measurement.*

E. Getting Optical Return Loss (ORL)

- The total ORL is calculated either between the span start and the span end, or on the total fiber span, depending on the option you have selected.
- ORL refers to the total effect of multiple reflections and scattering events within a fiber optic system.

To get the ORL value:

1. From the main window, select the **Measure** tab.
2. At the bottom of the window, tap **ORL**. Markers A and B appear on the graph.



3. Position markers A and B to delimit the area for which you want to know the ORL value.

Observation:

Length of the fiber =

Wavelength (nm)	Event distances (km)and and relative powers (dB)	Event loss(dB)	Max Reflectance	Section loss(dB)	Attenuation(dB /km)	ORL(dB)
1310						
1550						

Conclusion:

Question:

1) What is optical return loss?
2) How we can achieve better resolution in OTDR?
3) What does noise floor indicate in OTDR trace?

Experiment No-5

Objective: To study and characterize LED and LASER

Apparatus required:-

- FOL-DUAL module
- Optical Patch Cords
- Optical Power Meter
- Opti-Systems Software

Theory:

A **Light Emitting Diode(LED)** is a two-lead semiconductor light source that converts an electrical signal into an optical signal. It is basically a p-n junction diode that emits light when activated due to the application of suitable voltage applied to the leads.

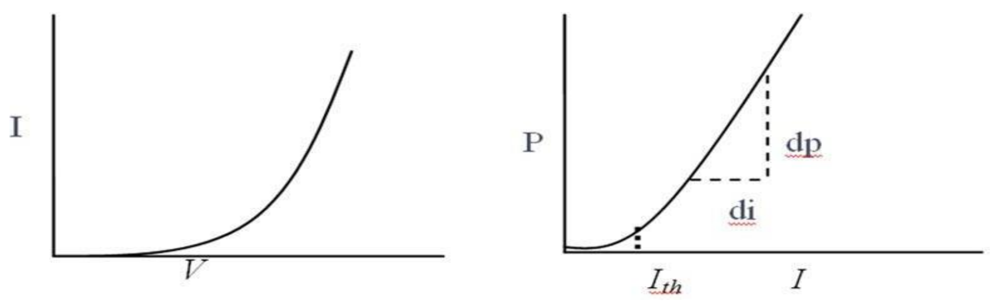
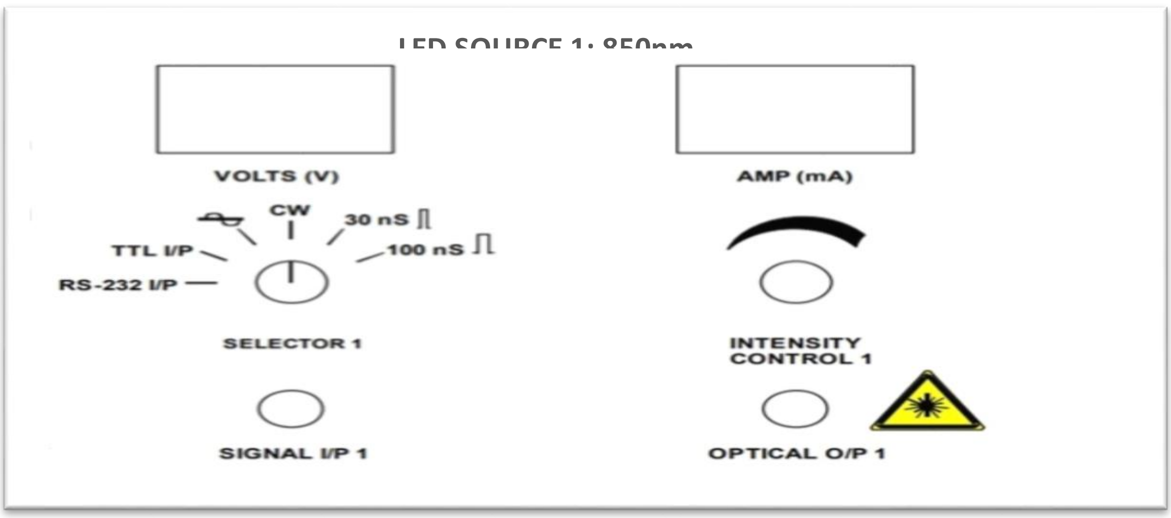


Figure 1. V-I & P-I characteristics of LED

Procedure:

(a). To study and plot the V-I characteristics for 850 nm LED source for the CW.



FOM-1A MODULE
Fig.2 LED Setup at 850 nm

Referring to the block diagram.

1. Make sure that the FOM-1A module is off.

2. Keep the Intensity Control pot fully anticlockwise.

3. Keep Signal Selector 1 Switch of 850 nm LED on CW position.

4. Turn ON the FOM-1A module.

5. Turn the Intensity Control pot slightly in the clockwise direction, until the Current display shows 0.1mA.

6. Record the current in mA and the corresponding voltage in volts.

7. Increase the current flowing through the LED Source 1 by moving the Intensity 1 pot in the clockwise direction.

8. Repeat the procedure for current readings in steps of 0.1mA upto the 45 mA. Record the current in mA and the corresponding voltage in volts.

9. Plot the graph for current (mA) v/s Voltage (V).

10. Find out the threshold current (I_{th}) in mA from the I-V graph.

(b). To study and plot the P-I characteristics for 850 nm LED source for the CW .

Referring to the block diagram.

1. Make sure that the FOM-1A module is off.

2. Keep the Intensity Control pot is fully anti-clockwise.

3. Keep Signal Selector 1 Switch of 850 nm on CW position.

4. Turn ON the FOM-1A module.

5. Turn the Intensity Control 1 pot slightly in the clockwise direction, until the Current display shows 0.1mA.

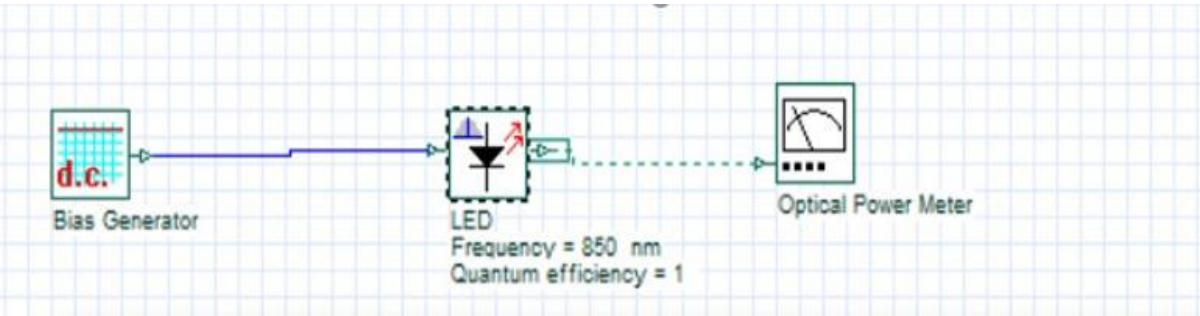
7. Record the current in mA and the corresponding detected Optical Power (dB) and (W) in the optical power meter.

8. Repeat the procedure for current readings in steps of 1mA up to 45 mA.

9. Plot the graph for current (mA) vs Detected Optical Power (dB) or (W).

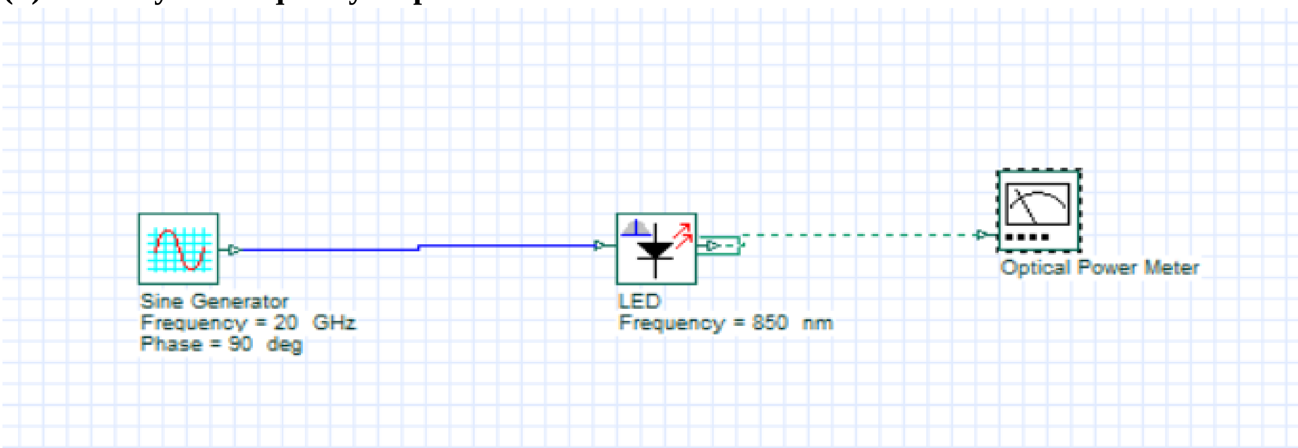
10. Find out the Threshold Current (I_{th}) in mA from the P-I graph.

(c) To study the LED's quantum efficiency at 850 nm



1. In the opti-system software, first we will draw the circuit diagram referring to the above figure.
2. By keeping the frequency constant, we will vary the quantum efficiency from 0.05 to 0.95 and plot the graph between Power in dB Vs quantum efficiency.

(d) To study the frequency response of LED at 850 nm.



1. In the opti-system software, first we will draw the circuit diagram by referring to the above figure.
2. By varying the frequency from 1 to 20 GHz in sine generator we will plot the graph between Power in dB Vs Frequency.

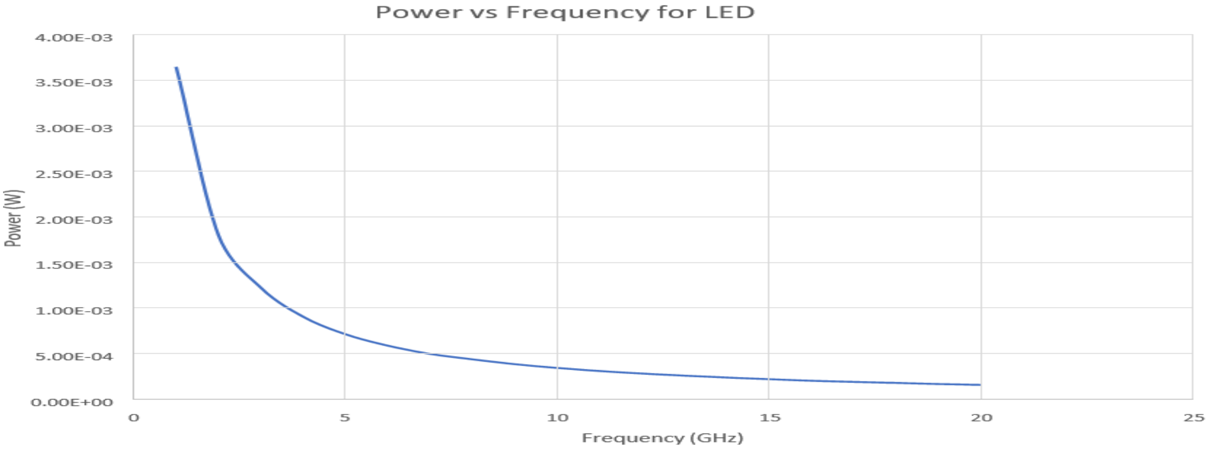
Observation:

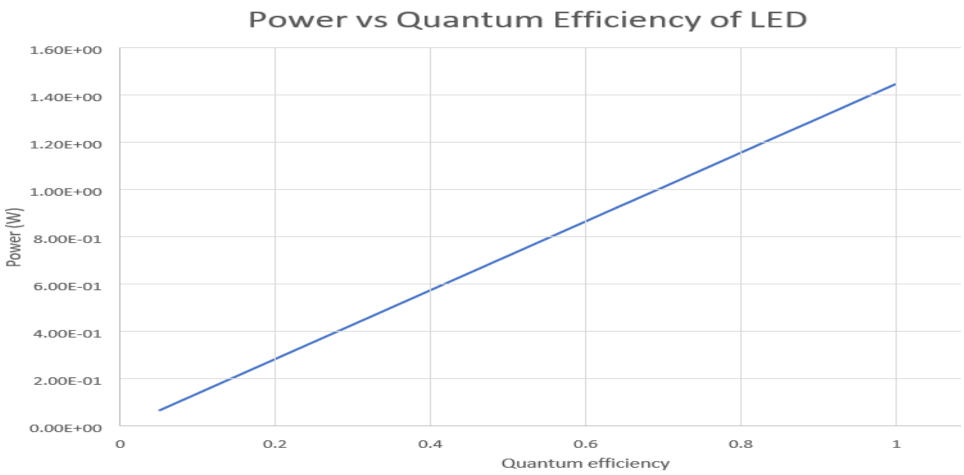
Sr. No.	Current (mA)	Voltage (V)	Power (dB)	Power (W)
1				
2				
3				
4				
5				

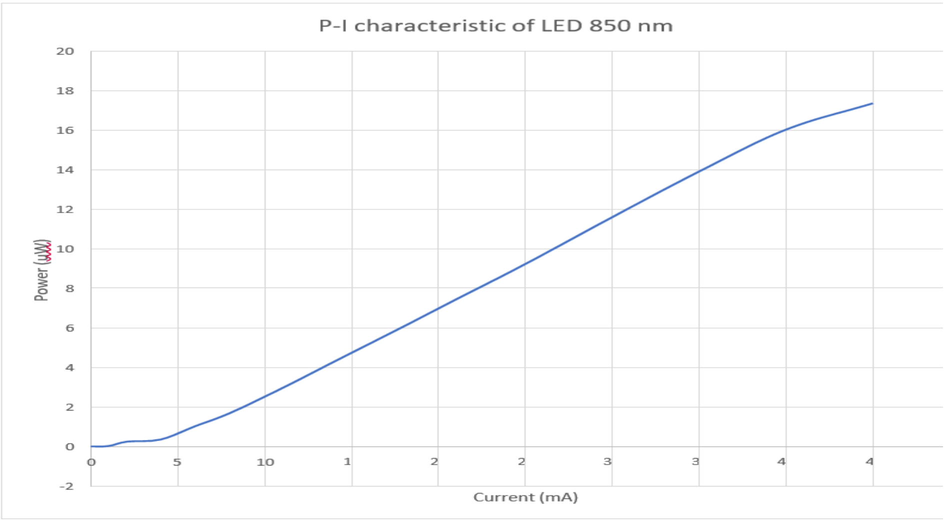
Calculation:

Find the value of I_{th} from I-V and P-I characteristics of LED

Graphs:







Conclusion: Hence we studied the I-V and P -I characteristics of LED at 850 nm and in opti-system software.

EXPERIMENT-6

Objective: To study and characterize the LASER.

Software required :

- Opti-Systems Software
- Optical Patch Cords
- Optical Power Meter
- FOM-1A Module

Theory:

Laser diode (LD), also known as, an injection laser diode (ILD), or diode laser is a semiconductor device that is similar to a light-emitting diode that emits a single wavelength or, in some cases, a short band of closely spaced wavelengths. A laser diode is a semiconductor device that produces high-intensity coherent light. LASER is an abbreviation for Light Amplification by Stimulated Emission of Radiation. The operation of this diode is based on stimulated emission. The P-N junction of a laser diodes are similar to that of an LED; but, unlike LEDs, the P-N junction of a laser emits coherent radiation.

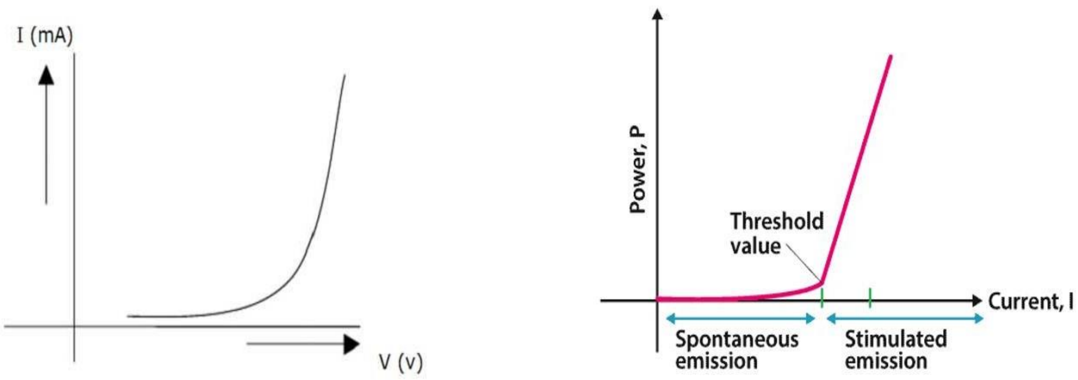


Figure 1. **V-I & P-I characteristics of Laser diode**

Procedure:

(a). To study and plot the V-I characteristics of Laser source at 1310 nm and 1550 nm for the CW

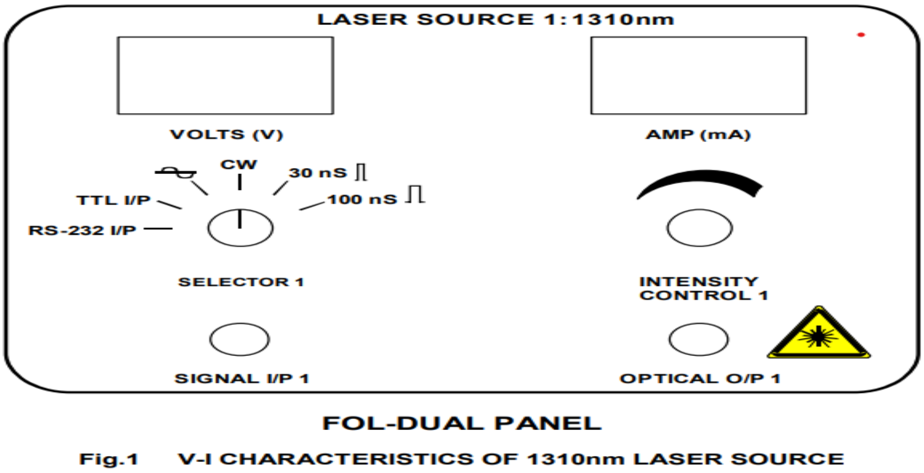


Fig.1 LASER Setup at 1310 and 1550 nm

Referring to the block diagram,

1. Make sure that the FOL-Dual module is off.

2. Keep the Intensity Control pot fully anticlockwise.

3. a. Keep Signal Selector 1 Switch of 1310 nm laser on CW position.

   b. Keep Signal Selector 1 Switch of 1550 nm laser on CW position.

4. Turn ON the FOL-DUAL module.

5. Turn the Intensity Control pot slightly in the clockwise direction, until the Current display shows 0.1mA.

6. Record the current in mA and the corresponding voltage in volts.

7. Increase the current flowing through the Laser Source 1 by moving the Intensity 1 pot in the clockwise direction.

8. Repeat the procedure for current readings in steps of 0.1mA up to the 45 mA. Record the current in mA and the corresponding voltage in volts.

9. Plot the graph for current (mA) v/s Voltage (V).

10. Find out the threshold current (Ith) in mA from the I-V graph.

(b) To study and plot the P-I characteristics for 1310 and 1550 nm Laser Source for the CW

Referring to the block diagram

1. Make sure that the FOL-DUAL module is off.

2. Keep the Intensity Control pot fully anti-clockwise.

3. a. Keep Signal Selector 1 Switch of 1310 nm on CW position.

b. Keep Signal Selector 2 Switch of 1550 nm on CW position.

4. Turn ON the FOL-DUAL module.

5. Turn the Intensity Control 1 pot slightly in a clockwise direction, until the Current display shows 0.1mA.

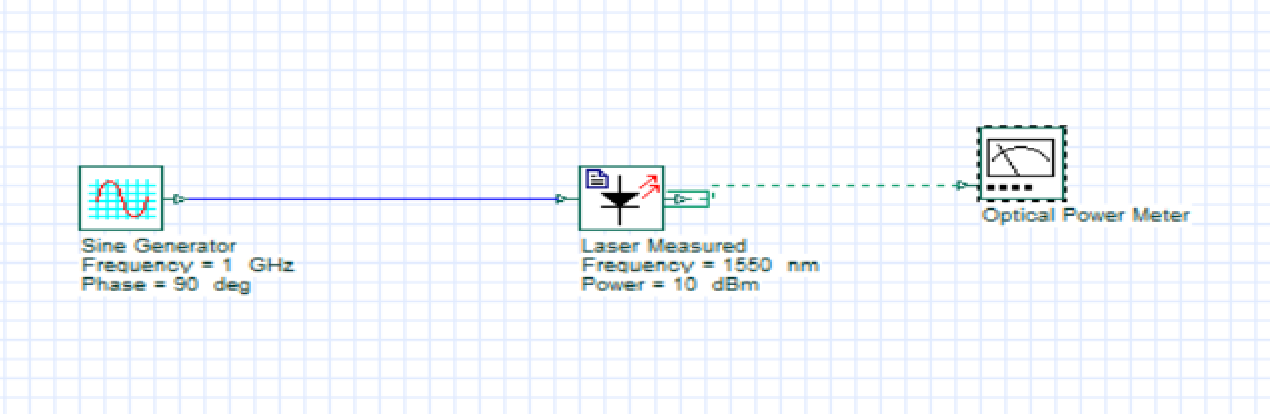
7. Record the current in mA and the corresponding detected Optical Power (dB) and (W) in the optical power meter.

8. Repeat the procedure for current readings in steps of 1mA up to 45 mA and obtain the readings in (dB) and (W) power meter.

9. Plot the graph for current (mA) vs Detected Optical Power (dB) or (W).

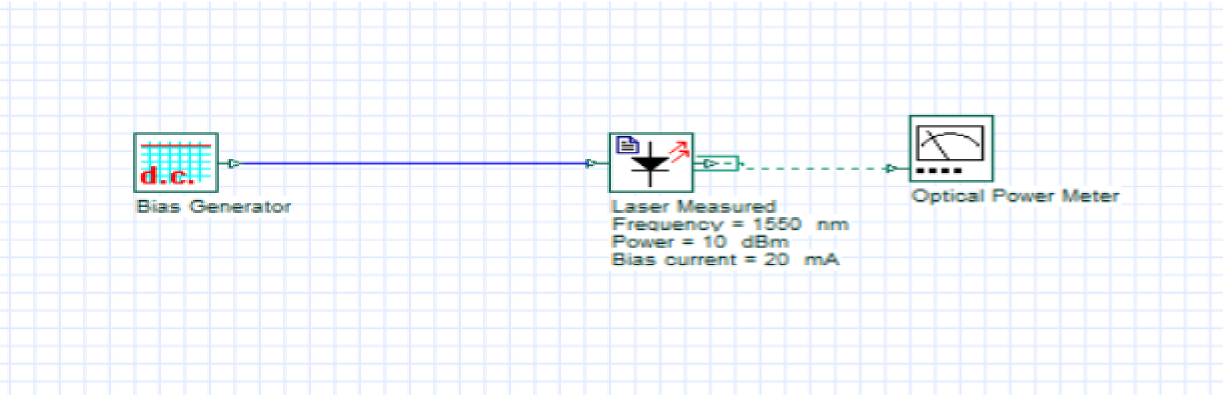
10. Find out the Threshold Current (Ith) in mA from the P-I graph.

(c) To study the frequency response of LASER at 1310 and 1510 nm .



1. First we will draw the circuit diagram in the opti-system software, separately for 1310 nm and 1550 nm.
2. By varying the frequency from 1 to 20 GHz , we will plot the graph between Power in dB vs frequency.

(d). To study the bias current response of LASER at 1310 nm and 1550 nm.



1. First we will draw the circuit diagram in the opti-system software, separately at 1310 and 1550 nm.
2. By varying the current from 1 to 20 mA , then plot the graph between Power in dB Vs current.

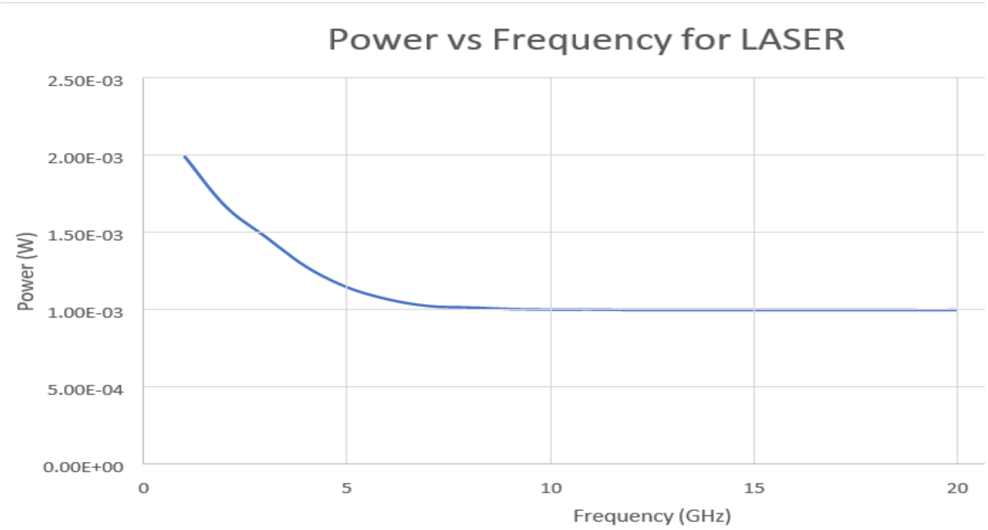
Observation :

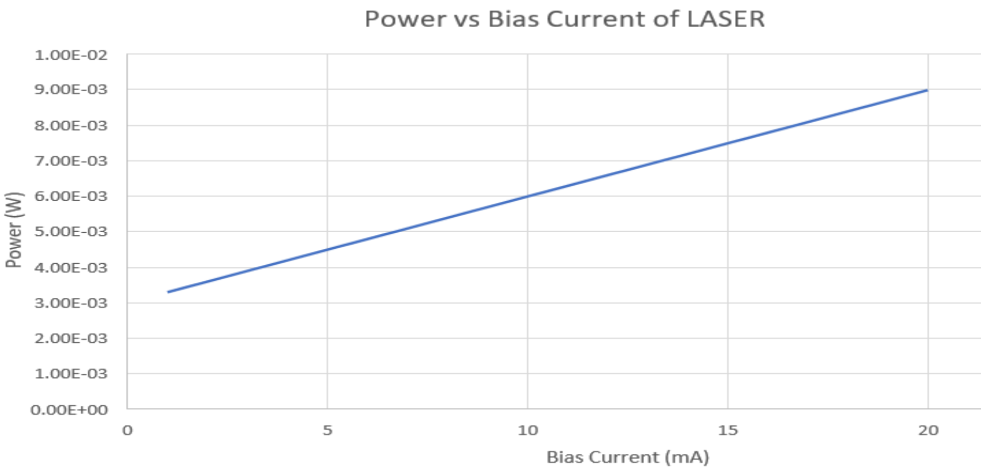
Sr. No.	Current (mA)	Voltage (V)	Power (dB)	Power (W)
1				
2				
3				
4				
5				

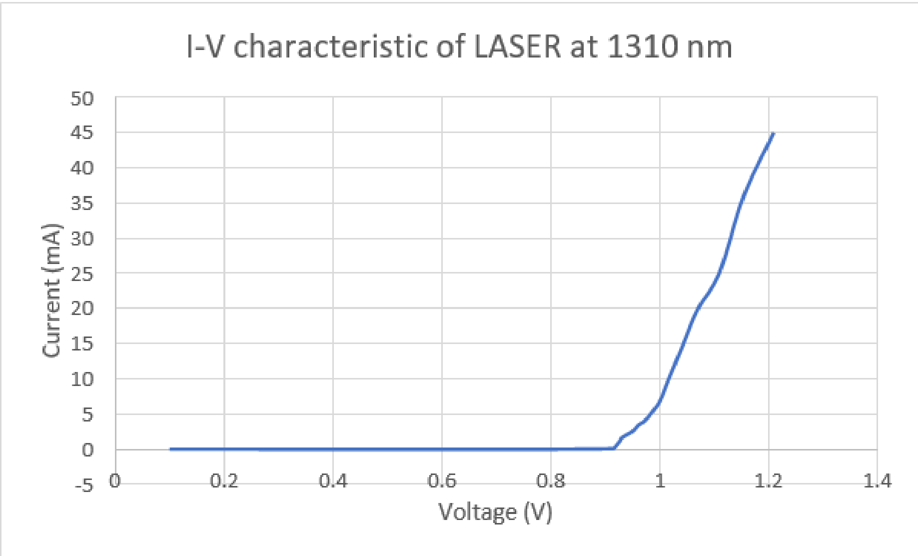
Calculation:

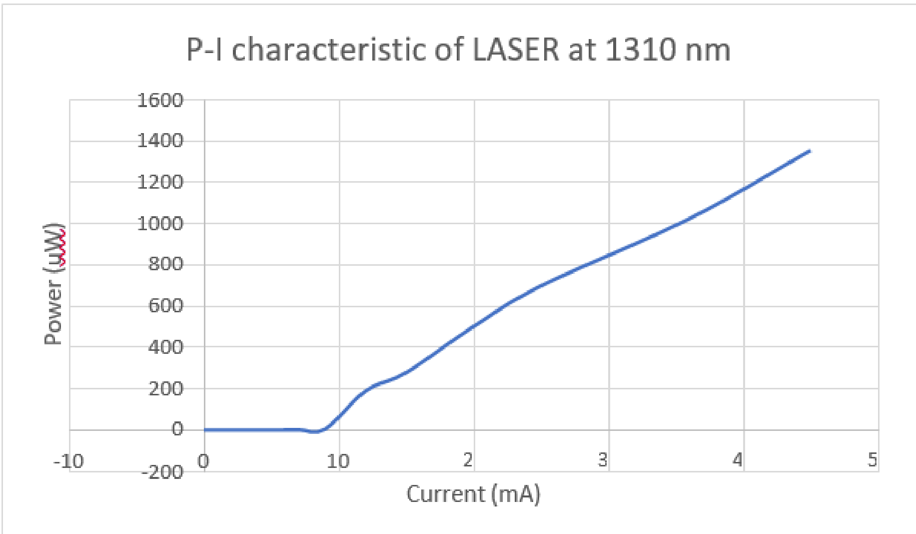
Find the value of I_{th} from I-V and P-I characteristics of LASER

Graphs:









Conclusion:

Hence, we studied the characteristics of LASER at and 1310 and 1550 nm respectively and in opti-systems software.

Experiment No.-7

Objective: - To Measure the Attenuation in Fiber Optic Attenuator

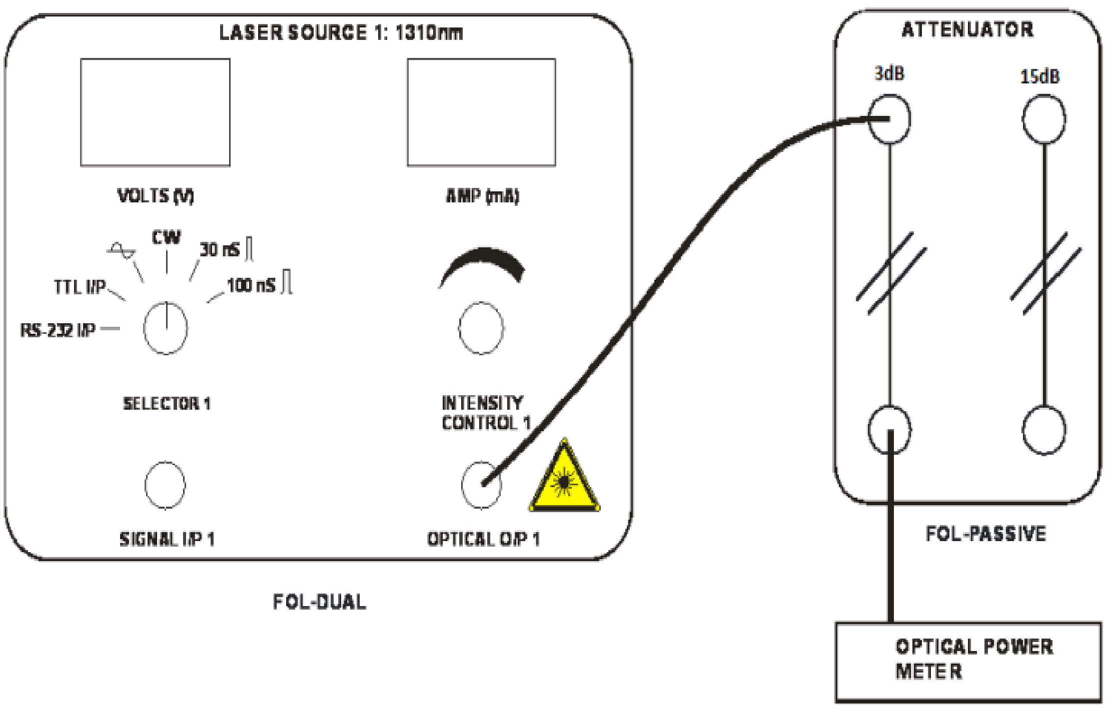
Apparatus Required: -

- FOL-DUAL
- FOL-PASSIVE
- 1 meter ST-ST glass Fiber cables
- Optical Power Meter

Theory:

In certain applications we may need to use calibrated attenuators in order to reduce the luminescent intensity of a known quantity. The fiber attenuators are easy to realize. They are made by realizing bad splicing between two fibers. The two cores of the two identical fibers are voluntarily spliced together transversely. Optical attenuators used in fiber optic communications systems may use a variety of principles for their functioning. Those using the gap – loss principle are sensitive to the modal distribution ahead of the attenuator, and should be used at or near the transmitting end, or they may introduce less loss than intended. Optical attenuators using absorptive or reflective techniques avoid this problem. The basic types of optical attenuators are fixed, step-wise variable and continuously variable.

Block Diagram



BLOCK DIAGRAM FOR MEASUREMENT OF ATTENUATION IN FIBER OPTIC ATTENUATOR

Procedure: -

1. Make sure that the intensity control 1 and intensity control 2 ports are turned fully anticlockwise before switching on the FOL- DUAL module.
2. Keep the selector 1 pot in FOL-DUAL module on CW selection.
3. Connect the optical power meter to the optical O/P 1 port of the laser source 1310 nm on the FOL-DUAL module.
4. Gradually turn the Intensity Control 1 Port clockwise till you get around 1.1mW of optical power reading on the Optical Power meter. Note down this as power P1.
5. Now remove the power meter and connect Optical O/P 1 port to one of the ports of the 3 dB attenuator on the FOL-Passive module.
6. Connect the optical power meter to remaining port of the 3dB attenuator.
7. Note down the reading as power P2 and find out the Attenuation loss,
8. A_{dB} = 10 log (P2 / P1) where, P2 is the Optical power after attenuator and P1 is the laser source power input to attenuator.
9. Repeat the measurement after altering the ports of the Attenuator. Thus deduce the attenuation A_{dB} in both the directions
10. Repeat the experiment for 15dB attenuator and 1550nm Laser source and calculate the attenuation, Loss A_{dB}.

Calculation:

Example:

P1 (1310nm Laser source power input to 3dB Attenuator) = 1.1mW

P2 (Optical power after 3dB attenuator) = 491.35uW

Attenuation loss for 3dB attenuator,

A_{dB} = 10 log (P2 / P1)

= -3.5dB

Example:

P1 (1310nm Laser source power input to 15dB Attenuator) = 1.1mW

P2 (Optical power after 15dB attenuator) = 31.00uW

Attenuation loss for 15dB attenuator,

$A_{\mathbf{dB}}$ = 10 log (P2 / P1)

= -15.5dB

Conclusion; -

The Attenuation for 3 dB and 15 dB attenuators is verified with 1310nm and 1550nm Laser source.

Experiment No.-8

Objective: - To Measure the Insertion Losses & Isolation Rate in Fiber Optic Isolator.

Apparatus Required: -

- FOL-DUAL
- FOL-PASSIVE
- 1 meter ST-ST glass Fiber cables
- Optical Power Meter

Theory: -

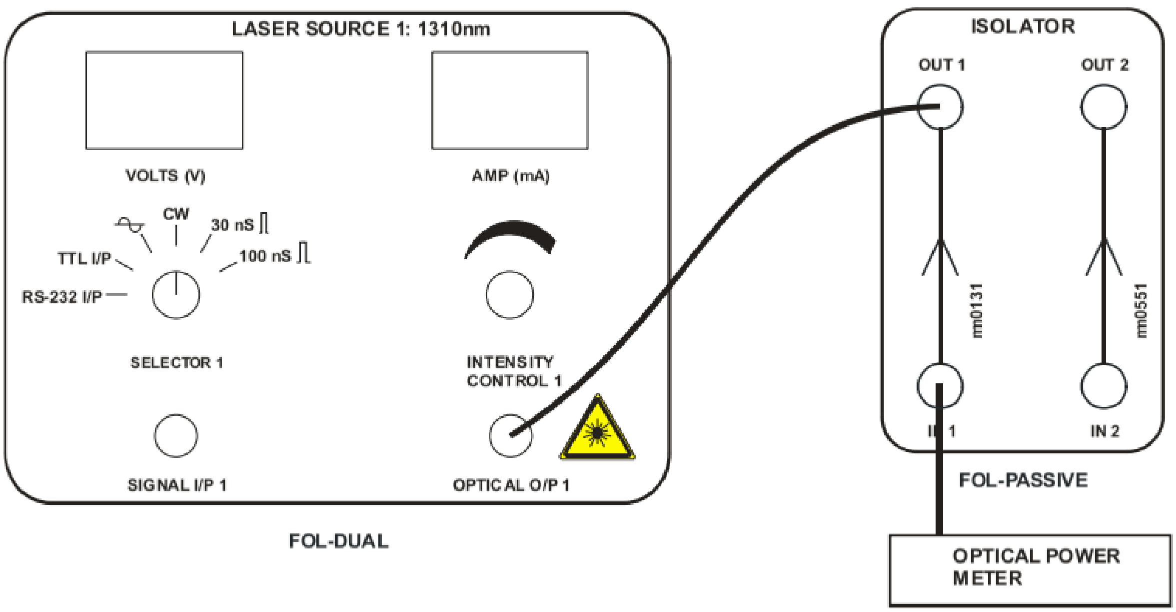
An optical isolator, or optical diode, is an optical component which allows the transmission of light in only one direction. They are typically used to prevent unwanted feedback into an optical oscillator, such as a laser cavity. The operation of the device depends on the Faraday effect (which in turn is produced by magneto-optic effect), which is used in the main component, the Faraday rotator.

The main component of the optical isolator is the Faraday rotator. The magnetic field, ***B***, applied to the Faraday rotator causes a rotation in the polarization of the light due to the Faraday Effect. The angle of rotation, β, is given by,

$$\beta = \nu B d$$

Where, ν is the Verdict constant of the material (amorphous or crystalline; solid, liquid, or gaseous) of which the rotator is made, and *d* is the length of the rotator. Specifically for an optical isolator, the values are chosen to give a rotation of 45 degrees.

Block Diagram



BLOCK DIAGRAM FOR MEASUREMENT OF ISOLATION RATE IN FIBER OPTIC ISOLATOR

Procedure

1. Make sure that the intensity control 1 and intensity control 2 ports are turned fully anticlockwise before switching on the FOL- DUAL module.
2. Keep the Selector 1 pot in FOL-DUAL module on CW selection.
3. Connect the optical power meter to the Optical O/P 1 port of the Laser Source: 1310nm on the FOL-DUAL module.
4. Gradually turn the Intensity Control 1 Port clockwise till you get around 1.3mW of optical power reading on the Optical Power meter. Note down this as power $P_{1.}$
5. Now remove the power meter and connect Optical O/P 1 port to input port of the isolator in FOL-PASSIVE module.
6. Connect the optical power meter to output port of the Isolator.
7. Note down the reading as power P_2 and find out the Insertion Losses,
8. $a_{dB} = 10 \log (P_2 / P_1)$. Where, P_2 is the Optical output power after Isolator and P_1 is the Laser source power input to Isolator.
9. Connect the optical power meter to the Optical O/P 1 port of the Laser Source: 1310nm on the FOL-DUAL module.
10. Gradually turn the Intensity Control 1 Port clockwise till you get around 1.7mW of optical power reading on the Optical Power meter. Note down this as power $P_{3.}$
11. Now connect the Optical O/P 1 port to output post of the isolator in FOL-PASSIVE module.
12. Connect the optical power meter to Input port of the Isolator.
13. Connect the optical power meter to Input port of the Isolator.
14. Note down the reading as power $P_{4.}$
15. Calculate the Isolation rate, $I_{dB} = 10 \log (P_3 / P_4)$.
16. Repeat the measurements for 1550nm Laser source

Calculation:

Example

P_1 (1310nm Laser source power input to Isolator input) = 1.3mW
P_2 (Optical power at Isolator output) = 1.1mW
Insertion losses are,
$\alpha_{dB} = 10 \log (P_2 / P_1)$
$= - 0.72dB$

P_3 (1310nm Laser source power input to Isolator output) = 1.7mW
P_4 (Optical power at Isolator input) = 150ηW
Isolation Rate is,
$I_{dB} = 10 \log (P_4 / P_3)$

$= - 40dB$

Conclusion:

We note that the Isolators are very efficient on the operating wavelength as they have low insertion losses (0.72dB for example) and an isolation rate that is higher than 40dB.

Experiment No. - 9

Objective: - Plot the Refractive index profile and Numerical aperture profile for α=1, 2, 3, 4, and 1000.

(a) Plot the refractive index profile for the values of α=1, 2, 3,...∞.

$$n^2(r) = n_1^2[1 - 2\Delta(r/a)^\alpha] \ ; \ 0<r<a \text{ (core)}$$

$$= n_1^2[1 - 2\Delta] \ ; \ r>a \text{ (cladding)}$$

(b) The local NA is defined for any shape of refractive index profile fiber by

$$NA(r) = [n^2(r) - n_2^2]^{1/2} \approx NA(0)[1-(r/a)^\alpha]^{1/2} \quad \text{for } r \leq a$$

$$= 0 \quad \text{for } r \geq a$$

Where the axial numerical aperture is defined by NA (0) = $n_1(2\Delta)^{1/2}$. It is given n_1=1.5, n_2=1.48. Hence, plot the NA(r) versus (r/a) for α=1, 2, 3,... ∞ and comment on the results. Identify the various names of the refractive index profile.

Software required: - Matlab R2019a

Theory: -

- In optics, the **refractive index** or **index of refraction** of a material is a dimensionless number that describes how fast light propagates through the material.
- It is expressed as a ratio of the speed of light in a vacuum relative to that in the considered medium. It is defined as

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

  where c is the speed of light in vacuum and v is the phase velocity of light in the medium. For example, the refractive index of water is 1.333, meaning that light travels 1.333 times as fast in a vacuum as in water.

Why Refractive index is important?

- The refractive index of a material medium is an important optical parameter since it exhibits the **optical properties** of the material.
- The refractive index coefficients are important parameters in the design of optical fiber and waveguide.
- It is used to calculate the focusing power of lenses.

- In optics, the **numerical aperture (NA)** of an optical system is a dimensionless number that characterizes the range of angles over which the system can accept or emit light.
- The numerical aperture (NA) of a fiber is a number that defines its light gathering capability.
- A larger NA corresponds to a larger acceptance angle, which result in the ability to collect more light.

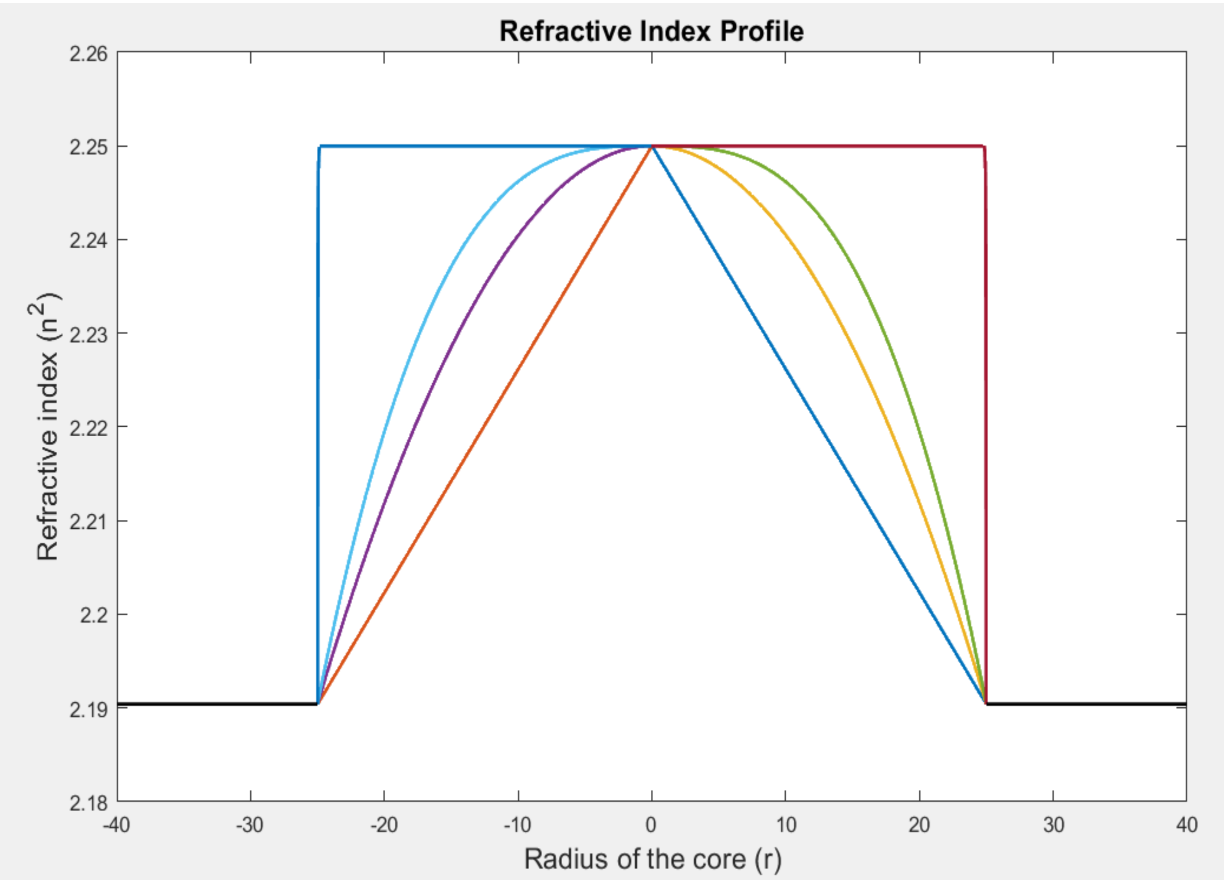
$$NA(r) = \begin{cases} [n^2(r) - n_2{}^2]^{\frac{1}{2}} = NA(0)\sqrt{1-\left(\frac{r}{a}\right)^{\alpha}} ; r < a \\ 0; otherwise \end{cases}$$

Procedure: -

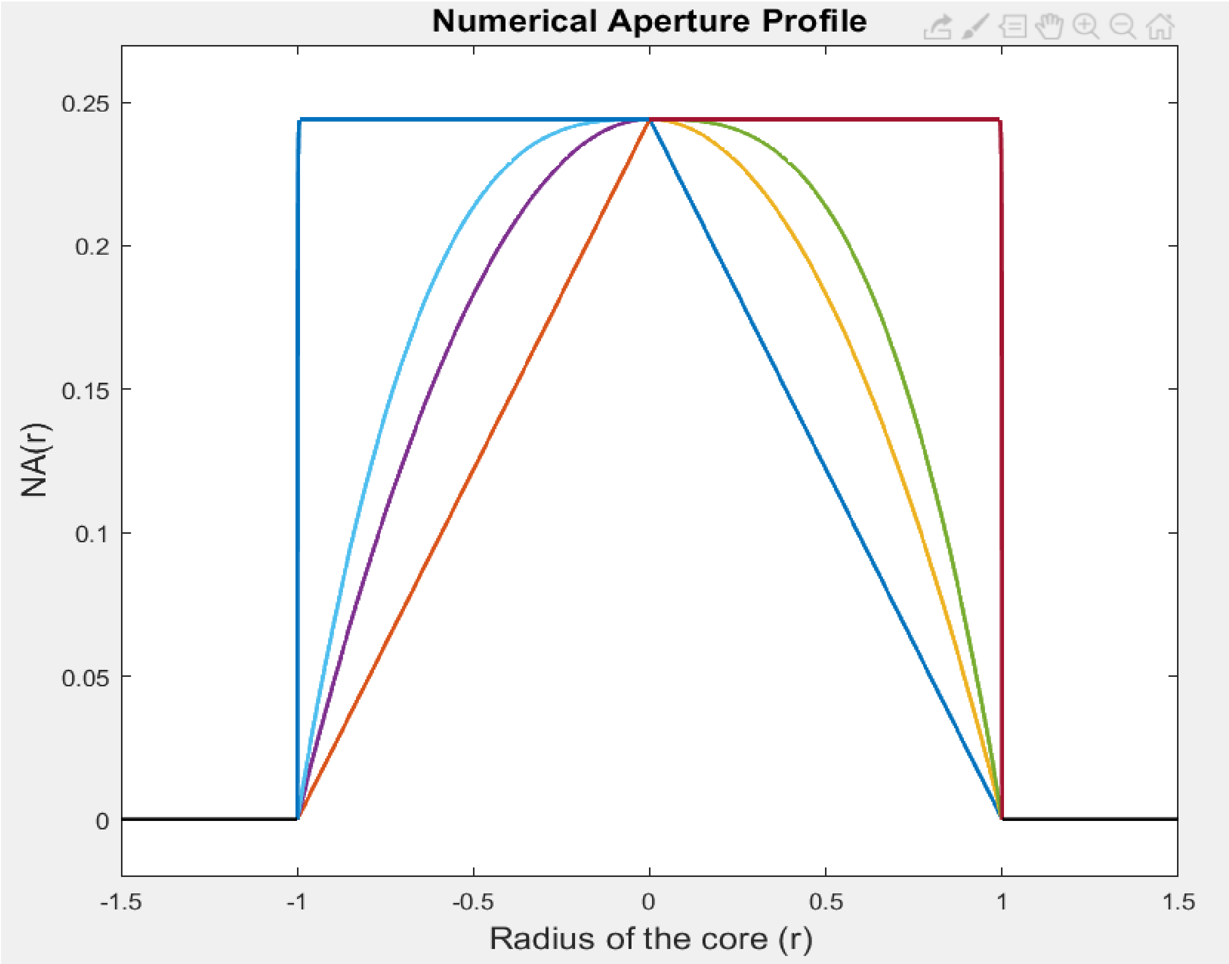
1. Matlab coding has to be done to plot those equations.
2. Plot all three questions and solve them with the help of the given values.

GRAPH: -

(a).



(b).



Results: -

α = 1; Triangular refractive index profile

α = 2; Parabolic refractive index profile

α = 3; Step index profile

(1) The graph becomes more flatter as we are increasing the value of ‘α’ in both graphs.

(2) The value of refractive index n(r) is constant for r >a.

Experiment No. – 10

Objective: - To study the material dispersion in silica fiber.

The material dispersion in silica fiber can be defined as:

$$D_m\left(\frac{ps}{km-nm}\right)=\frac{\Delta\tau}{L\Delta\lambda_0}=-\frac{1}{\lambda_0 c}\left(\lambda_0^{\ 2}\frac{d^2n}{d\lambda_0^{\ 2}}\right)\times 10^9$$

Where λ_0 is measured in µm and c=3x10^8 m/s.

$$n(\lambda_0)=C_0+C_1\lambda_0^{\ 2}+C_2\lambda_0^{\ 4}+\frac{C_3}{(\lambda_0^{\ 2}-l)}+\frac{C_4}{(\lambda_0^{\ 2}-l)^2}+\frac{C_5}{(\lambda_0^{\ 2}-l)^3}$$

where C_0 = 1.4508554, C_1 = - 0.0031268, C_2 = - 0.0000381, C_3 = 0.0030270,
C_4 = - 0.0000779, C_5 = 0.0000018, l = 0.035

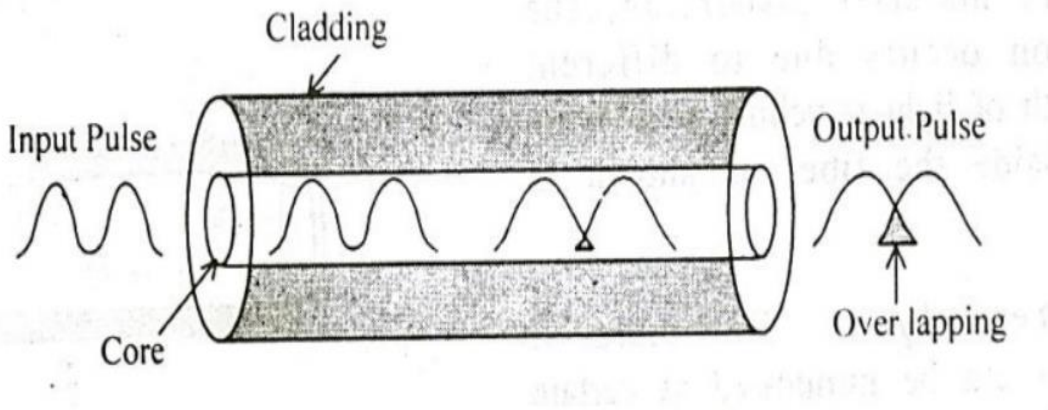
Plot:

1) $n(\lambda_0)$ v/s λ_0
2) $dn(\lambda_0) / d\lambda_0$ v/s λ_0
3) $d^2n(\lambda_0) / d\lambda_0^2$ v/s λ_0
4) D_m v/s λ_0

Software required: - Matlab R2019a

Theory: -

When an optical signal or pulse is guided into the fiber the pulse spreads/broadens as it transmits through the fiber. This occurrence is called dispersion.



The spreading of the optical pulse limits the information-carrying capacity of the fiber.

There are two different types of dispersion in optical fibers:

1. Intramodal dispersion
2. Intermodal dispersion

Intramodal or chromatic dispersion occurs in all types of fibers. Intermodal dispersion occurs only in multimode fibers.

Intramodal dispersion primarily depends on fiber materials. There are two types of Intramodal dispersion:

1. Waveguide Dispersion
2. Material Dispersion

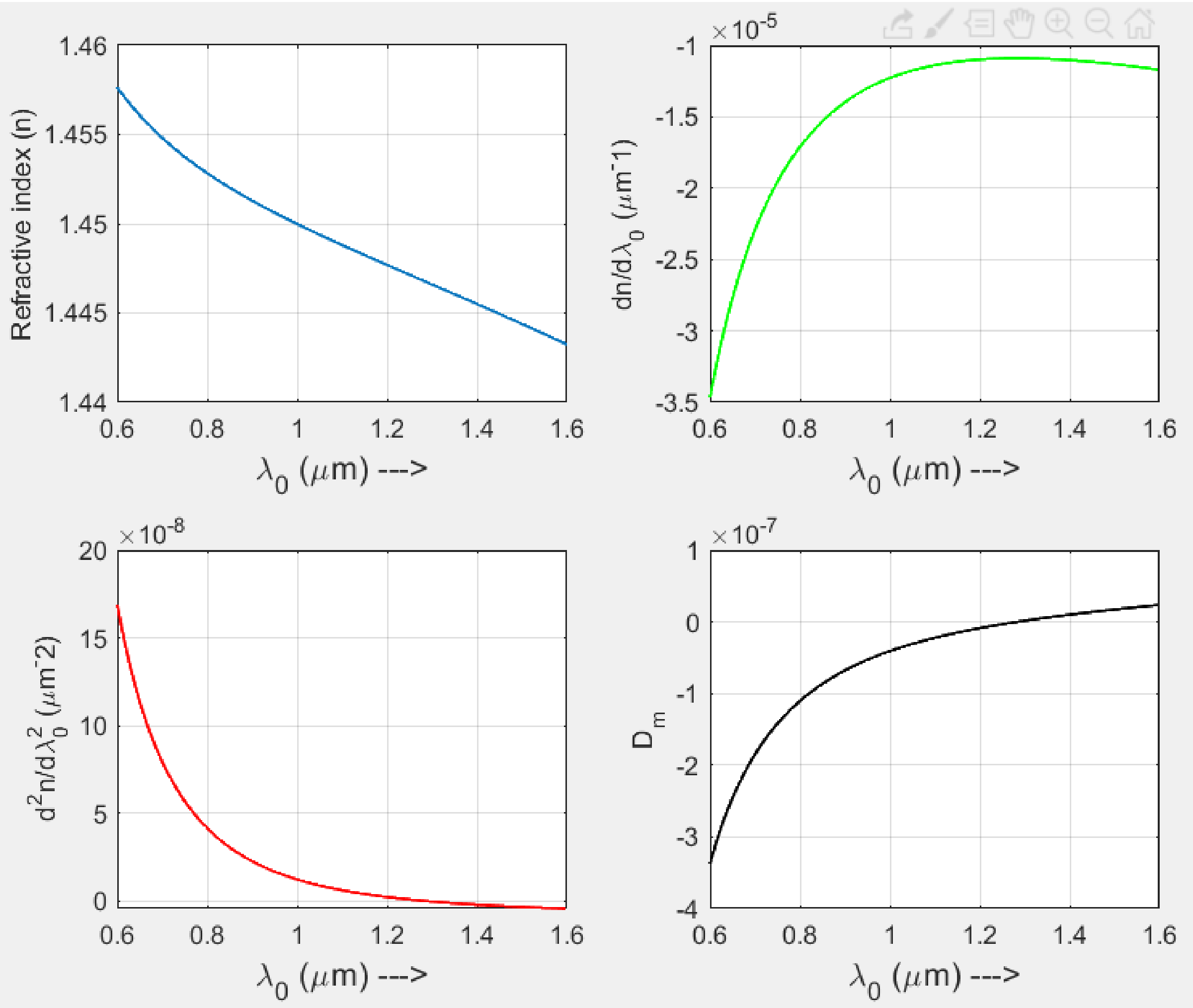
Waveguide Dispersion: - It is caused by the difference in the index of refraction between core and cladding.

Material Dispersion: - Material dispersion take place due to different wavelength traveling at different speed inside the fibers. From the material dispersion equation, we can say that the material dispersion is proportional to the spectral width ($\Delta\lambda$) and also to the length 'l' traversed in the medium. Material dispersion is usually specified in the units of **ps/km-nm**.

Procedure:

1. Matlab coding has to be done to plot those equations.
2. Plot all four questions and solve them with the help of the given values.

Graphs: -



Results: -

1. The value of $n(\lambda_0)$, $dn(\lambda_0)/d\lambda_0$, and $d^2n(\lambda_0)/d\lambda_0^2$ for pure silica is obtained from the given equation for the given length.

2. The wavelength where $d^2n(\lambda_0)/d\lambda_0^2 = 0$ is called zero material dispersion wavelength (ZMDW) and a pulse of light centered around the ZMDW and passing through fused silica suffers negligible dispersion.