Electronics Engineering Lab-I (PG) (ECC507) Lab Manual

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Indian Institute of Technology (ISM)
Dhanbad, Jharkhand, INDIA

Venue: - Optical Communication Lab

List of Experiments

Experiment No-1

Objective: To observe and characterize the Gain of EDFA (Erbium Doped Fiber Amplifier).

Software Required: Opti-System

Theory:

Erbium Doped Fiber Amplifier (EDFA) is an optical amplifier which is used to boost the intensity of optical signals being carried through a fiber optic communication system.it has got fiber whose core is heavily doped with Erbium ions. It works on the concept on the stimulated emission. It works in the C-band(1530-1560 nm) and L-band(1570-1610 nm).

Erbium has several important properties that make it an excellent choice for an optical amplifier. Erbium ions (Er3+) have quantum levels that allows them to be stimulated to emit in the 1540nm band, which is the band that has the least power loss in most silica-based fiber. Erbium's quantum levels also allow it to be excited by a signal at either 980nm or 1480nm, both of which silica-based fiber can carry without great losses.

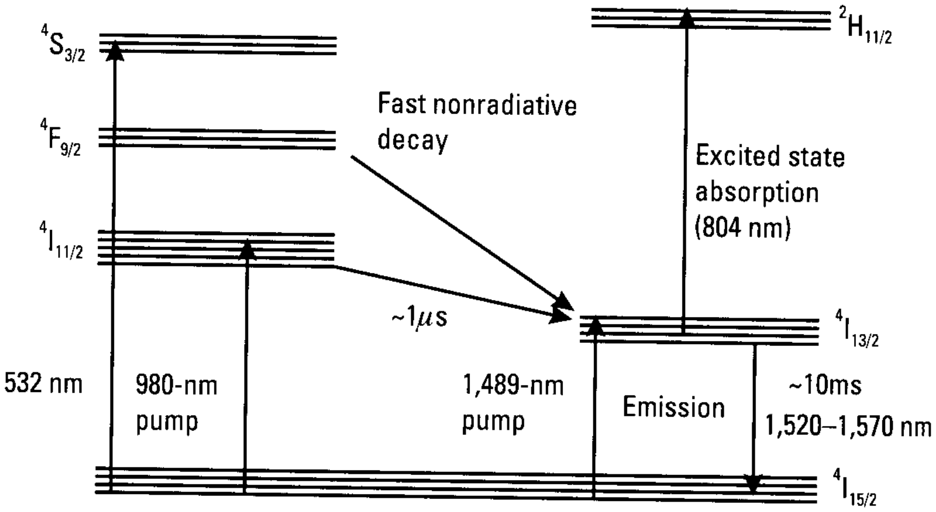


Fig.1. Energy-Band Diagram of Erbium

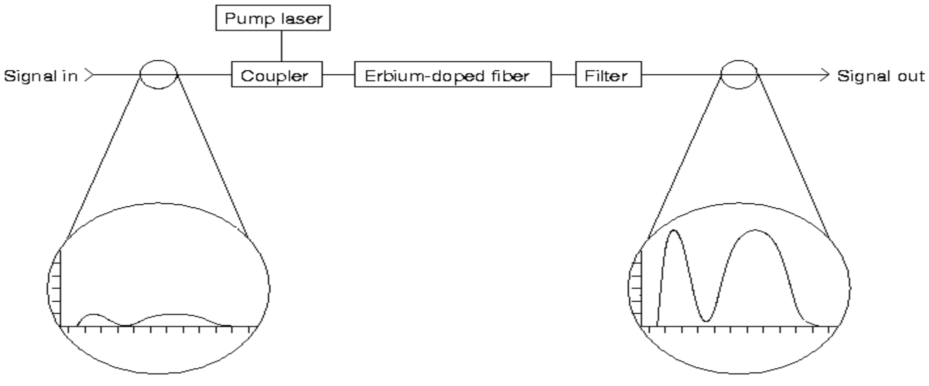


Fig.2 Block Diagram of EDFA

It has got some advantages:

- It is insensitive to light polarization state.
- It has got high gain.
- It has got low noise figure: 4.5 dB to 6dB
- It has no distortion at high bit rates
- It has the property of simultaneous amplification of wavelength division multiplexed signals.
- It has got immunity to cross talk among wavelength multiplexed channels
- It does not require high speed electronics.

Procedure:

1. First of all, we will open the opti-systems software.
2. The given circuit diagrams were constructed by arranging all the components.
3. In the first diagram, length was kept variable and it was varied from 1 to 20 m.
4. for the second diagram, the CW laser power was kept variable and it was kept varied from -48 to -2 db.
5. In the third diagram, the pump laser power was kept variable and it was varied from 10 to 200mW.
6. In the last diagram, the input frequency was kept variable and it was varied from 1520 to 1600 nm(wavelength).

Circuit diagrams:

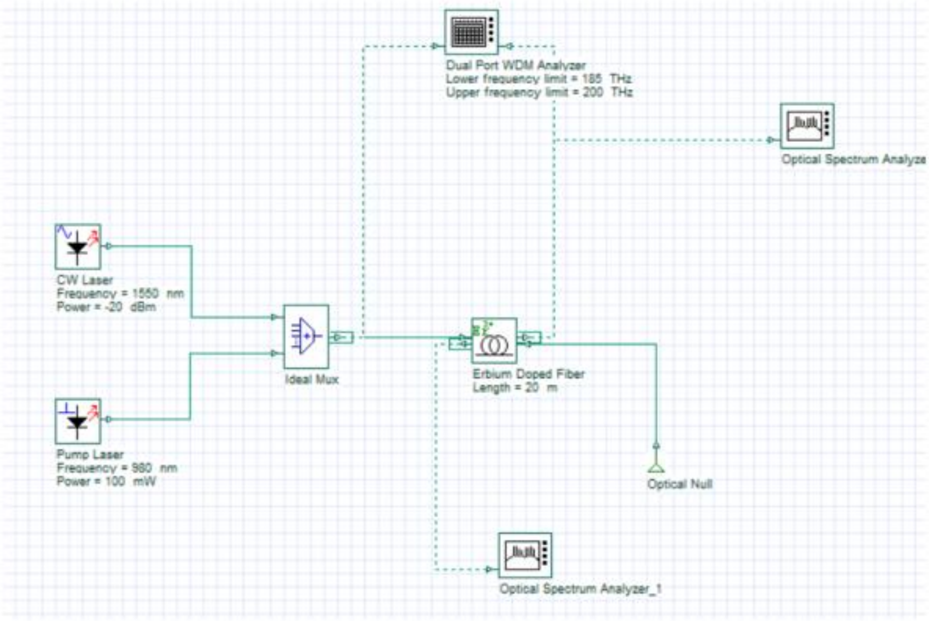


Fig.3.When the length is variable

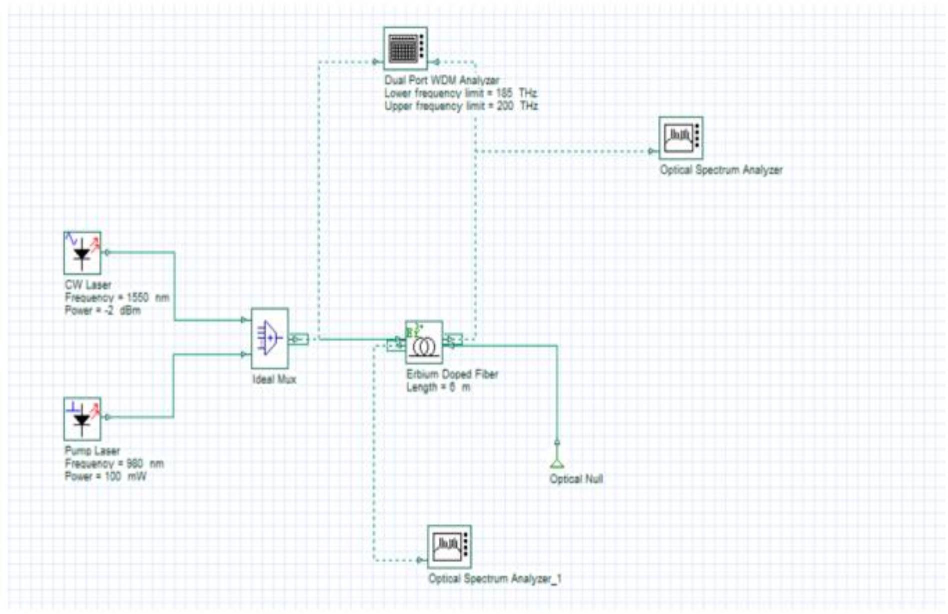


Fig.4.When the CW laser power is variable

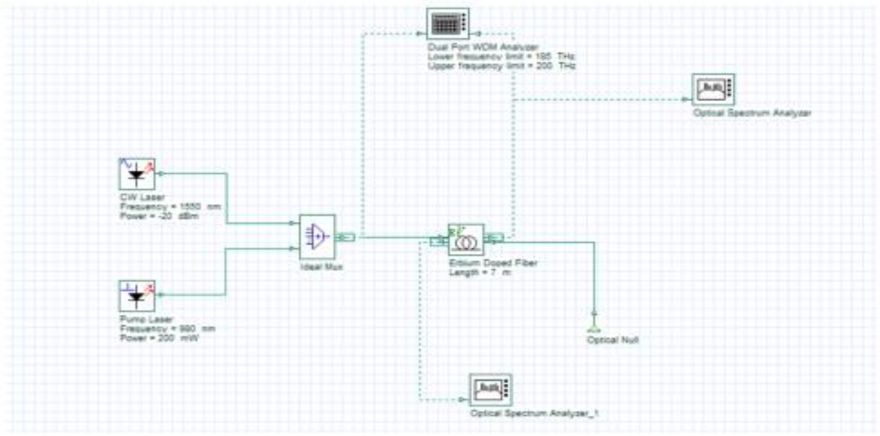


Fig.5 When the pump laser power is variable

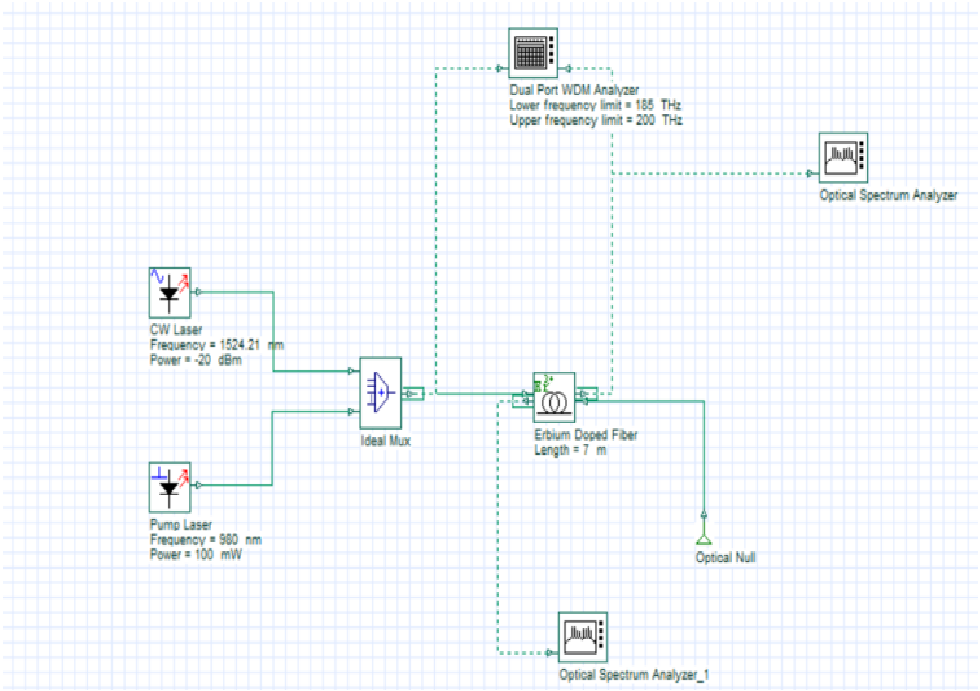


Fig 6. When the input frequency is variable

Observation:

Table1

Length(m)	Gain	Noise Figure

Table 2

CW Laser power(dB)	Gain	Noise Figure

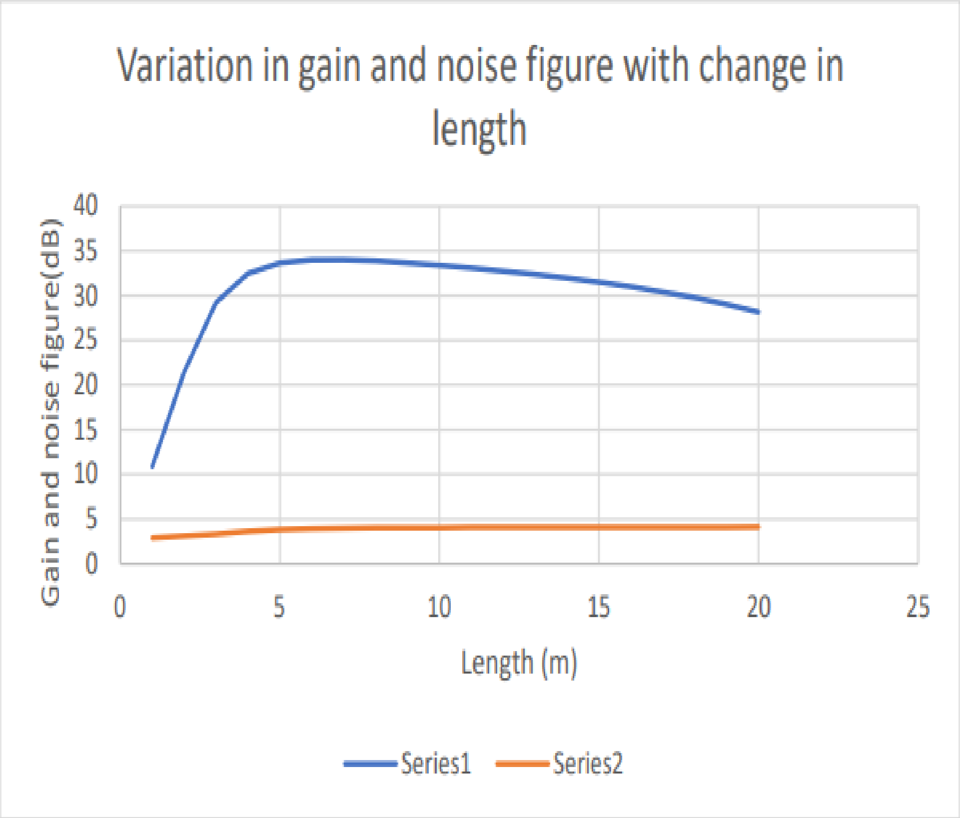
Table 3

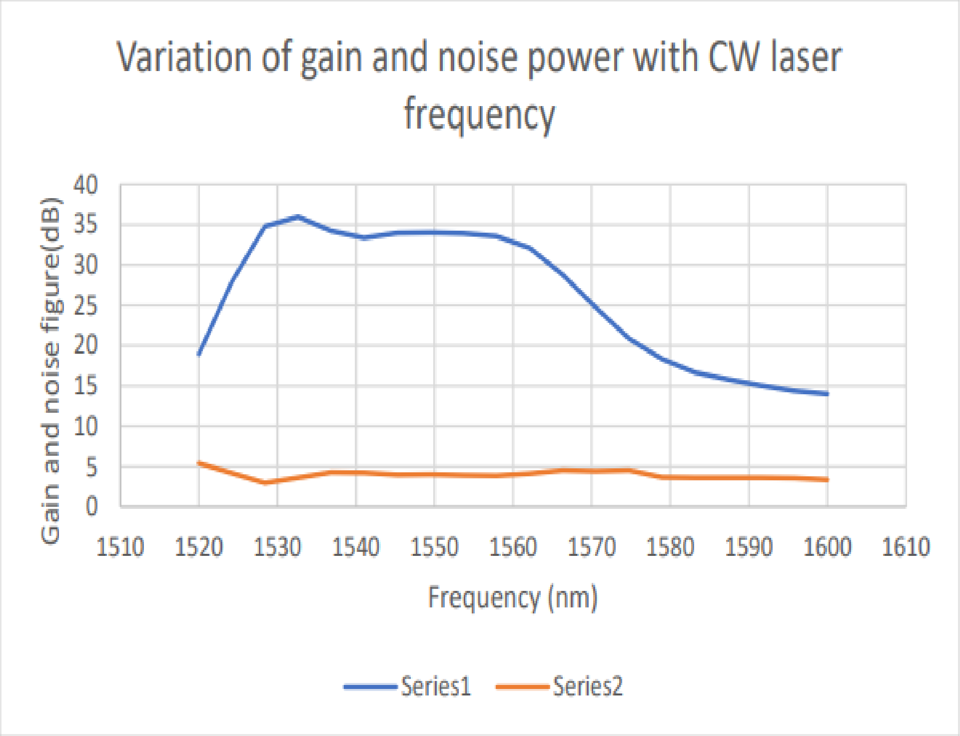
Pump Laser Power(mW)	Gain	Noise Figure

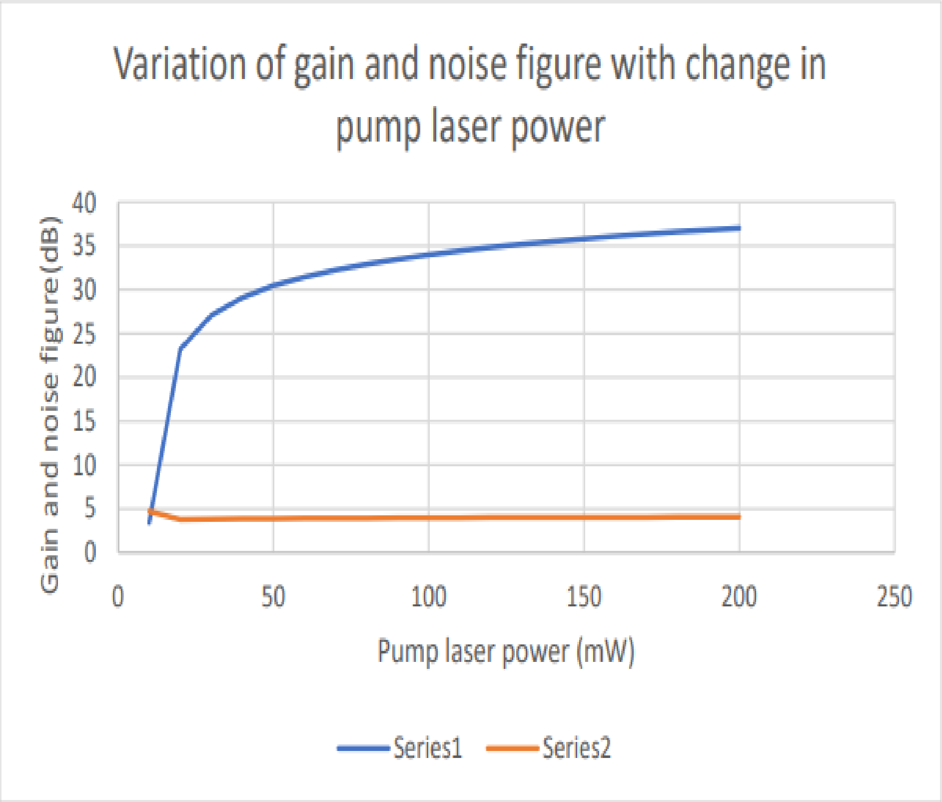
Table 4

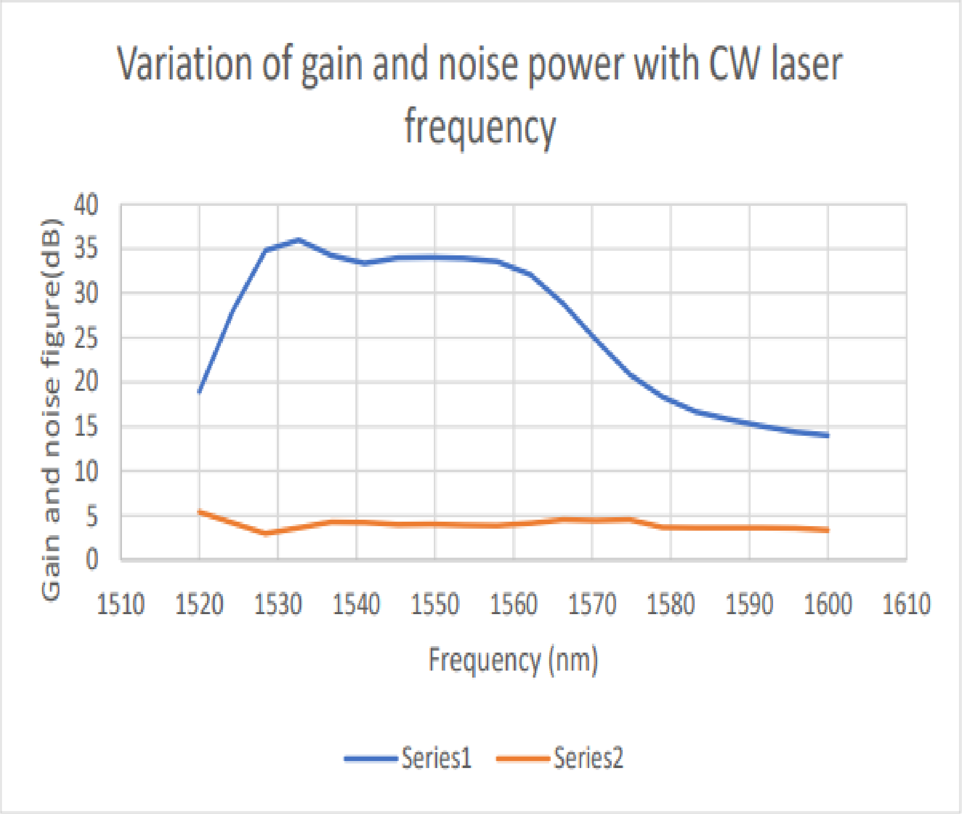
Input Frequency(nm)	Gain	Noise Figure

Graphs:




Variation of gain and noise power with CW laser frequency
Gain and noise figure(dB)
40
35
30
25
20
15
10
5
0
1510
1520
1530
1540
1550
1560
1570
1580
1590
1600
1610
Frequency (nm)
Series1
Series2


Variation of gain and noise figure with change in pump laser power
Gain and noise figure(dB)
40
35
30
25
20
15
10
5
0
0
50
100
150
200
250
Pump laser power (mW)
Series1
Series2



Results:
From the following graphs, we can conclude that as the length gets varied the gain also increases along with length but after a certain value, it starts to get decrease. When the CW laser power gets varied after a certain value of input power it starts to get decrease. When the pump laser power gets varied the gain gets decreased and after a certain time it gets saturated. When the input frequency gets varied we can how the EDFA gets functions.

Conclusion:
Hence, we have studied the characteristics of EDFA under different conditions.

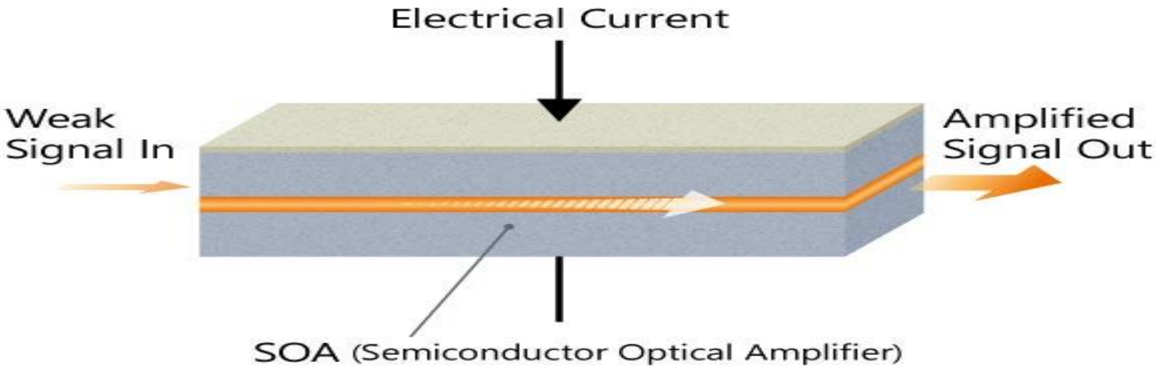
Experiment No. – 2

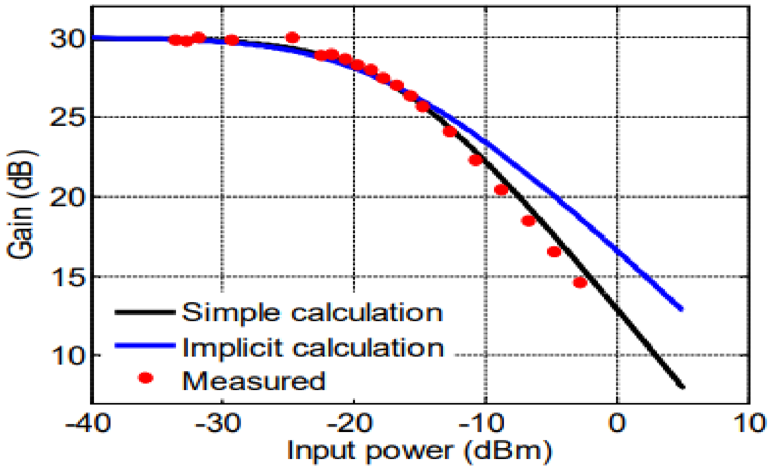
Objective: To observe and characterize the Gain of Semiconductor Optical Amplifier (SOA).

Software required: Opti-system

Theory:

Semiconductor Optical Amplifier (SOA) is essentially an InGaAsP laser that is operating below its threshold point. Like semiconductor lasers, SOA also consists of gain and passive regions.





$G = G0 \, exp \, [(1 - G) \, Pin / \, Psat \,]$

$G0 = exp(g0L)$

Procedure:

1.First of all, we have varied the input power from -40 dB to 10 dB and saw the variation in the gain.

2.Secondly, we have again varied the input power and saw the variation in the noise power.

3.Then we have varied the injection current and saw the variation in the gain.

4.Then we have seen the variation of the total power along wavelength at different values of input power.

Observations:

Table- 1

Power(dB)	Gain(dB)

Table- 2

Gain(dB)	Noise Power(dB)

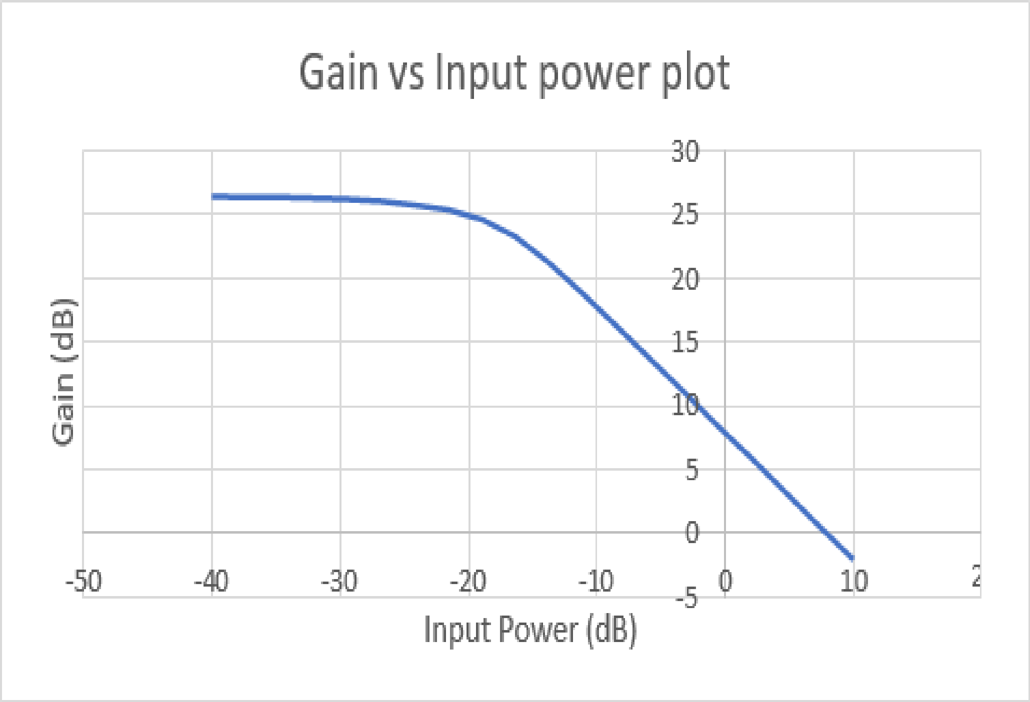
Table- 3

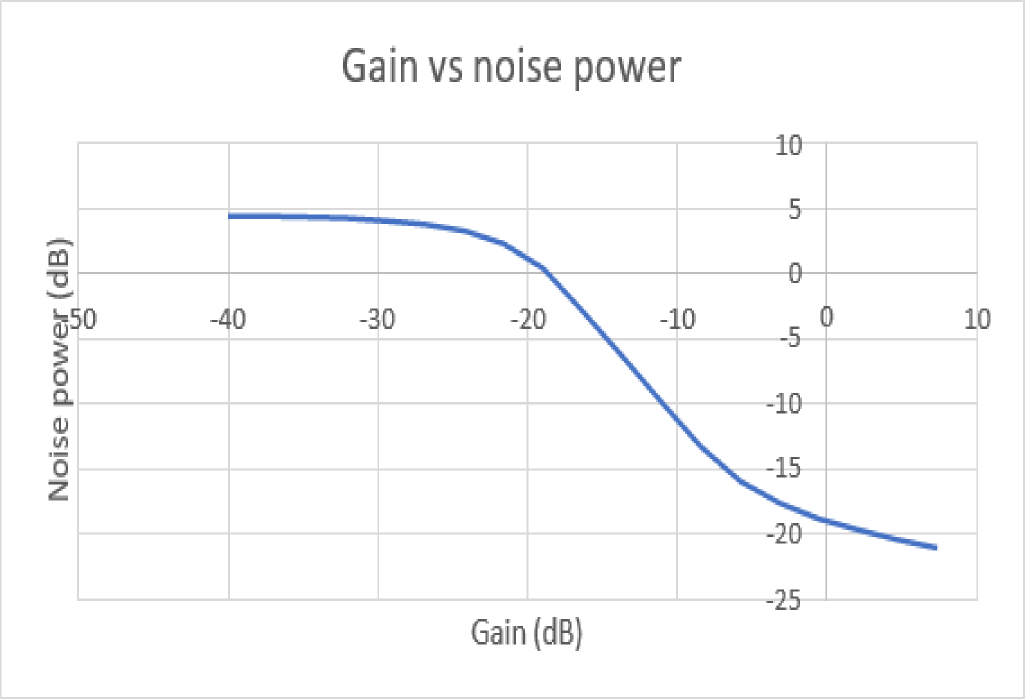
Injection current (mA)	Gain(dBm)

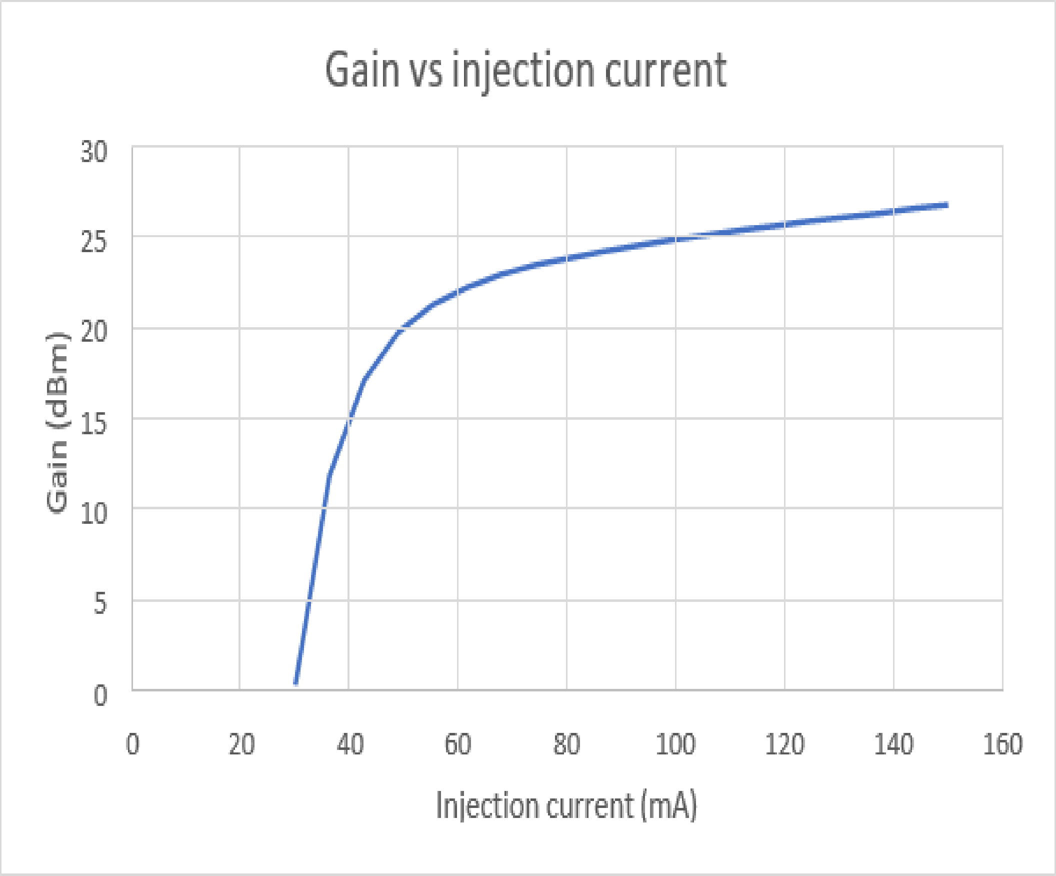
Table- 4

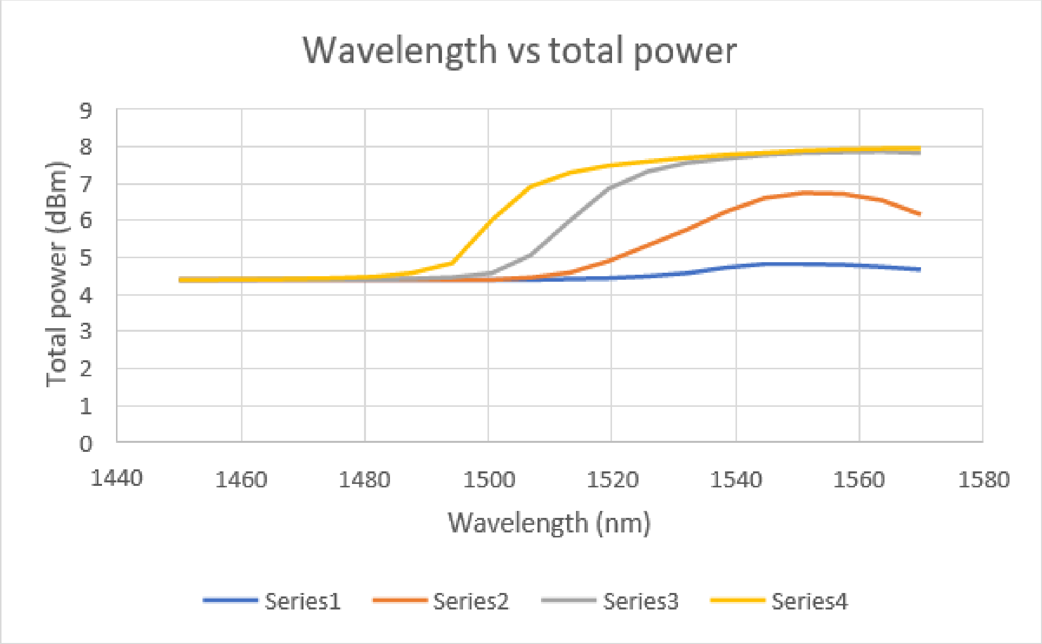
Wavelength(nm)	Total power (dBm) when input power= -30dBm	Total power (dBm) when input power= -20dBm	Total power (dBm) when input power= -10dBm	Total power (dBm) when input power= 0dBm

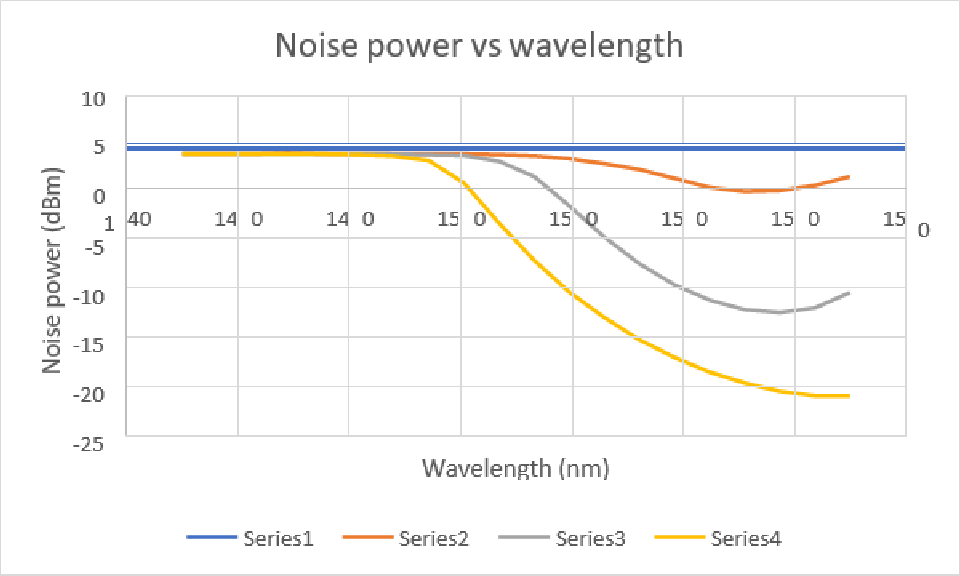
Graphs:




Gain vs noise power
Noise power (dB)
Gain (dB)
10
5
0
-5
-10
-15
-20
-25
-50
-40
-30
-20
-10
0
10


Gain vs injection current
Gain (dBm)
Injection current (mA)
30
25
20
15
10
5
0
0
20
40
60
80
100
120
140
160





Results:

As we have seen that as the input power gets varied the gain is constant up to a certain level and then starts decreasing. Then we have seen in the noise power variation is also the same as that of the gain. When the injection current gets varied the gain also increases with the current and after a certain value it gets saturated. For different values of input power peak was observed at 1545 nm , gain decreases along the wavelength, and at 0 dBm gain will be maximum.

Conclusion:

Hence, we have studied and characterized the SOA under different condition.

Experiment No-3

Objective: To Observe a Semi-Conductor Amplifier (SOA) application for four-wave mixing using opti-systems software.

Software Required: Opti-Systems

Theory:

Four-Wave mixing (FWM) is one of the most attractive and promising wavelength conversion techniques in optical communication systems. Four-wave mixing is a non-linear effect that takes place when two signals (pump and signal) are injected into an SOA. A new signal is generated whose intensity depends upon the individual interacting signals, but the phase and frequency of the newly generated signals will be the linear combination of the signals present in the mixing.

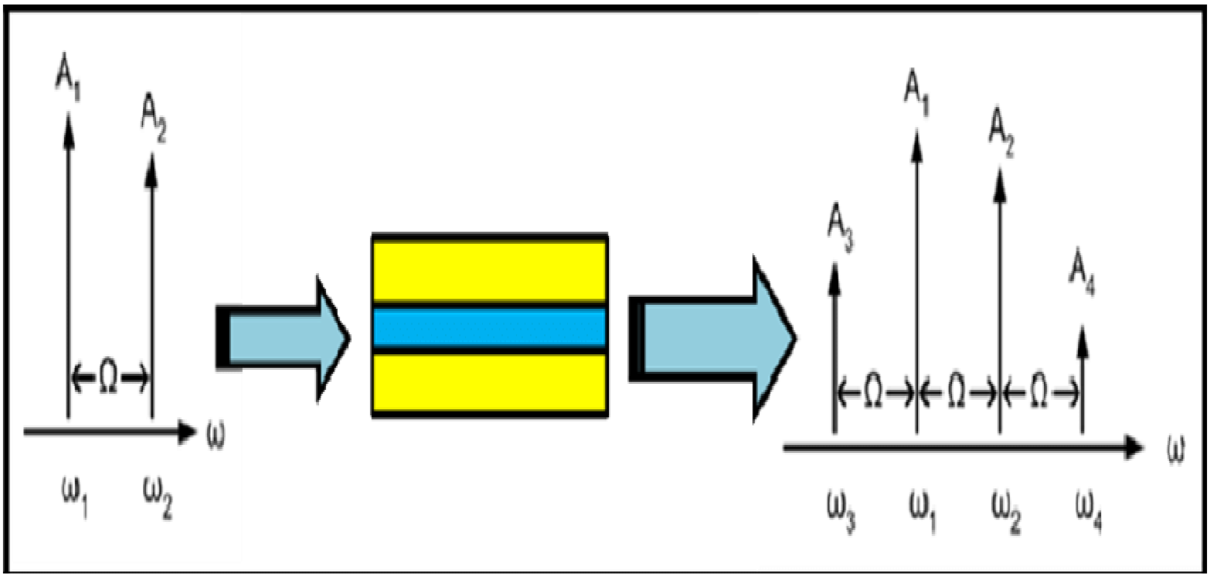
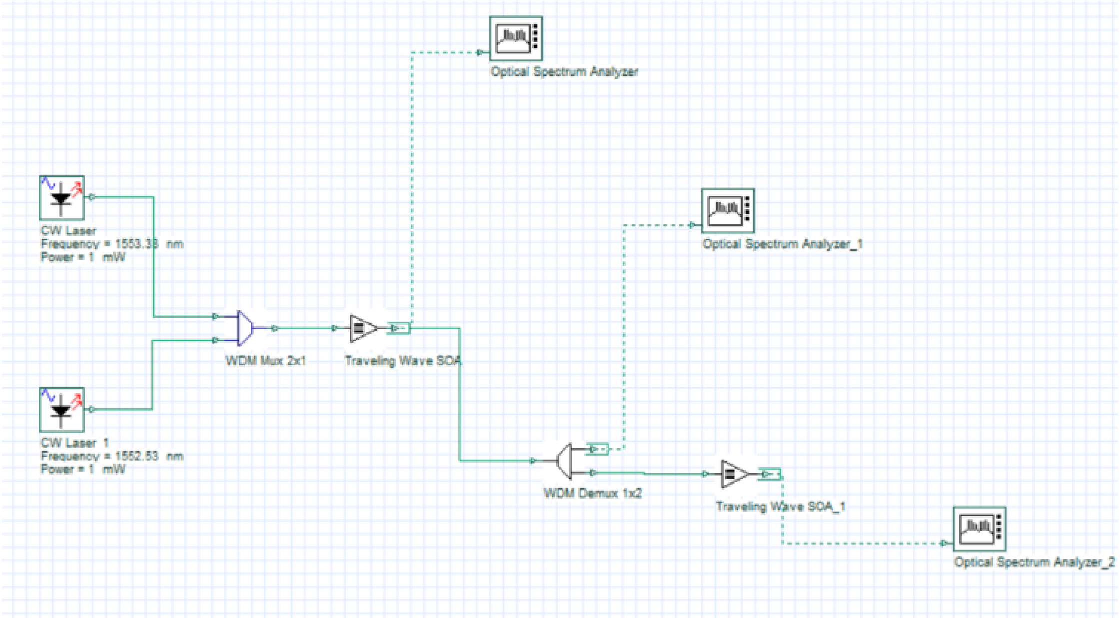


Fig.1.Schematic Representation of Four Wave Mixing(FWM) in SOA

Procedure:

1. First we will draw the given circuit diagram in the opti-systems software.
2. Then, we will plot a graph between the pump power(mW) and the output power(dBm).
3. Through the optical spectrum analyzer we will be analyzing the various plots of WDM 2*1 MUX,Signal power of first SOA,signal power of second SOA after de-multiplexing.

Circuit Diagram:



Observation:

Pump Power(mW)	Output Power(dBm)

Graphs:

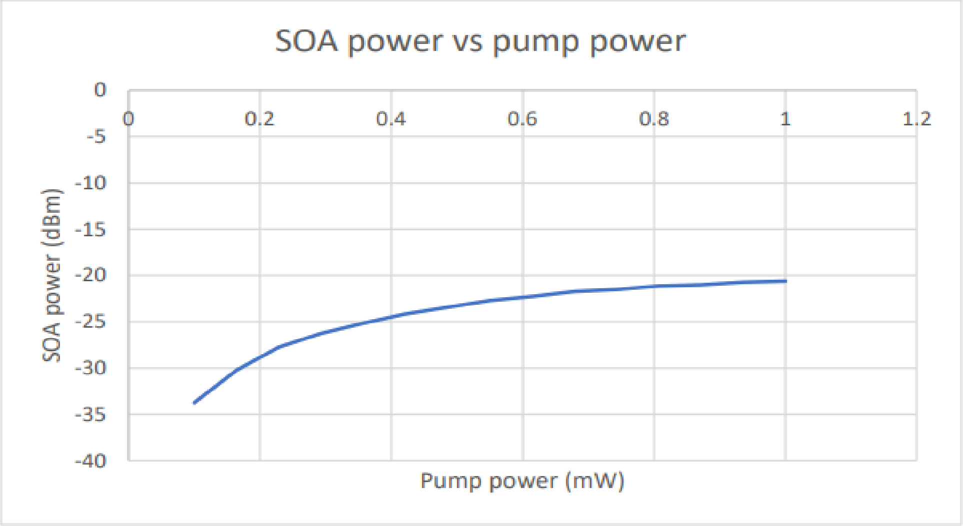


Fig.2.Output SOA power vs Pump Power

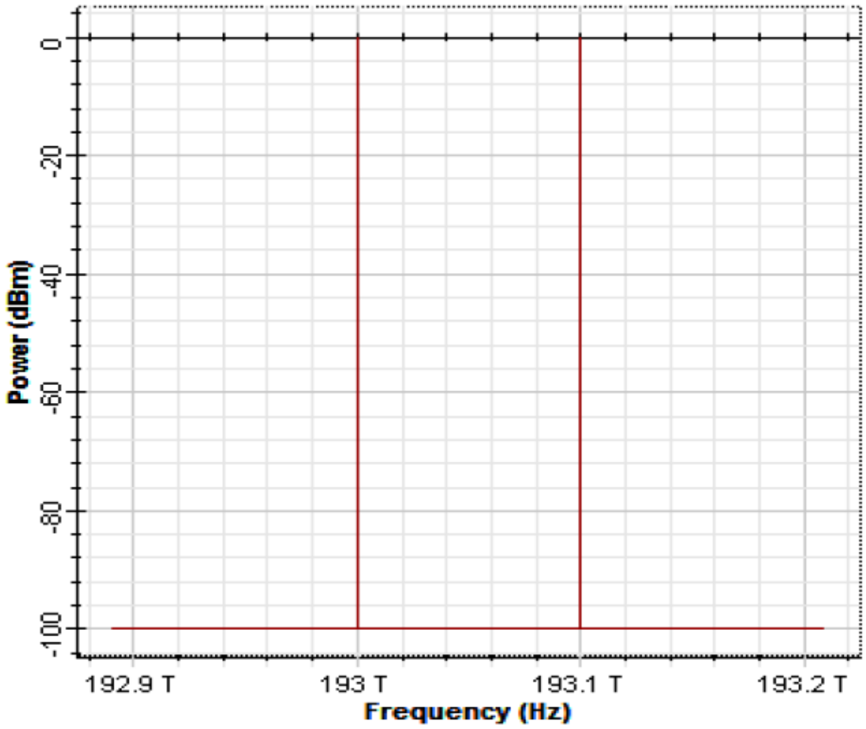


Fig.3.Output Spectrum Analyzer Output for signal power after WDM 2*1 MUX

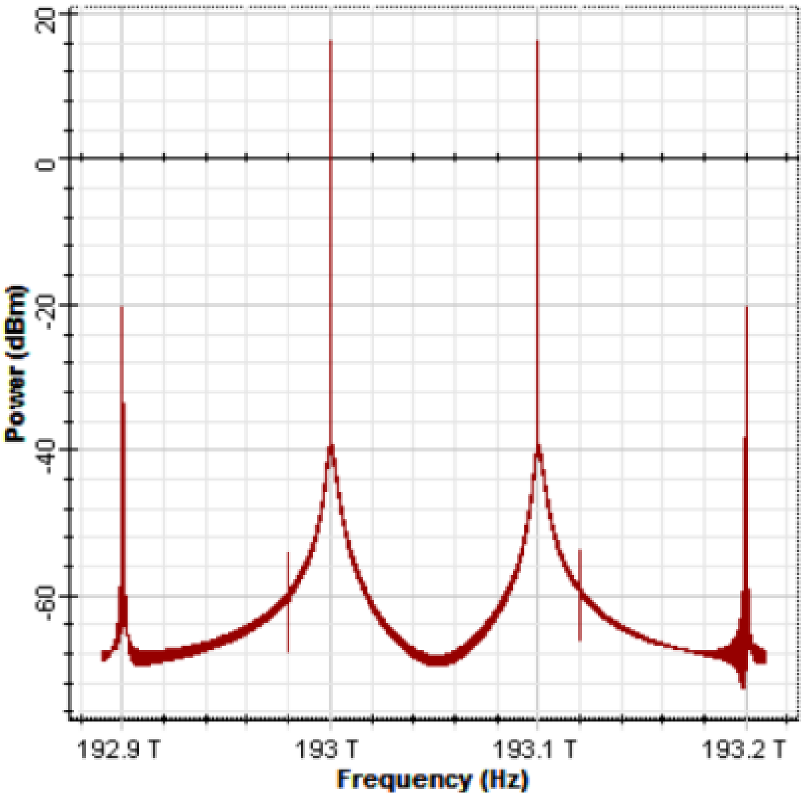


Fig.4.Optical Spectrum Analyzer Output after first SOA for signal Power

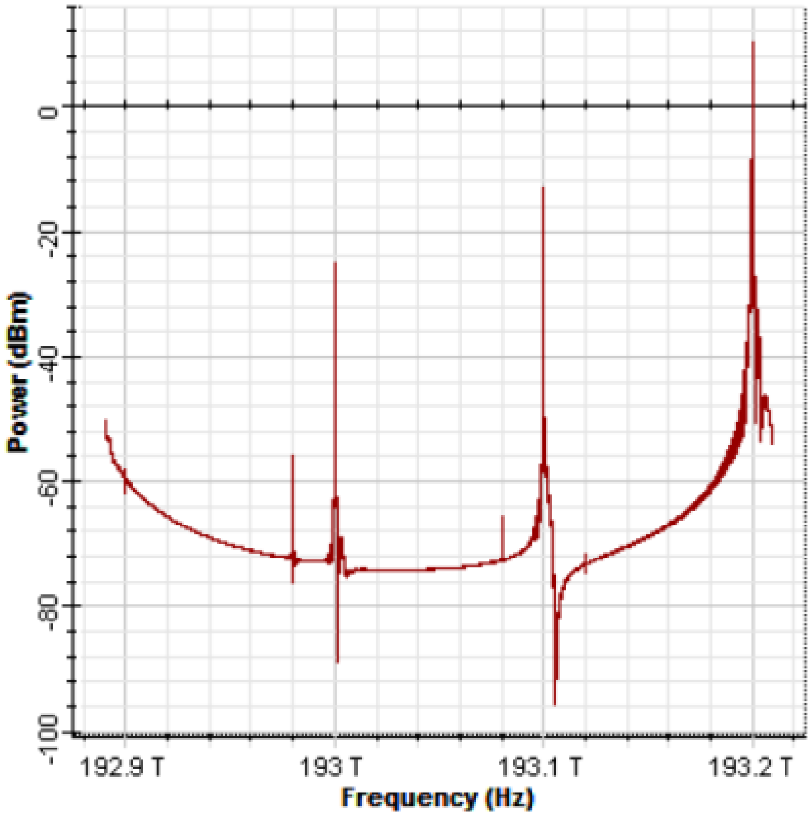


Fig.5. Signal Power after de-multiplexing and passing through second SOA

Results:

It can be inferred from the plots as the input power increases the pump power also increases and after a certain point it gets saturated. The frequency used is in GHz range which can be used for the generation of a new frequency and it is getting matched with the theoretical calculation.

Conclusion:

Hence, we have studied the SOA characteristics using Four Wave Mixing (FWM) under different conditions.

Experiment No.- 4

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

Apparatus Required: -

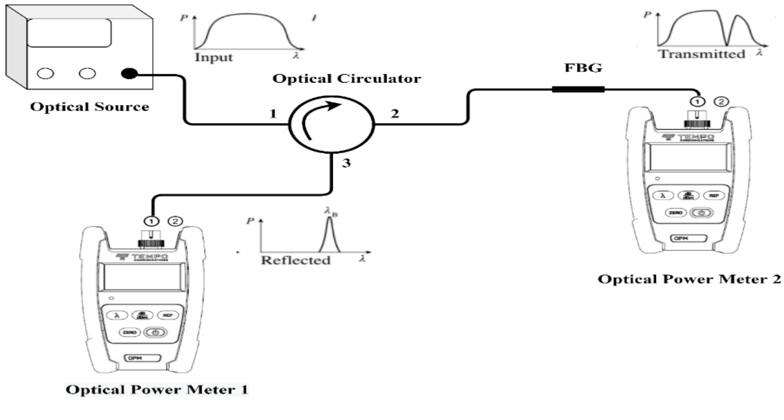
- FBG,
- Broadband light source,
- Optical circulator,
- Optical power meter,
- connecting optical patch cables.

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:

$$\lambda B = 2.neff.\wedge$$

Where $\wedge$ is the grating period and $neff$ 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.- 5

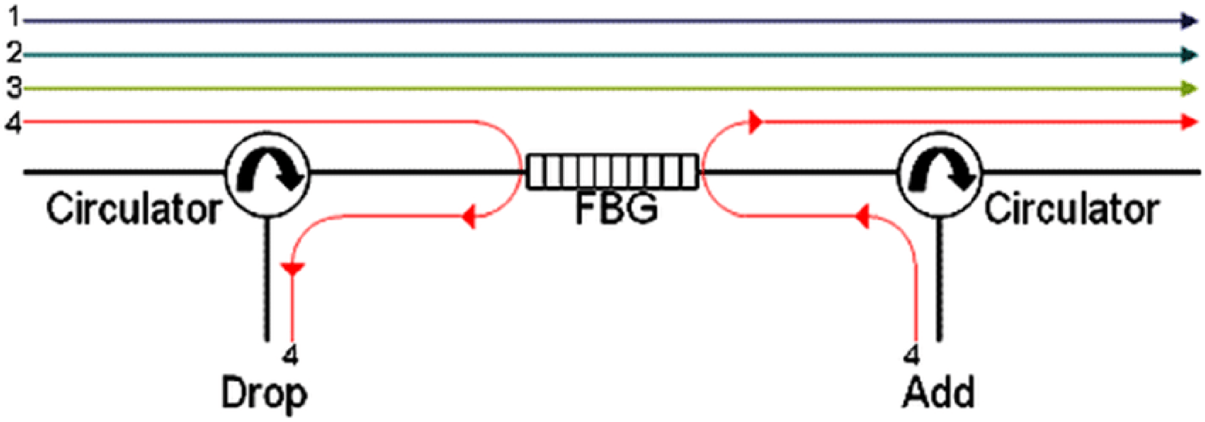
Objective: To study optical ADD/DROP multiplexer using fiber bragg grating.

Apparatus Required: -Opti-system

Theory:

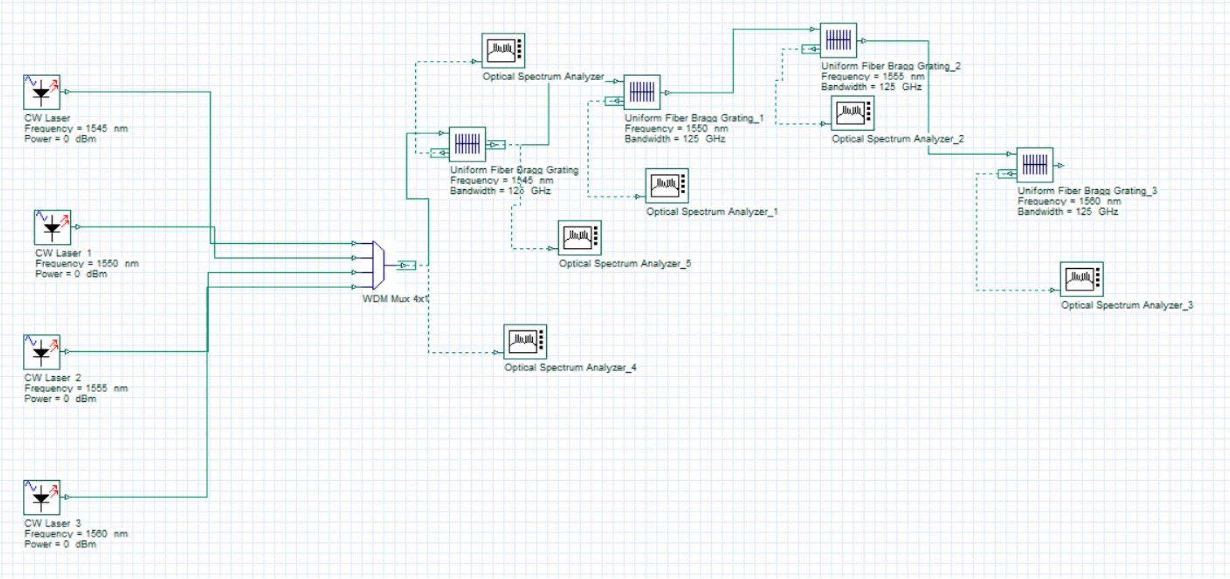
An optical add-drop multiplexer (OADM) is a device used in wavelength-division multiplexing systems for multiplexing and routing different channels of light into or out of a single mode fiber (SMF). This is a type of optical node, which is generally used for the formation and the construction of optical telecommunications networks. "Add" and "drop" here refer to the capability of the device to add one or more new wavelength channels to an existing multi-wavelength WDM signal, and/or to drop (remove) one or more channels, passing those signals to another network path.

With the help of FBG we can filter out the particular wavelength from the system which can be seen in figure below.



Add-drop multiplexer using fiber Bragg gratings (FBGs) and optical circulators.

The OADM allows dropping several fixed wavelength channels and at least one wavelength channel. By properly assigning wavelengths channels that are add-dropped at an OADM node, the tuning range required for FBGs can be made as small as the channel spacing. OADMs have potentially low insertion loss. The operation and performance of this OADM are experimentally investigated using optisystem.

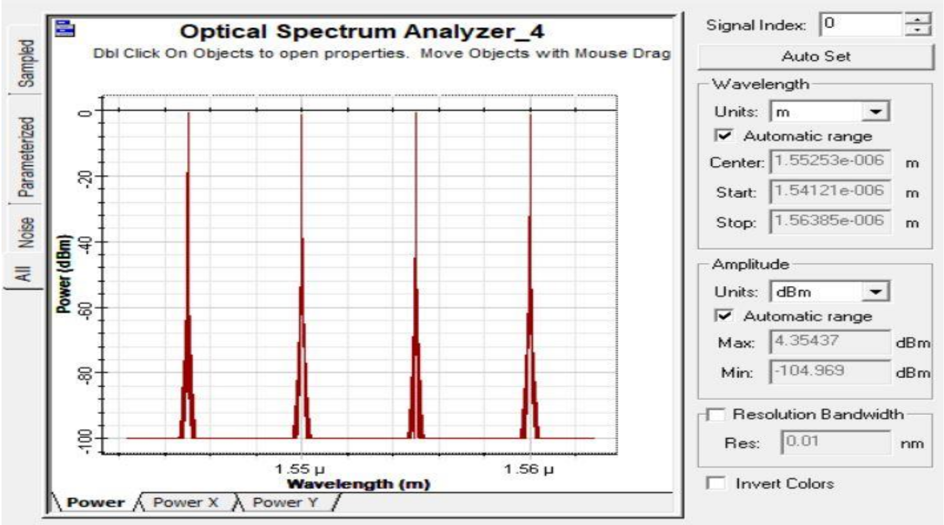


Simulation setup of add-drop multiplexer using fiber Bragg gratings (FBGs)

Procedure:

- Connect all the component from optisystem component libraray as shown in the above figure above.
- Set the parameter for different component used in the setup.
- Different wavelength signal are transmitted by WDM to perform ADD/DROP multiplexing.
- At first FBG any signal can be drop (remove) by tunning the FBG with the wavelength which need to be drop.
- Next the remaining wavelength is given to the next FBG.
- Similarly, the same ADD/DROP operation is done with all the FBGs

Results:



Signal Index: 0

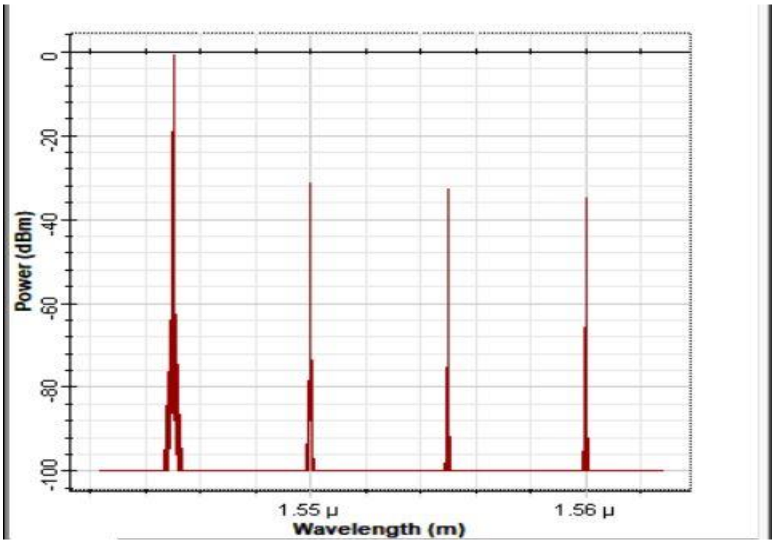
Wavelength
Units: m
☑ Automatic range
Center: 1.55253e-006 m
Start: 1.54121e-006 m
Stop: 1.56385e-006 m

Amplitude
Units: dBm
☑ Automatic range
Max: 4.35437 dBm
Min: -104.969 dBm

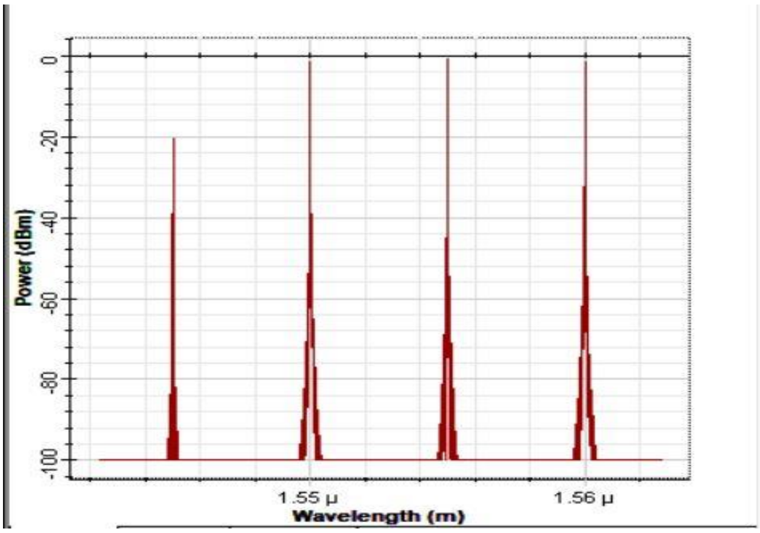
☐ Resolution Bandwidth
Res: 0.01 nm

☐ Invert Colors

Wavelength division multiplexing signal to perform OADM.



Drop signal with wavelength 1545 nm at first FBG.



The output of the first FBG is given to second FBG.

Conclusion:

Thus, by proper tunning the FBGs required wavelength can be add or drop to perform OADM. The system can be used for optical switching applications.

Experiment No.- 6

Objective: To demonstrate wavelength to power conversion interrogation technique using FBG.

Apparatus Required: -

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

Theory: -

I. FBG as a sensing element

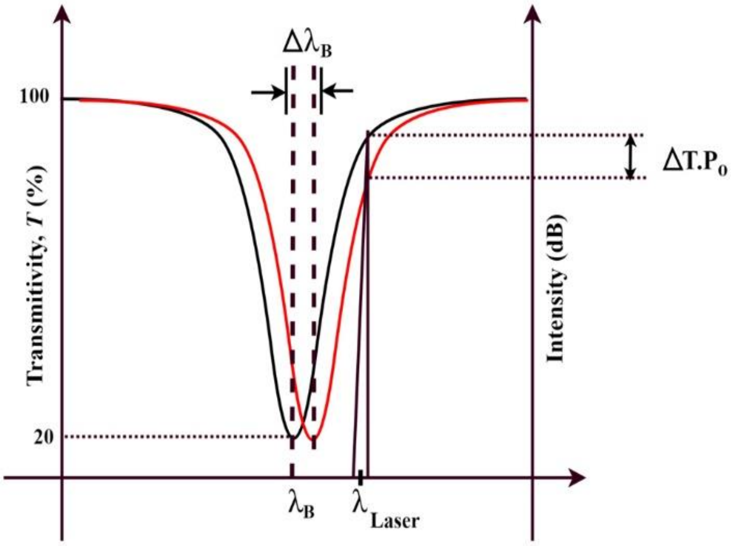
FBGs have demonstrated their remarkable sensing capability as well. They are sensitive to applied strain and temperature variation in its vicinity. The applied strain and temperature variation produce a change in grating period and effective refractive index of fiber Bragg grating, which produces red 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.

II. Wavelength Shift to Power Conversion

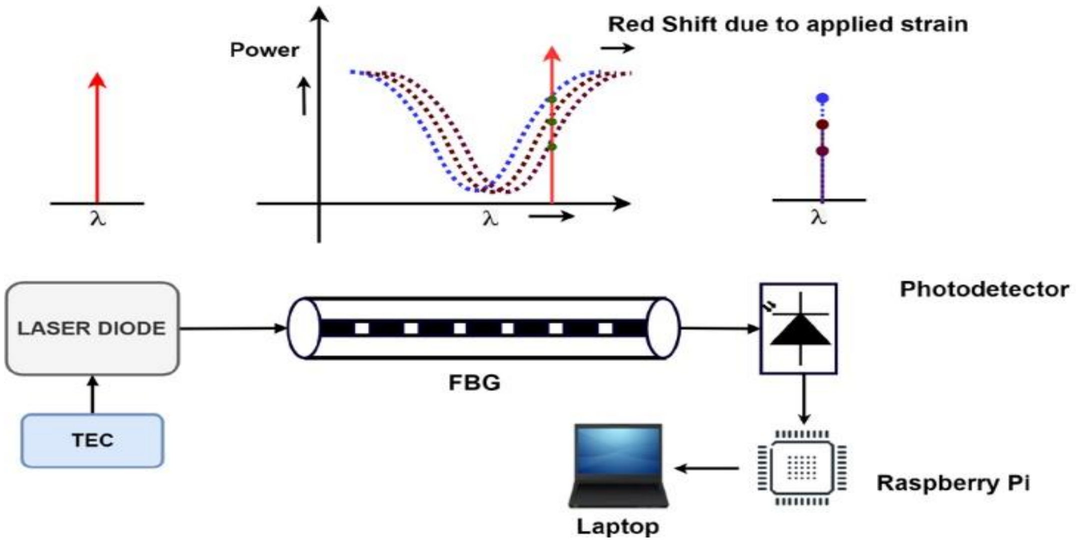


In this experiment, as shown in figure above the wavelength of laser source is tuned at linear region of transmission spectra. Whenever there is change in Bragg wavelength ($\Delta\lambda_B$) due to applied external strain, the transmitivity (T) of the FBG changes (ΔT) that results in change in optical power (P_0).In this measuring range, change in Bragg wavelength is comparatively small. By using the principle of small-signal model, the relationship between $\Delta\lambda_B$ and ΔT can be given as $\gamma = {}^{\Delta T}/_{\Delta\lambda_B}$.

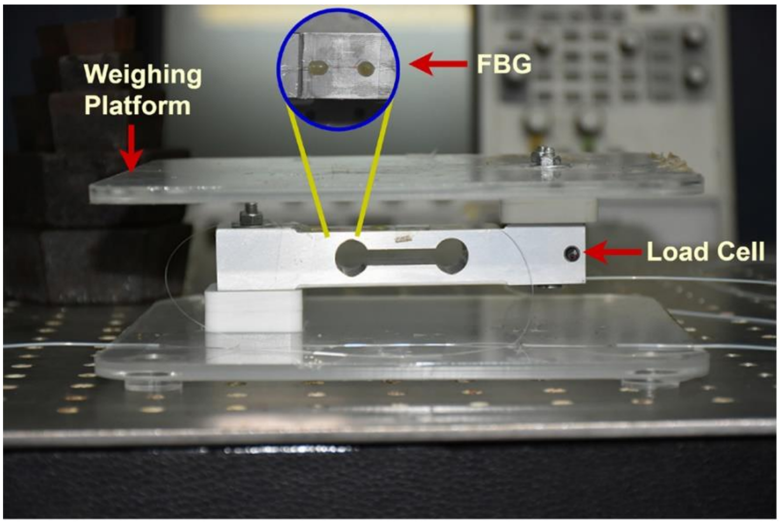
Thus,the optical power provide at photodetector can be given as:

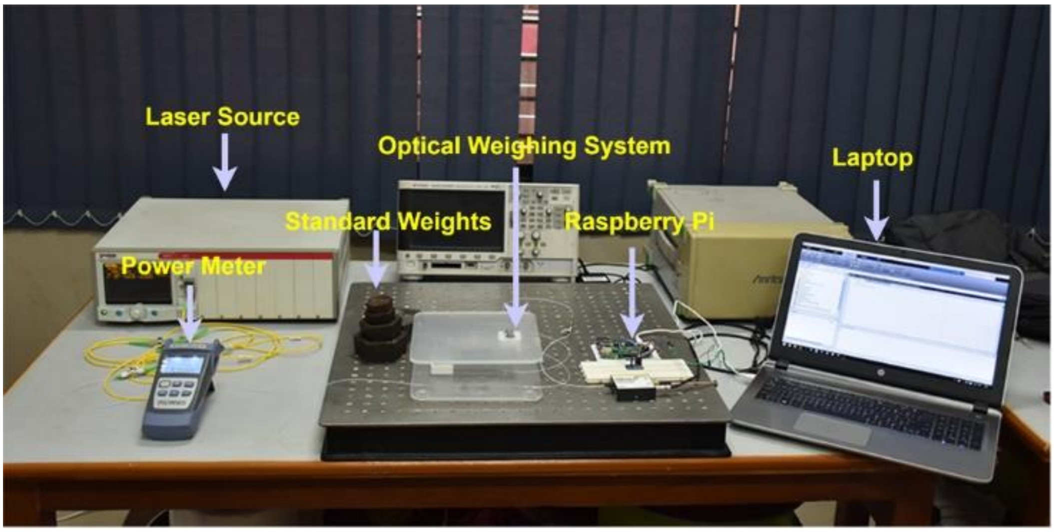
$$P_{out} = m(P_0.T + \gamma.P_0.\Delta\lambda_B)$$

Where T is the transmittivity of the FBG where the laser source is tuned, m is the loss occurred due to connectors, etc.

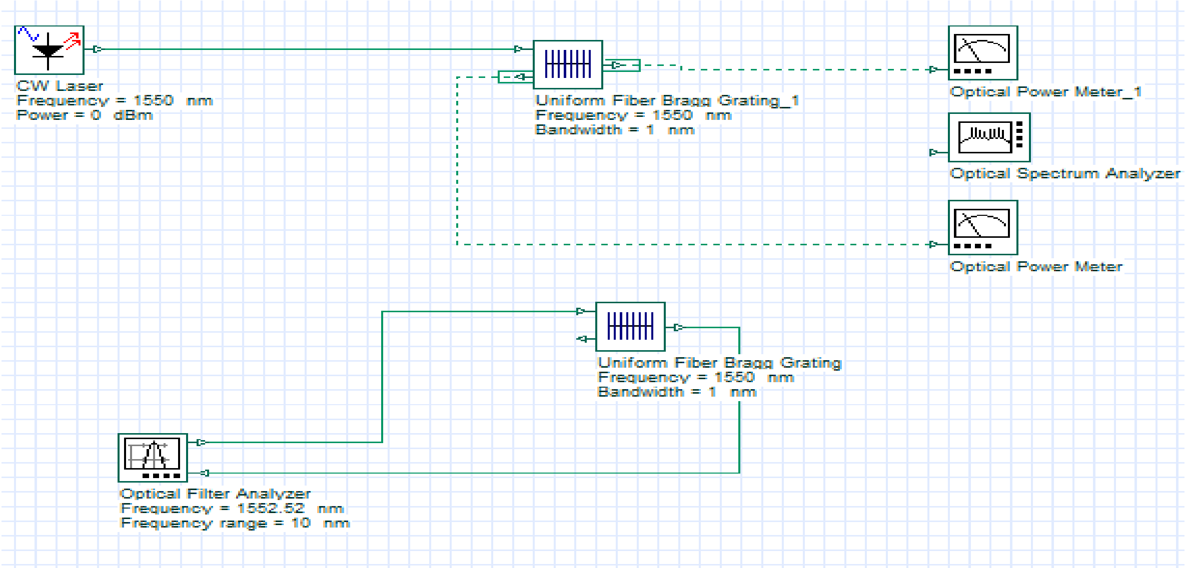


A. Laboratory set up for interrogation using FBG.





B. Optisystem setup for interrogation using FBG



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 record power.

Observation Table:

S. No.	Wavelength shift	Applied strain	Recorded Power (dBm)

Result:

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

Experiment No.-7

Objective: To characterize optical time domain reflectometer and analyze different types of fault in fiber under test.

The objective of this experiment is to understand the basic working principle and phenomenon of OTDR, preparing the OTDR by setting the parameters for fiber under test to detect different faults such as attenuation coefficient, maximum reflectance, ORL, event and section loss etc.

Equipment Required:

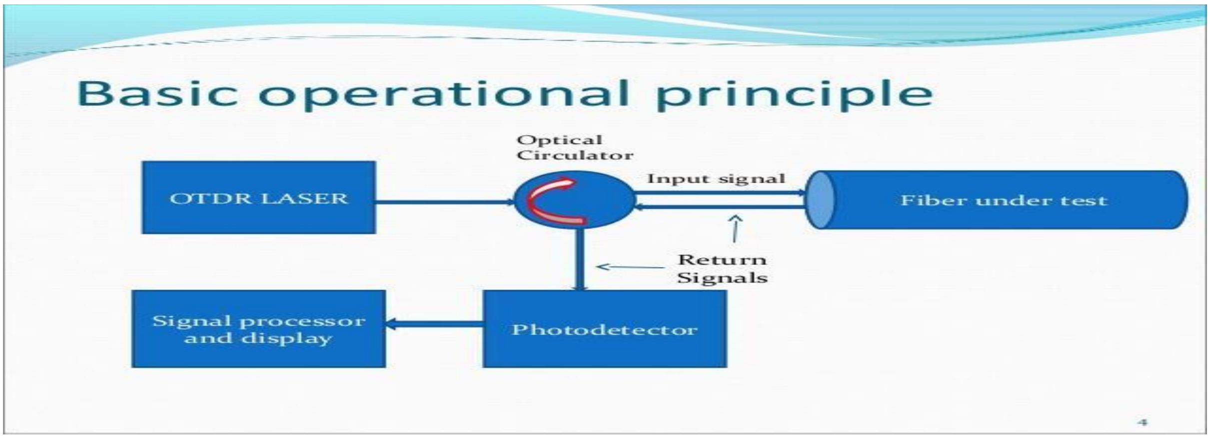
- OTDR
- Optical Fiber
- Connectors

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



Basic operational principle

OTDR LASER

Optical Circulator

Input signal

Fiber under test

Return Signals

Photodetector

Signal processor and display

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.

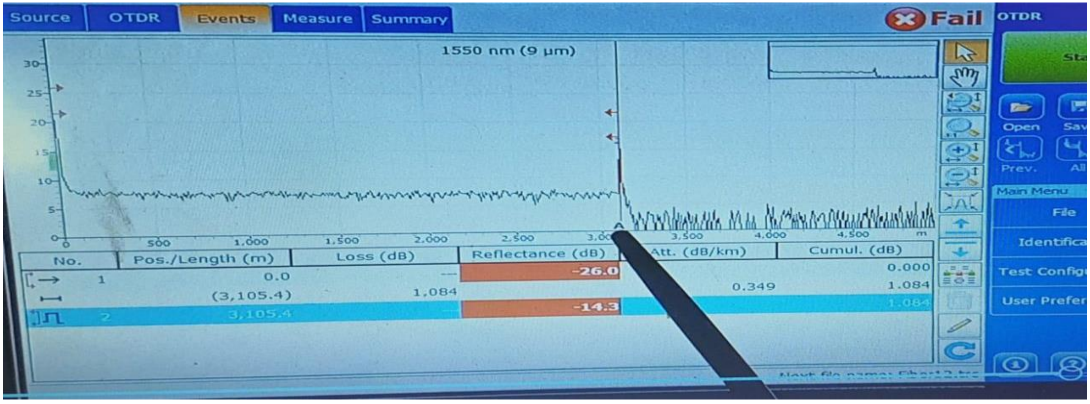
- Useful information returned will be measured by the OTDR detector, and act as the time or curve segments of fiber at different positions.
- Thus, the properties of the optical fiber link is then determined by analysing the amplitude and temporal characteristics of the waveform of the reflected and 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



No.	Pos./Length (m)	Loss (dB)	Reflectance (dB)	Att. (dB/km)	Cumul. (dB)
1	0.0	---	-26.0		0.000
	(3,105.4)	1,084		0.349	1.084
2	3,105.4		-14.3		1.084

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

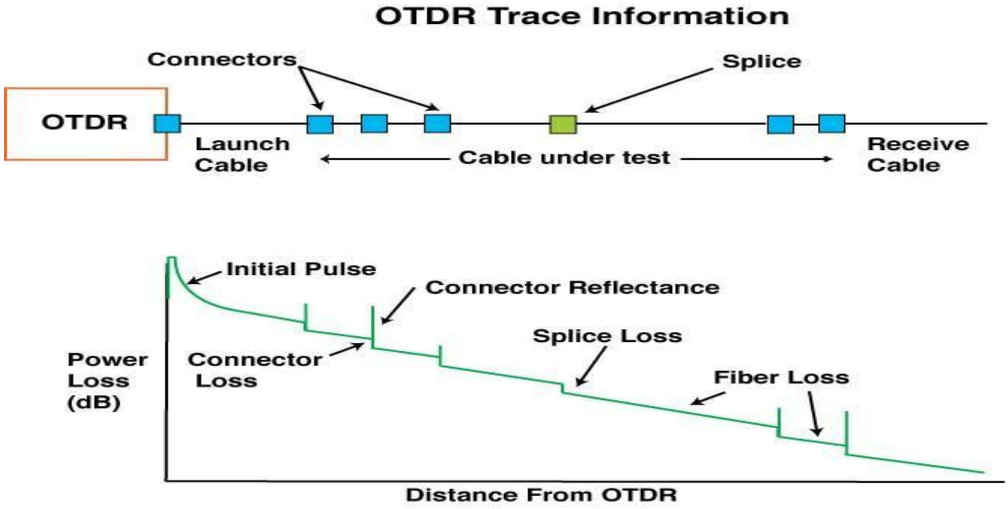


Fig 3. OTDR trace for different types of faults.

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

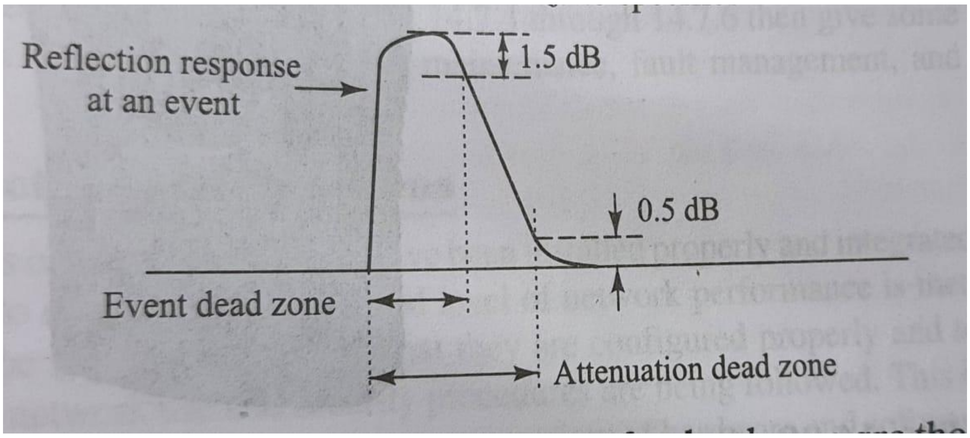


Fig 4. Dead zone

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:

First the OTDR is connected to a optical fiber under test using FC patch cord and then the parameter setting is done**.**

I. Laboratory setup

II. 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.
- **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.

III. Fault analysis in fiber under test:

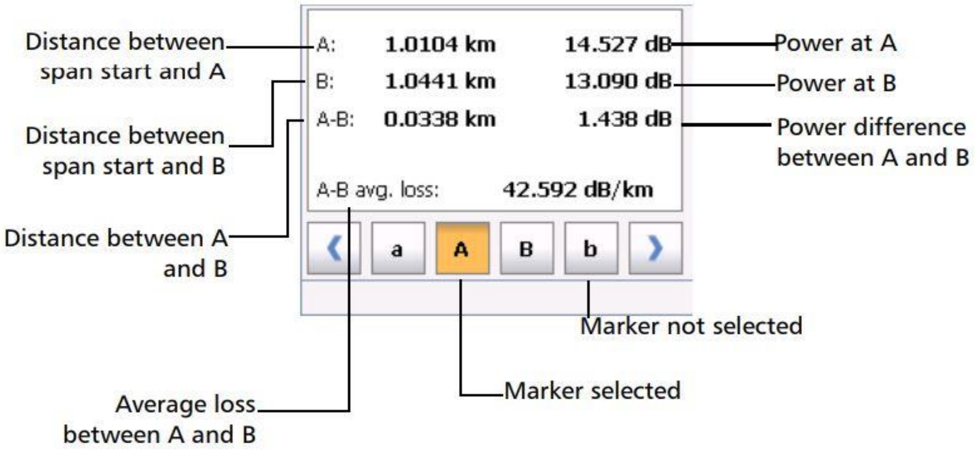
For analyzing the results the markers can be moved or zoom in on or out of any event or trace segment to measure splice loss, fiber section attenuation, reflectance, and optical return loss.

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.

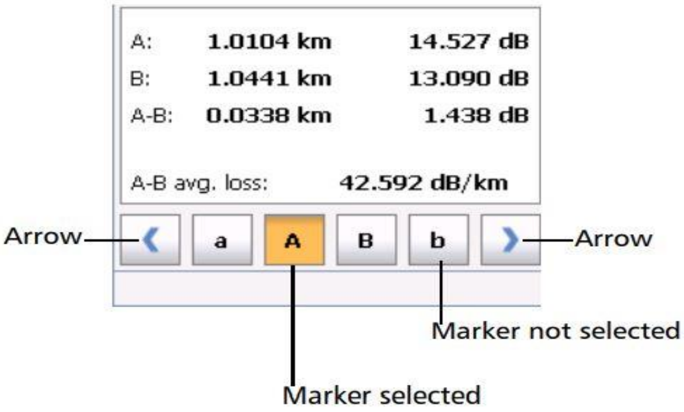


A: 1.0104 km 14.527 dB
B: 1.0441 km 13.090 dB
A-B: 0.0338 km 1.438 dB

A-B avg. loss: 42.592 dB/km

To move a marker with the arrow buttons:

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



A: 1.0104 km 14.527 dB
B: 1.0441 km 13.090 dB
A-B: 0.0338 km 1.438 dB

A-B avg. loss: 42.592 dB/km

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.

A: 1.0104 km 14.527 dB
B: 1.0441 km 13.090 dB
A-B: 0.0338 km 1.438 dB

A-B avg. loss: 42.592 dB/km

4-Point Event Loss: 1.426 dB

Max. Reflectance: -52.0 dB

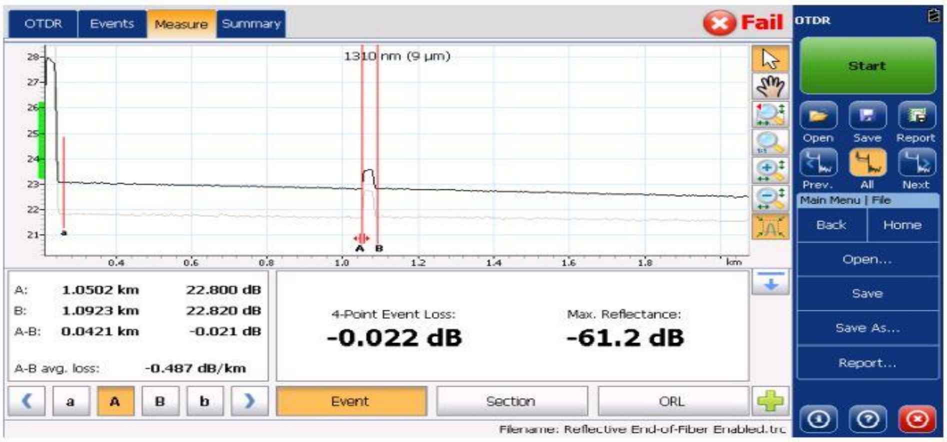
Filename: Macrobend & Mer

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.



A: 1.0502 km 22.800 dB
B: 1.0923 km 22.820 dB
A-B: 0.0421 km -0.021 dB

A-B avg. loss: -0.487 dB/km

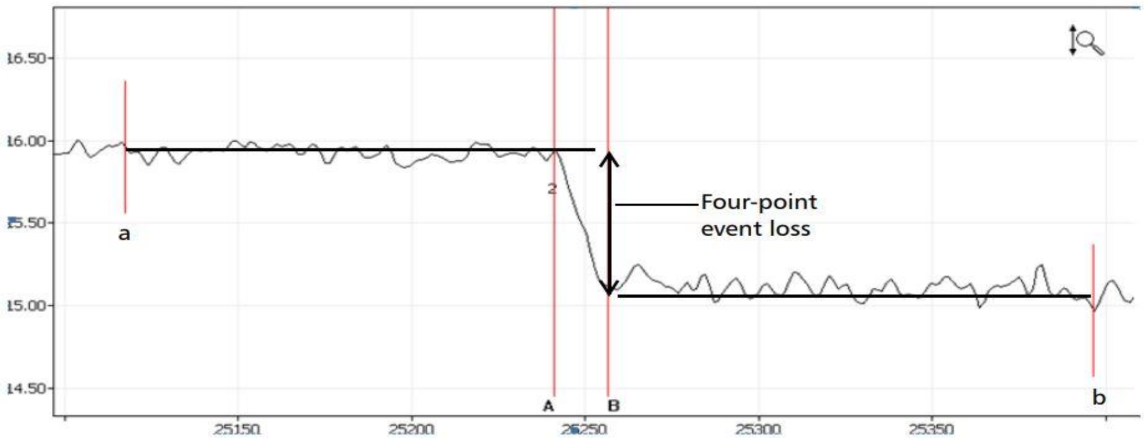
4-Point Event Loss: -0.022 dB

Max. Reflectance: -61.2 dB

Filename: Reflective End-of-Fiber Enabled.trc

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.



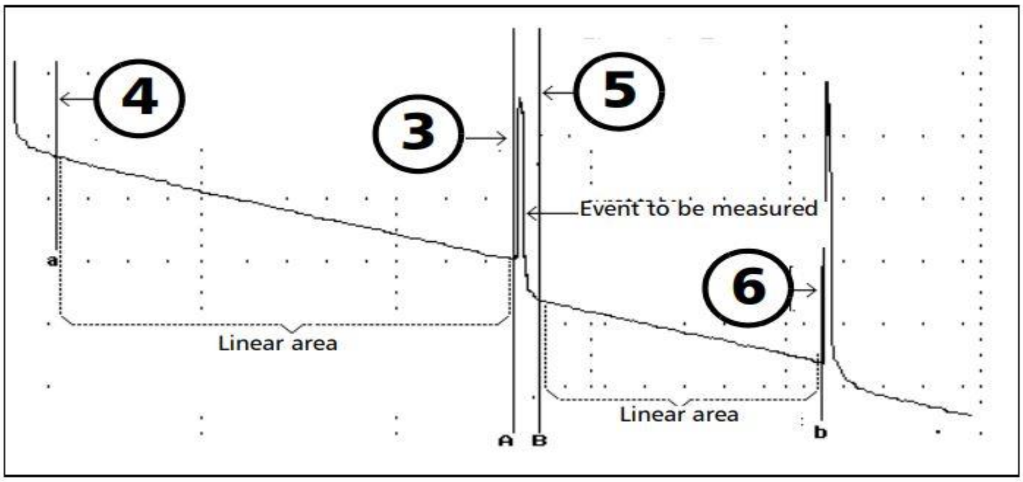
The two fitted lines are then extrapolated toward the center of the event and the loss event is directly read from the drop in power between the two lines.

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).



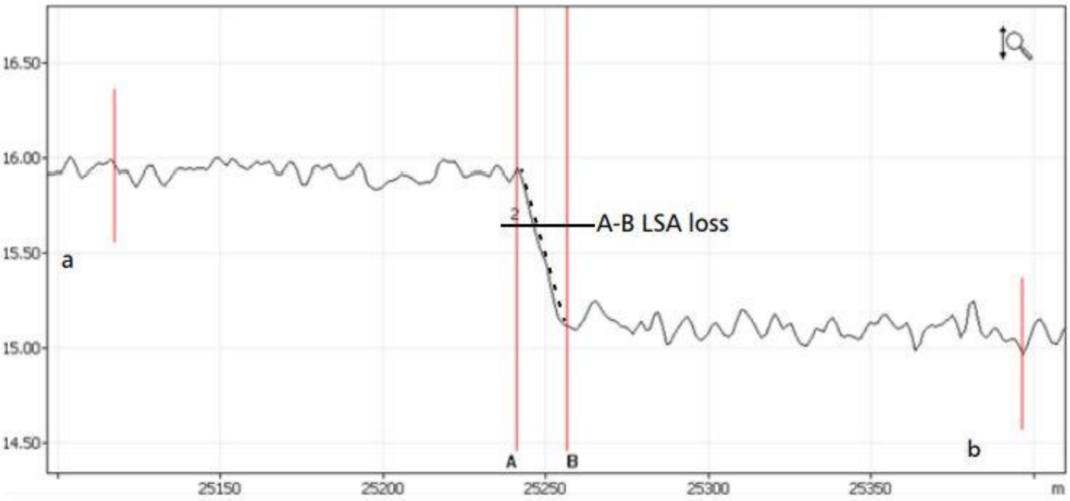

4-Point Event Loss: 1.426 dB

Max. Reflectance: -52.0 dB

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.*

A-D LSA Loss: 0.003 dB

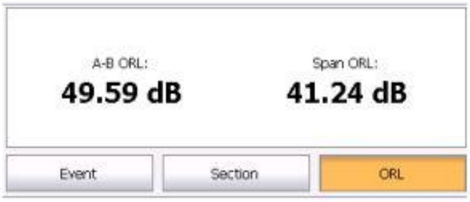
A-D LSA Attenuation: --- dB/km

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.



A-B ORL: 49.59 dB

Span ORL: 41.24 dB

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-8

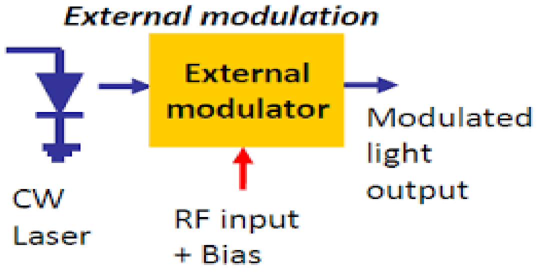
Objective: - To characterize of Mach-Zehnder Modulator (MZM) for different biasing conditions using opti-system.

Apparatus Required: - Optisystem software

Theory:

i. External modulator:

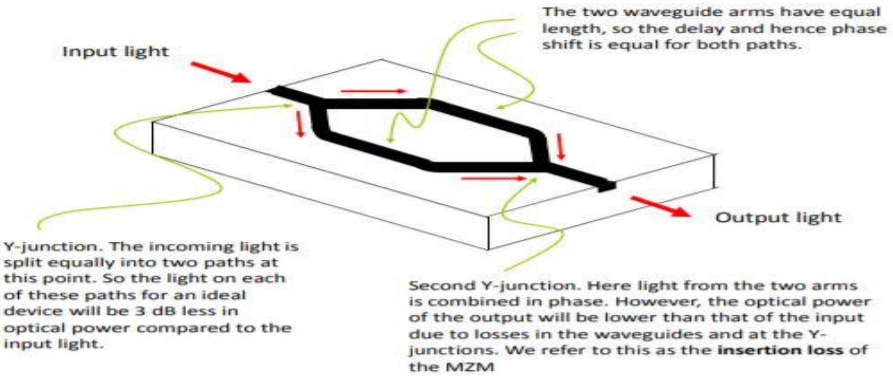
We can modulate the light from a laser with an external component known as a modulator. Hence termed as external modulation and external modulator. Laser emits constant optical power, this is then passed through an optical modulator (external modulator).External modulation is a voltage driven device. As we adjust the voltage, the amount of optical power absorbed will vary. In this way, we achieve modulation of the optical power coming out of the modulator.



One advantage of external modulation is that it can be used to implement optical phase modulation, which opens up the possibility of coherent optical communications and therefore increased receiver sensitivity.

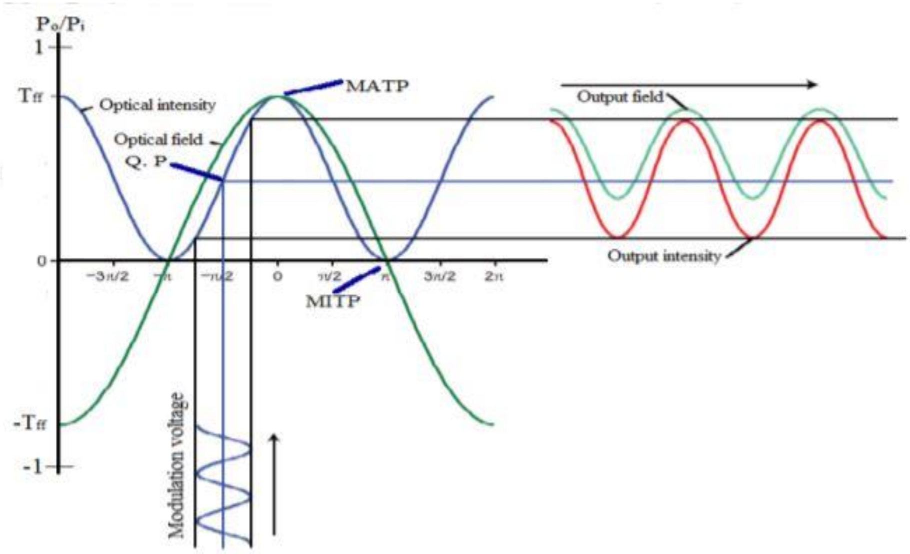
ii. Mach-Zender modulator Structure:

External modulators that are based on the interferometer principle are known as Mach-Zehnder modulators (MZM). Thus, Mach-Zehnder modulator (MZM) is an interferometric structure which are made from a material with strong electro-optic effect (eg-LiNbO3).

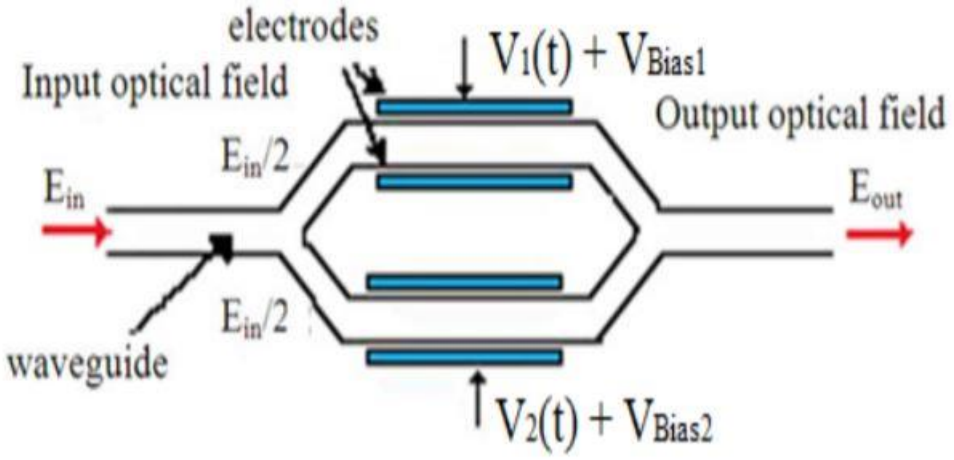


Applying electric fields to the arms changes optical path lengths resulting in phase modulation Combining two arms with different phase modulation converts phase modulation into intensity modulation.

iii. MZM Transfer characterstics:



iv. Mach-Zender modulator at different biasing condition:



The input optical carrier and electrical drive signal is given by :

$$E_{OP}(t) = E_0 \exp[j(2\pi f_{OP})t] \quad \text{(1) and}$$

$$V_{RF(t)} = V_e \cos(2\pi f_{RF})t \quad (2)$$

Where E_0 =amplitude of optical carrier and V_e =amplitude of electrical signal

The DD-MZM output can be given as:

$$E_{DDMZM}(t) = \frac{E_0}{2}(exp(\omega_{OP})t)[e^{j(\gamma\pi+\eta\pi(\cos(2\pi f_{RF})t)} + e^{j\eta\pi(\cos(2\pi f_{RF}+_{\theta})t}] \quad (3)$$

Where,

$\eta = \frac{V_{DC}}{V_\pi}$ normalized bias voltage

$\gamma = \frac{V_{RF}}{V_\pi}$ normalized amplitude of drive modulating voltage

$V_\pi = half\ wave\ voltage$

- **DD_MZM biased at Quadrature point:**

Quadrature point is located at linear region where the modulator offers maximum linearity. A bias voltage of $V_{bias} = \frac{V_\pi}{2}$ = 2V is required between the branches. Here $\gamma = \frac{1}{2}\ and\ \theta = \pi$.

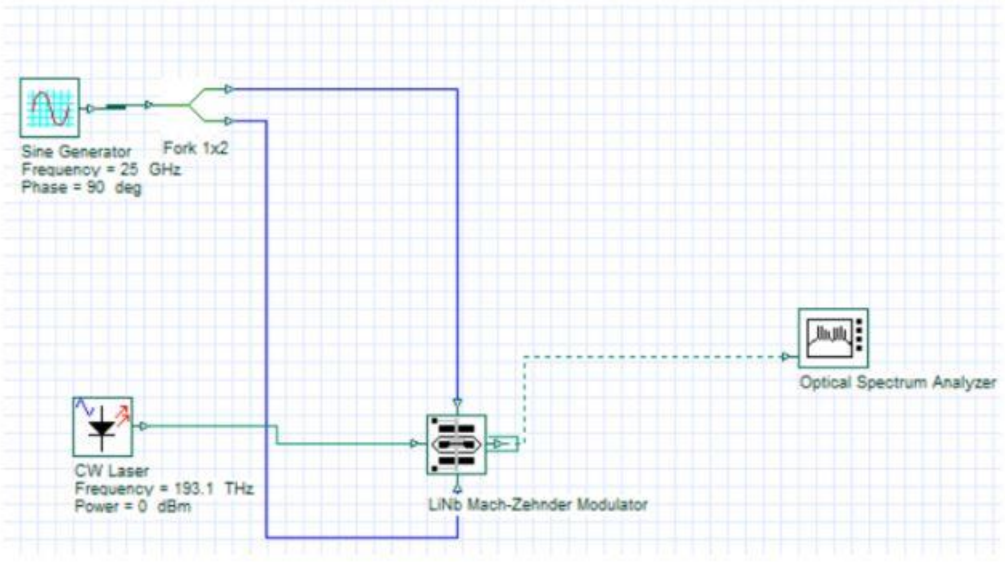
- **DD_MZM biased at minimum transmission point:**

Minimum transmission point (MITP) is an ideal situation where there is no power at the output. A bias voltage of $V_{bias} = V_\pi = 4V$ is required between the branches. Here $\gamma = \frac{1}{2}\ and\ \theta = \frac{\pi}{2}$.

- **DD_MZM biased at maximum transmission point:**

Maximum transmission point (MATP) is situation where there is maximum power at the output. A bias voltage of $V_{bias} = V_\pi = 0$ is required between the branches. Here $\gamma = 1\ and\ \theta = 0$.

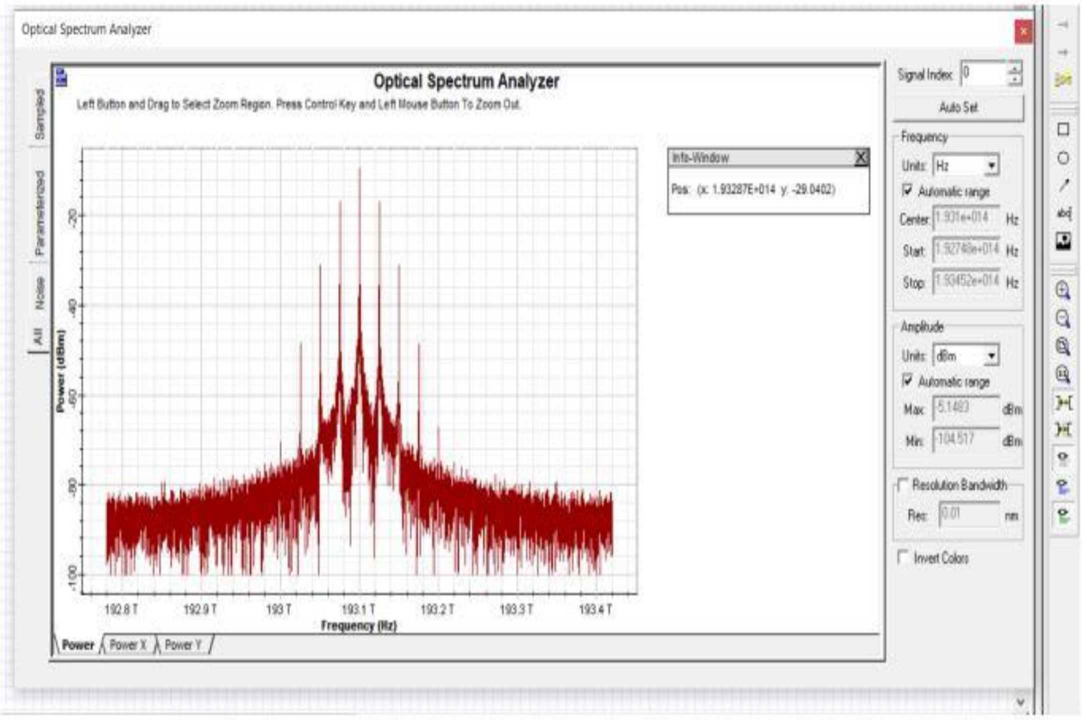
Procedure:



Simulation experiment setup for external modulation using Lithium niobate DD_MZM.

- Connect all the component from optisystem component libraray as shown in the above figure.
- Set the parameter for different biasing condition.
- Analyze the results

Results:



Pos: (x: 1.93287E+014 y: -29.0402)

Signal Index: 0

Units: Hz

☑ Automatic range

Center: 1.931e+014 Hz

Start: 1.92748e+014 Hz

Stop: 1.93452e+014 Hz

Units: dBm

☑ Automatic range

Max: -5.1483 dBm

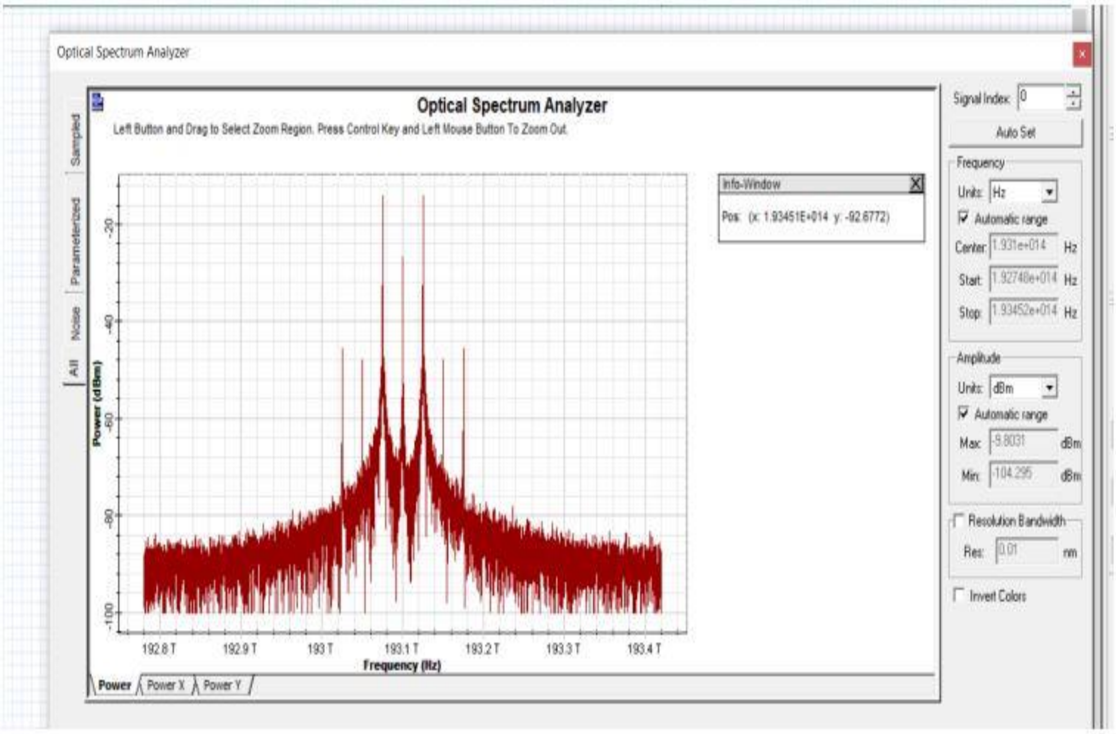
Min: -104.517 dBm

☐ Resolution Bandwidth

Res: 0.01 nm

☐ Invert Colors

Fig 1: Optical spectrum analyzer output for quadrature point



Pos: (x: 1.93451E+014 y: -92.6772)

Signal Index: 0

Units: Hz

☑ Automatic range

Center: 1.931e+014 Hz

Start: 1.92748e+014 Hz

Stop: 1.93452e+014 Hz

Units: dBm

☑ Automatic range

Max: -9.8031 dBm

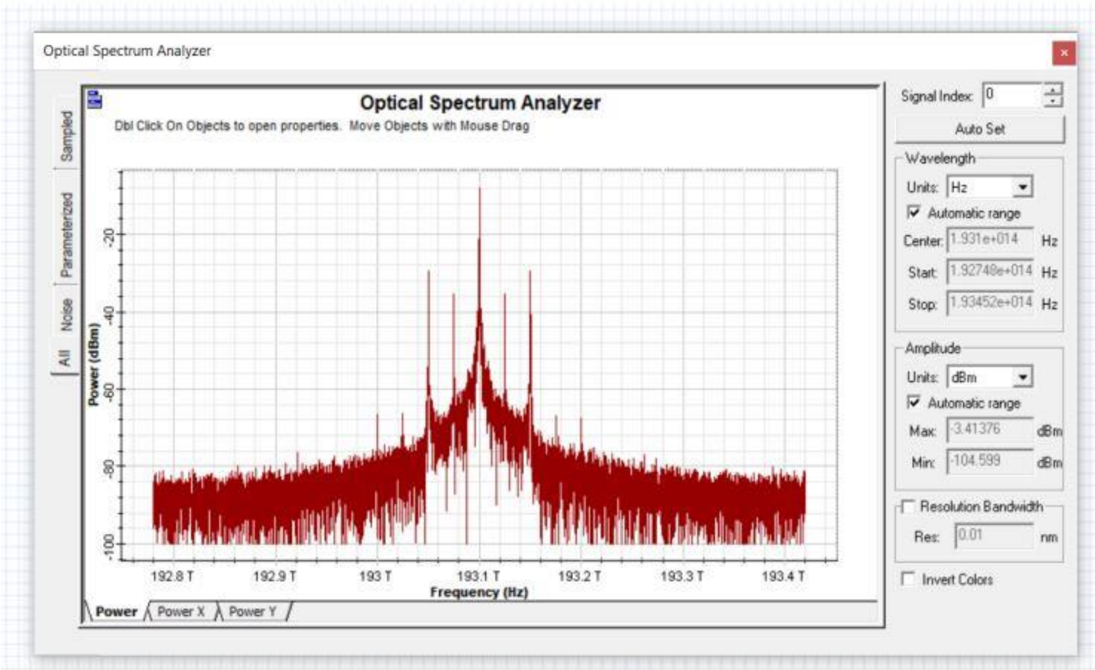
Min: -104.295 dBm

☐ Resolution Bandwidth

Res: 0.01 nm

☐ Invert Colors

Fig 2: Optical spectrum analyzer output for MITP.



Signal Index: 0

Units: Hz

☑ Automatic range

Center: 1.931e+014 Hz

Start: 1.92748e+014 Hz

Stop: 1.93452e+014 Hz

Units: dBm

☑ Automatic range

Max: -3.41376 dBm

Min: -104.599 dBm

☐ Resolution Bandwidth

Res: 0.01 nm

☐ Invert Colors

Fig 3: Optical spectrum analyzer output for MATP.

Conclusion:

- At quadrature point all sidebands are present.
- At MITP all second order sidebands are suppressed.
- At MATP all first order sidebands are suppressed.

Experiment No.-9

Objective: - To Measure the Attenuation in Fiber Optic Attenuator

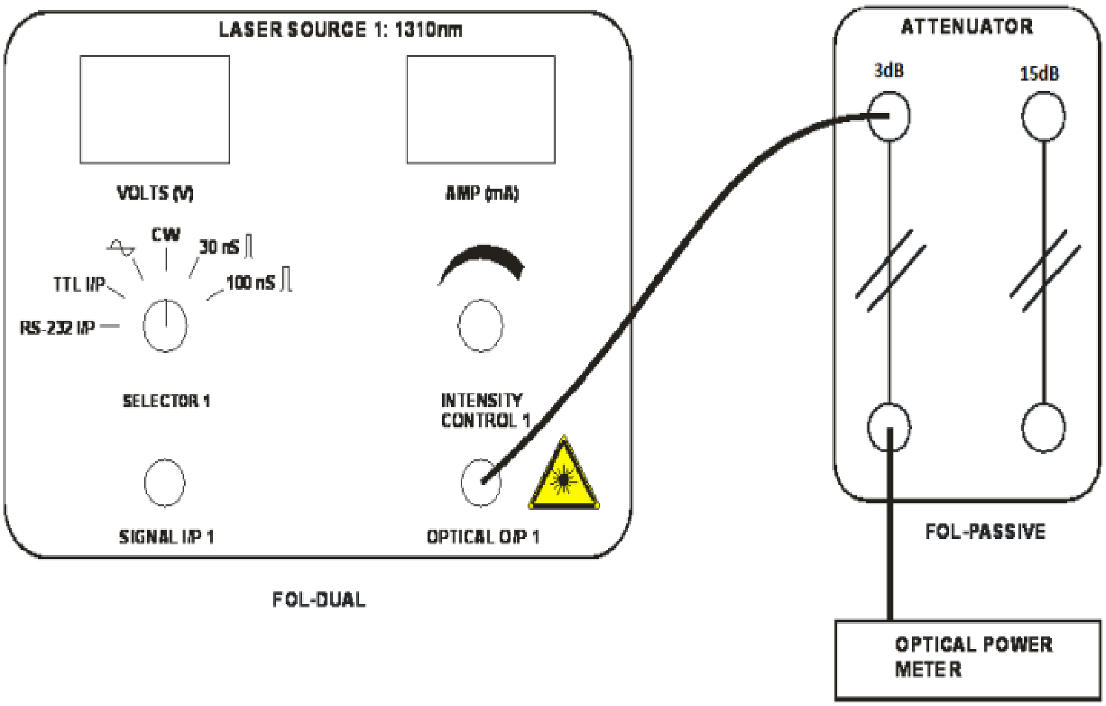
Apparatus Required: -

- 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_{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.-10

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: -

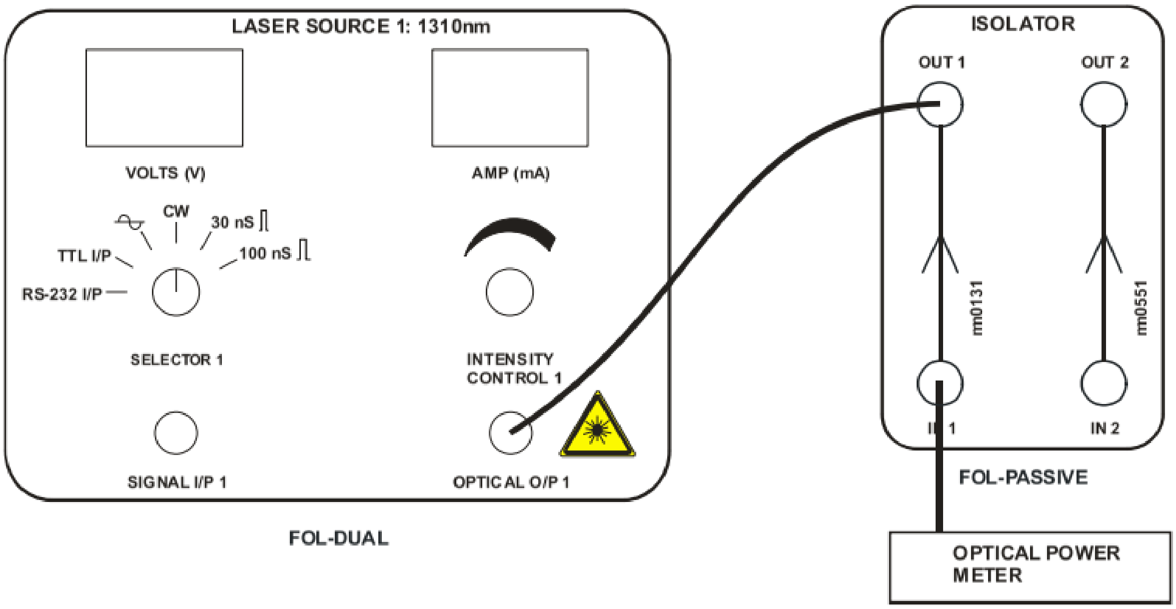
An optical isolator, or optical diode, is an optical component which allows the transmission of light in only one direction. They are typically used to prevent unwanted feedback into an optical oscillator, such as a laser cavity. The operation of the device depends on the Faraday effect (which in turn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

$$\beta = \nu \mathrm{B} d$$

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,
α_{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.