DEPARTMENT OF ELECTRONICS ENGINEERING

INDIAN INSTITUTE OF TECHNOLOGY (ISM)

DHANBAD- 826004

LAB MANUAL

FOR

ELECTRONICS ENGINEERING LABORATORY (PG)

Modular - II

ECC508

DEPARTMENT OF ELECTRONICS ENGINEERING
INDIAN INSTITUTE OF TECHNOLOGY (ISM) DHANBAD

Subject: Electronics Engineering Lab (ECC508), L-T-P: 0-0-3

PG (Modular -II) - Photonics

Electronics Engineering Laboratory (PG): -

Sl. No.	List of Experiments
1	Write a MATLAB program to plot the normalized index b, against the normalized freq. V, for different values of symmetric coefficient 'a' and for the first three values of 'v'.
2	To observe Laser Characteristics and find threshold current using conventional techniques.
3	To observe and characterize Fiber Bragg Grating as an optical filter (Software).
4	To study the length dependence of attenuation in the given optical fiber.
5	To check the characteristics of a 3-port Circulator at various wavelengths
6	To Observe and characterize Fiber Bragg Grating (FBG) as an optical filter (Hardware).
7	To Observe and characterize Fiber Bragg Grating (FBG) as an optical sensor.
8	Design a WDM fiber optic link with the given components and determine the total loss in the system for each wavelength
9	Equalization of optical channel strength in a multi-wavelength fiber optic system using attenuators.
10	(a). Familiarization with the hardware equipment and characterization of LED and LASER Diodes. (b). Study of optical passive components like circulators, isolators, and attenuators.

DO'S AND DON'TS DO'S

DO'S

- Maintain strict discipline.
- Proper handling of apparatus must be done.
- Before switching on the power supply get it checked by the lecturer.
- Switch off the mobiles.
- Be a keen observer while performing the experiment.

DON'TS

- Do not touch or attempt to touch the mains power directly with bare hands.
- Do not manipulate the experiment results.
- Do not overcrowd the tables.
- Do not tamper with equipment.
- Do not leave the table without prior permission from the teacher.

EXPERIMENT No. - 1

OBJECTIVE: - Write down a MATLAB program to plot the normalized index b, against the normalized freq. V, for three values of asymmetric coefficient 'a' and for the first three values of 'v'. (Values of a=0, a=10, and a=∞ may be used).

The transcendental equation is given as:

$$V\sqrt{1-b} = v\pi + tan^{-1}\sqrt{\frac{b}{(1-b)}} + tan^{-1}\sqrt{\frac{b+a}{(1-b)}}$$; where v is an integer.

For plotting different order modes, consider the values of v as 0,1,2 and for each mode take the three values of a such as 0,8 and 50.

Here, $V = k_0 d(n_1^2 - n_2^2)^{1/2}$; Normalized freq./V-number,

$$b = \frac{\left(\frac{\beta}{k_0}\right)^2 - n_2^2}{n_1^2 - n_2^2}$$; Normalized mode index,

$$a = \frac{n_2^2 - n_3^2}{n_1^2 - n_2^2}$$; Asymmetry measure.

SOFTWARE REQUIRED: - Matlab 2019a

THEORY: -

Normalized frequency (v): -

The *V number* is a dimensionless parameter which is often used in the context of **step-index fibers**. It is defined as

$$V = \frac{2\pi}{\lambda} a\, NA = \frac{2\pi}{\lambda} a \sqrt{{n_{core}}^2 - {n_{cladding}}^2}$$

Where λ is the vacuum wavelength, '*a*' is the radius of the **fiber core**, and NA is the **numerical aperture**.

Since the V-number of the optical fiber is proportional to the frequency, it is also called as the normalized frequency.

For *V* values below ≈ 2.405, a **fiber** supports only one mode per polarization direction (→ ***single-mode fibers***).

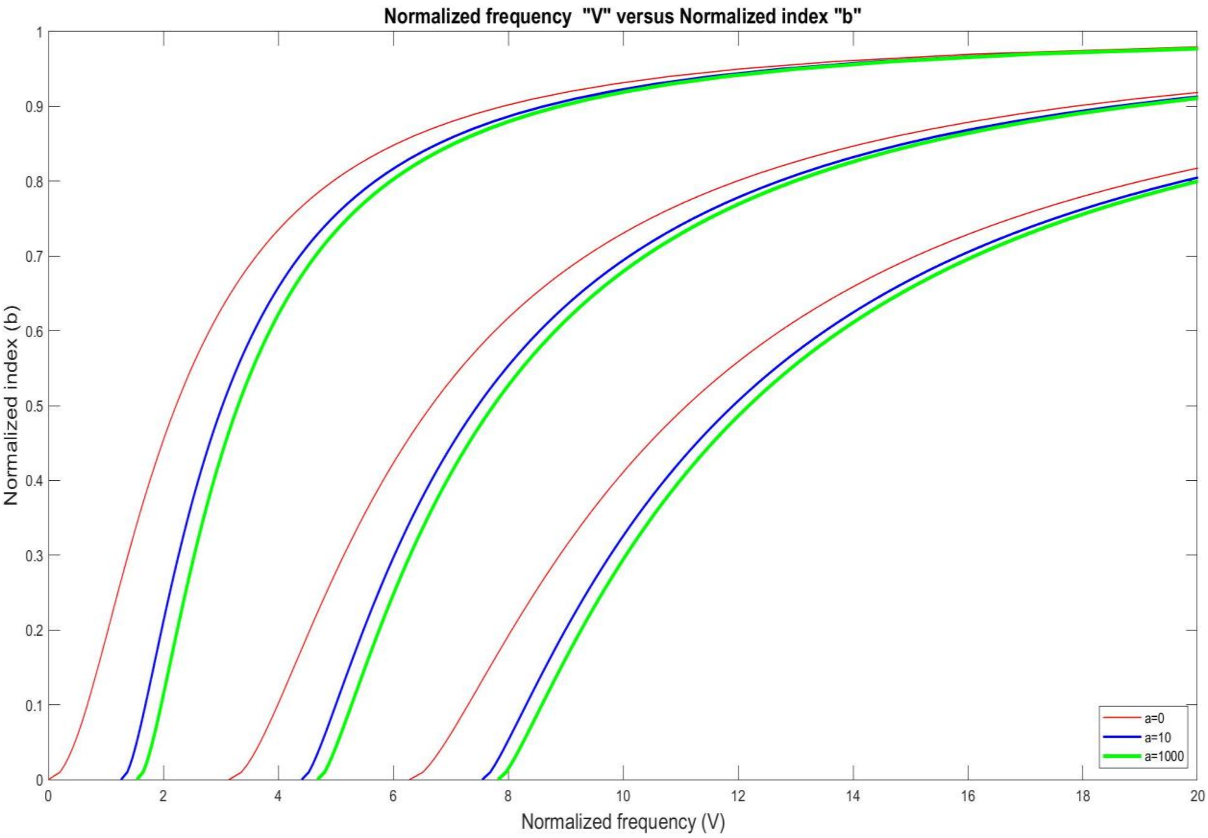
Multimode fibers can have much higher *V* numbers. For large values, the number of supported modes of a step-index fiber (including polarization multiplicity) can be calculated approximately as

$$M \approx \frac{V^2}{2}$$

PROCEDURE: -

1) Mat lab coding has to be done to plot those equations.
2) Plot all the three questions and solve it with the help of the given values.

RESULT: -



EXPERIMENT No. – 2

OBJECTIVE: - To observe Laser Characteristics and find threshold current using conventional techniques.

SOFTWARE REQUIRED: - Opti-System, MS-Excel

In the Optisystem software following components are required: -

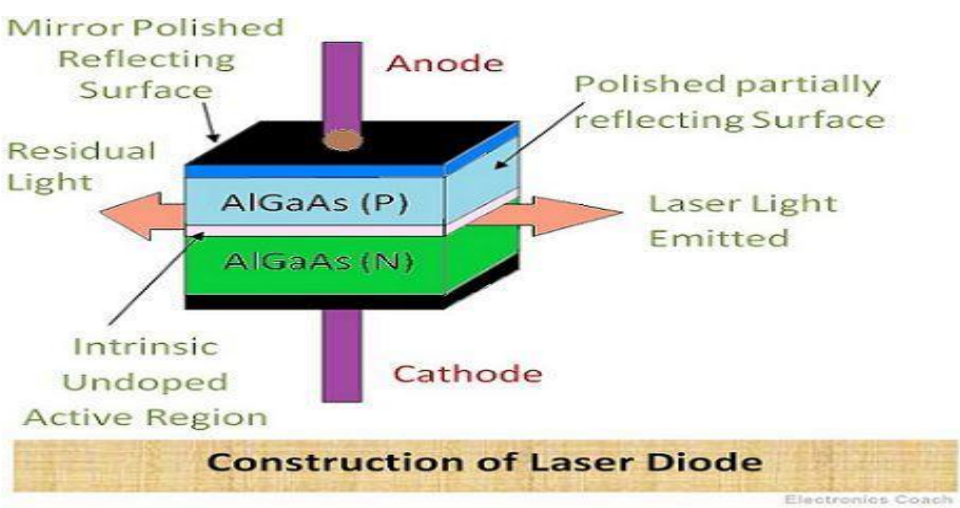
1. DC Bias Generator – 1
2. Laser Rate Equations -1
3. Optical Power Meter -1

THEORY: - A laser diode is a semiconductor that uses a p-n junction for producing coherent radiation with the same frequency and phase which is either in the visible or infrared spectrum. It is also called an injection laser diode and, the technology is similar to that found in LED. LASER stands for Light Amplification by Stimulated Emission Radiation. LASER Diodes are widely used in Optical fiber systems, CD players, LASER printers, etc.

Construction of LASER Diode: The Laser diode is made up of two layers of Semiconductors i.e. P-type and N-type. The layers of semiconductors are made up of GaAs doped with materials like selenium, aluminum, or silicon. The construction is the same as that of LED except the channels used in Laser are narrow to produce a single beam of light.

And one more difference in a Laser diode is that an intrinsic layer of GaAs (undoped) is also present. This layer is called the active layer. The active layer is enclosed by layers of lower refractive index. This act as optical reflectors.

These layers along with the active layer form a waveguide so that light can travel only in a single path in a single and fixed direction. The beam of light is produced in this section. The metal contacts are provided to facilitate biasing.



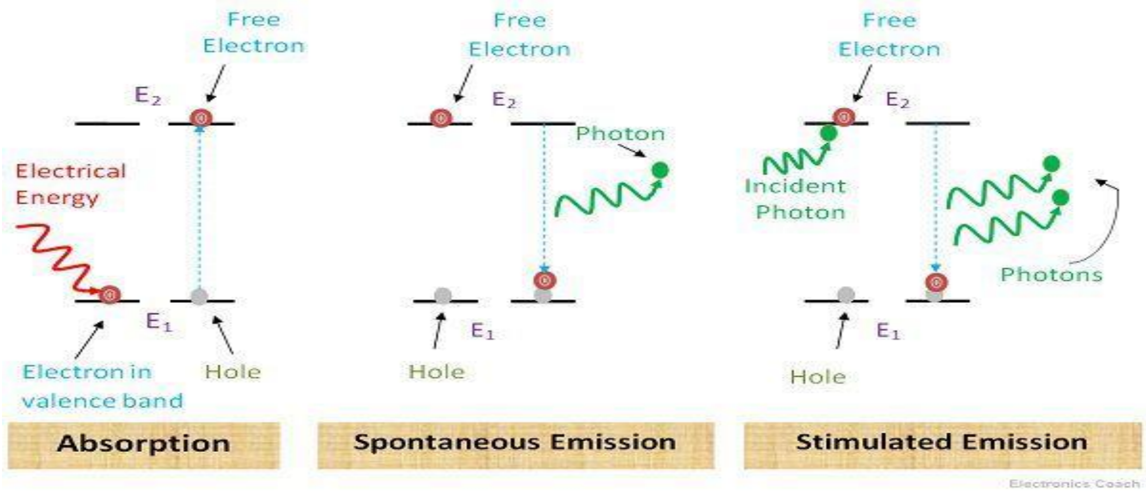
Working of LASER Diode: There are basically three phenomena by which an atom can emit light energy that are **Absorption, Spontaneous Emission** & **Stimulated emission.**

Absorption: In absorption, the electrons at lower energy levels jump to higher energy levels i.e. from the valence band to the conduction band when the electrons are provided with an external source of energy. Now, there are holes at lower energy levels i.e. valence band and electrons at higher energy levels i.e. conduction band.

Spontaneous Emission: Now, if the electrons in higher energy levels are unstable then they will tend to move to the lower energy level in order to achieve stability. But if they will move from higher energy levels to lower energy levels they will definitely release the energy which will be the energy difference between these two levels. The energy released will be in the form of light and thus photons will be emitted. This process is called **spontaneous emission.**

Stimulated Emission: In stimulated emission, the photons strike electrons at the higher energy level and these photons are supplied from an external light energy source. When these photons strike the electrons, electrons gain energy and they recombine with holes and release an extra photon. Thus, one incident photon stimulates another photon to release. Thus, this process is called **stimulated emission.**

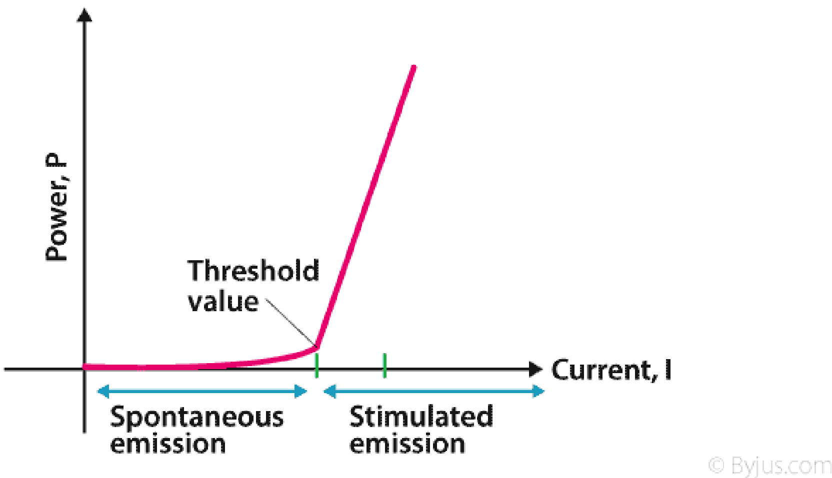
Population inversion: The density of electrons at energy levels is the population of electrons and it is more in the valence band or lower energy band and less in the conduction band or higher energy level. If the population of electrons increases at a higher energy level or the lifetime of higher energy states is long then stimulated emission will increase. This increase of population at higher energy level is termed as **population inversion.**



Characteristics of Laser Diode:

The laser diode is characterized as follows:

- **Monochromatic:** An insubstantial width of radiated narrow light containing only a single color.
- **Well-directed:** In this type, the light will be directed in a narrow beam. It is easy to launch through an optical fiber.
- **Coherent:** A light with a single wavelength emitted by LED with a wide wavelength.
- The important characteristic of a laser diode is its approach or the threshold. The laser diode doesn't operate until a minimum power is applied. If the light is below its energy, then the emission is weaker than the threshold compared to the full energy.



Relevant Equations:

The relationship between optical power and the diode drive current can be obtained from the rate equations that govern the interaction of photons and electrons in the active region. The total carrier population is determined by carrier injection, spontaneous emission, and stimulated emission. The rate equations are given by:

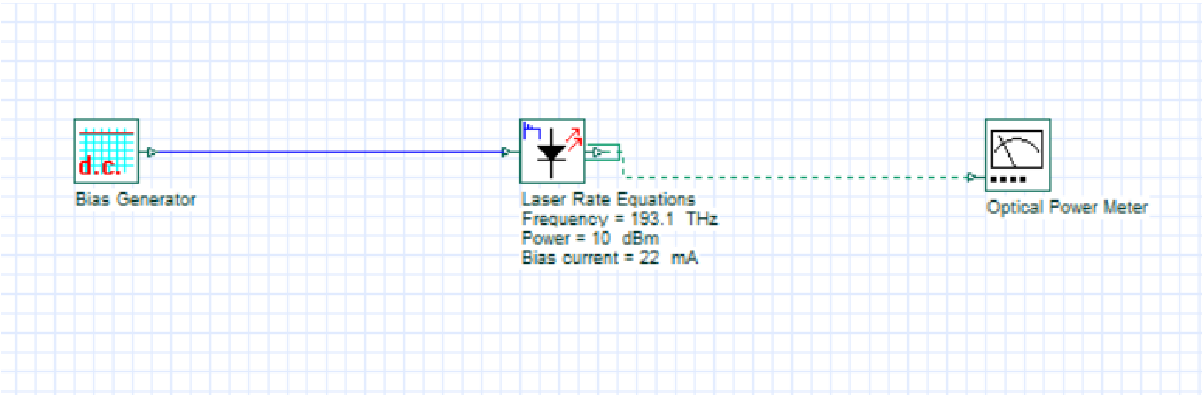
$$\frac{d\phi}{dt} = C_n\phi + R_{SP} - \phi/\tau_{ph}$$

It governs the number of photons and

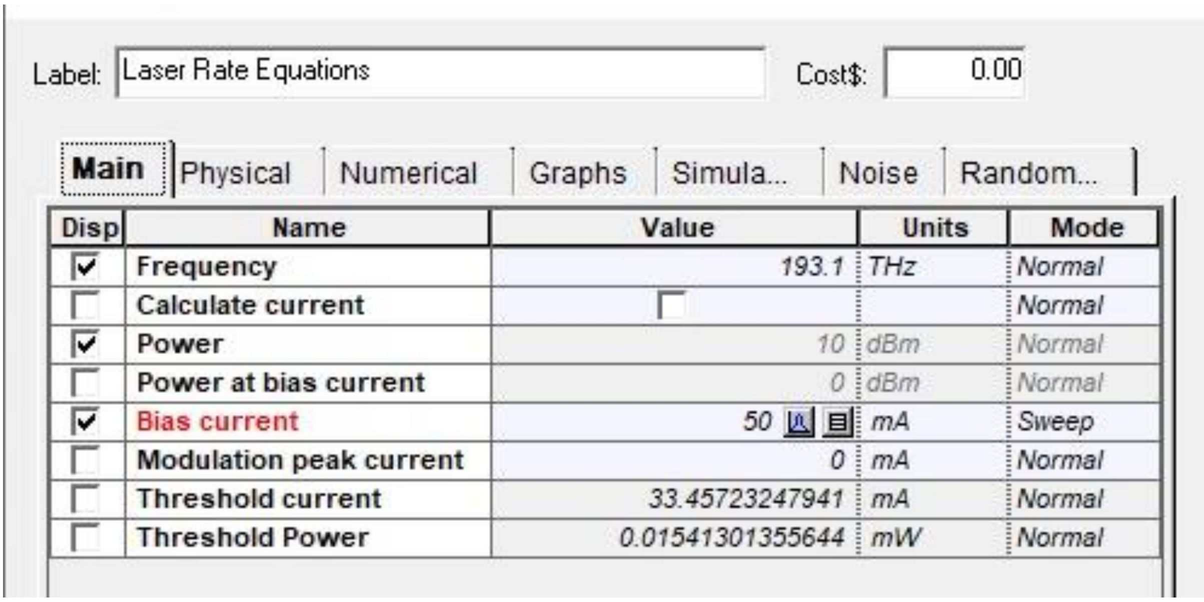
$$\frac{dn}{dt} = \frac{J}{qd} - \frac{n}{\tau_{sp}} - C_n\phi$$

governs the number of electrons.

CIRCUIT DIAGRAM: -



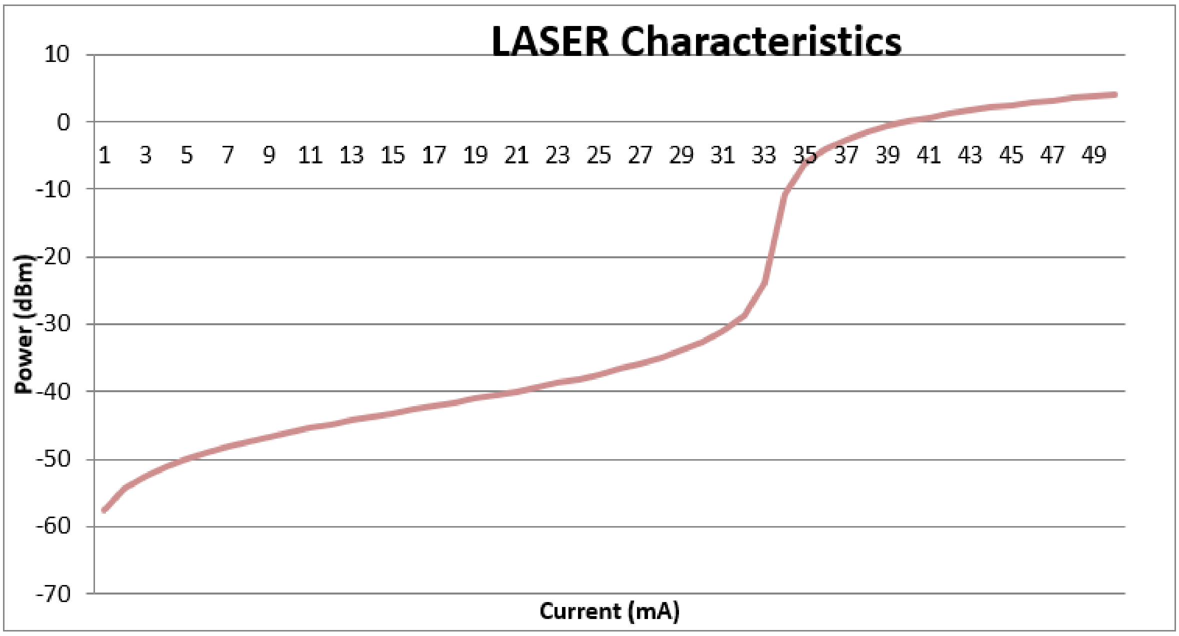
LASER SETTINGS: -



OBSERVATION TABLE: -

Sweep	Bias Current (mA)	Output Power (dBm)

GRAPH: -



RESULTS: -

LASER characteristics have been plotted; also the threshold current has been calculated.

EXPERIMENT No. – 3

OBJECTIVE: - To observe and characterize Fiber Bragg Grating as an optical filter.

SOFTWARE REQUIRED: - Opti-System, MS-Excel

In the Optisystem software following components are required: -

1. Optisystem software
2. CW Laser
3. Uniform fiber Bragg grating
4. Optical power meter
5. Optical spectrum analyzer

THEORY: - Fiber Bragg gratings are one of the most useful, reliable, versatile, practical, and attractive passive devices in the fields of optical fiber communications and fiber optic sensors. Their simplicity of operation coupled with attractive and unique features, such as all-fiber construction, self-wavelength-value referencing, absolute encoding, capability for multi-point cascading, and batch fabrication, make FBGs perform key roles in any measurement or monitoring plant.

A fiber Bragg grating (FBG) is a type of distributed Bragg reflector constructed in a short segment of optical fiber that reflects particular wavelengths of light and transmits all others. This is achieved by creating a periodic variation in the refractive index of the fiber core, which generates a wavelength-specific dielectric mirror. Hence a fiber Bragg grating can be used as an inline optical fiber to block certain wavelengths, can be used for sensing applications, or can be used as a wavelength-specific reflector. The fundamental principle behind the operation of an FBG is Fresnel reflection, where light traveling between media of different refractive indices may both reflect and refract at the interface.

The refractive index will typically alternate over a defined length. The reflected wavelength (λ_B) called the Bragg wavelength, is defined by the relationship,

$$\lambda_B = 2n_e\Lambda$$

Where n_e is the effective refractive index of the grating in the fiber core and Λ is the grating period.

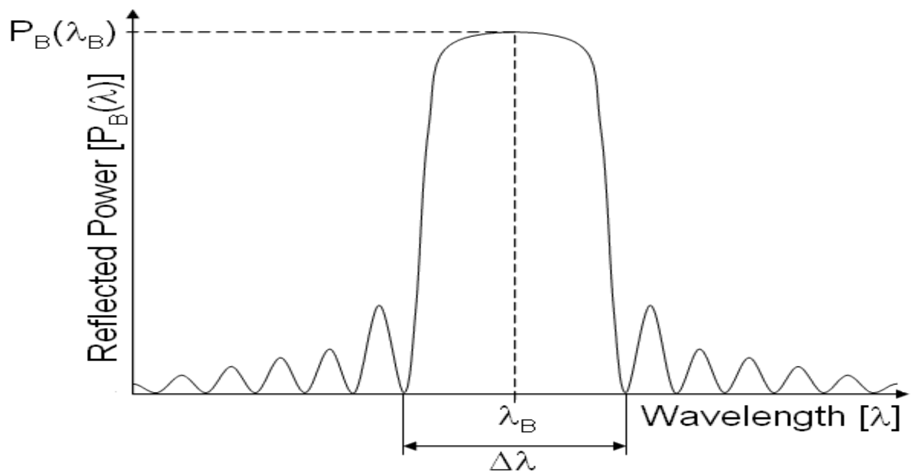


Fig: FBG reflected power as a function of wavelength

The wavelength spacing between the first minima or the bandwidth (Δλ), is (in the strong grating limit) given by,

$$\Delta\lambda = \left[\frac{2\delta n_0 \eta}{\pi}\right] \lambda_B$$

Working principle:

Fiber Bragg Gratings are made by laterally exposing the core of a single-mode fiber to a periodic pattern of intense laser light. The exposure produces a permanent increase in the refractive index of the fiber's core, creating a fixed index modulation according to the exposure pattern. This fixed index modulation is called a grating.

At each periodic refraction change a small amount of light is reflected. All the reflected light signals combine coherently to one large reflection at a particular wavelength when the grating period is approximately half the input light's wavelength. This is referred to as the Bragg condition, and the wavelength at which this reflection occurs is called the Bragg wavelength. Light signals at wavelengths other than the Bragg wavelength, which are not phase matched, are essentially transparent. This principle is shown in Figure 1.

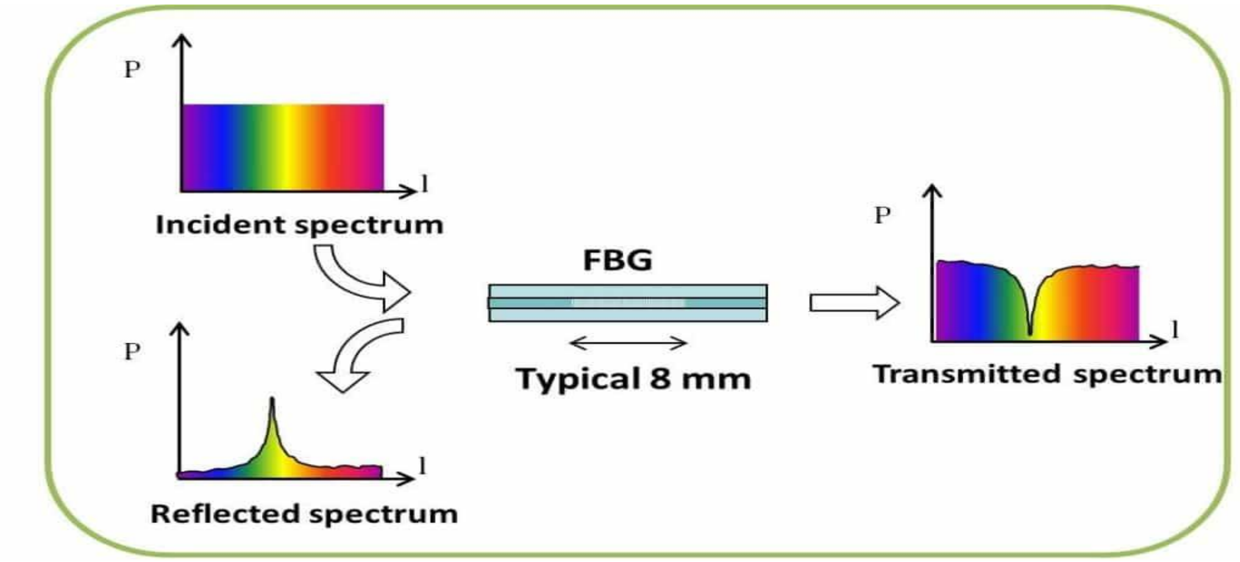


Fig: Working principle of FBG

Therefore, light propagates through the grating with negligible attenuation or signal variation. Only those wavelengths that satisfy the Bragg condition are affected and strongly back-reflected. The ability to accurately preset and maintain the grating wavelength is a fundamental feature and advantage of fiber Bragg gratings.

The central wavelength of the reflected component satisfies the Bragg relation: λ_{Bragg} = 2nΛ, with n the index of refraction and Λ the period of the index of refraction variation of the FBG. Due to the temperature and strain dependence of the parameters n and Λ, the wavelength of the reflected component will also change as function of temperature and/or strain, see Figure 2. This dependency is well known what allows determining the temperature or strain from the reflected FBG wavelength.

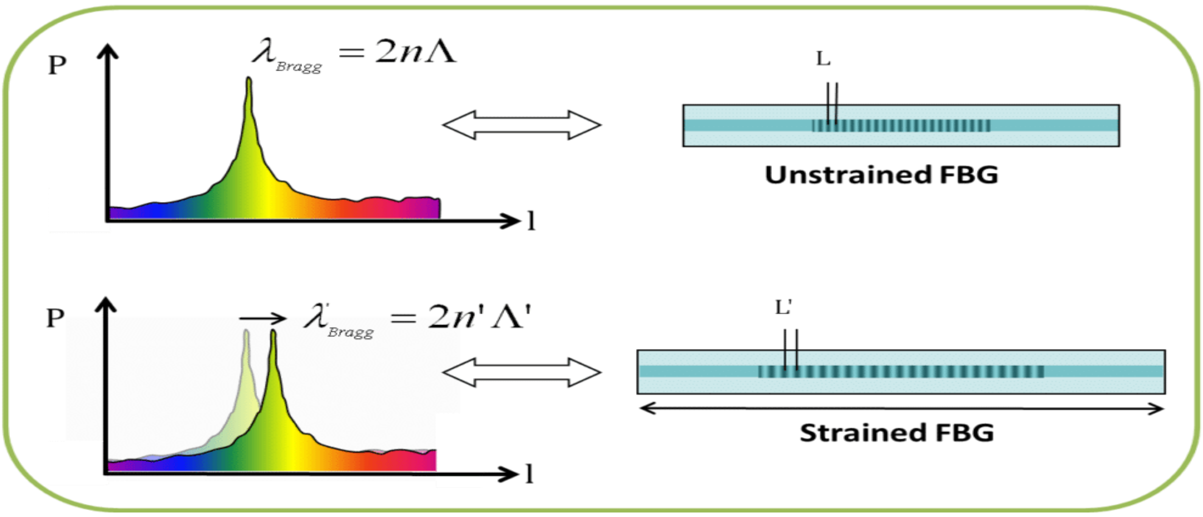
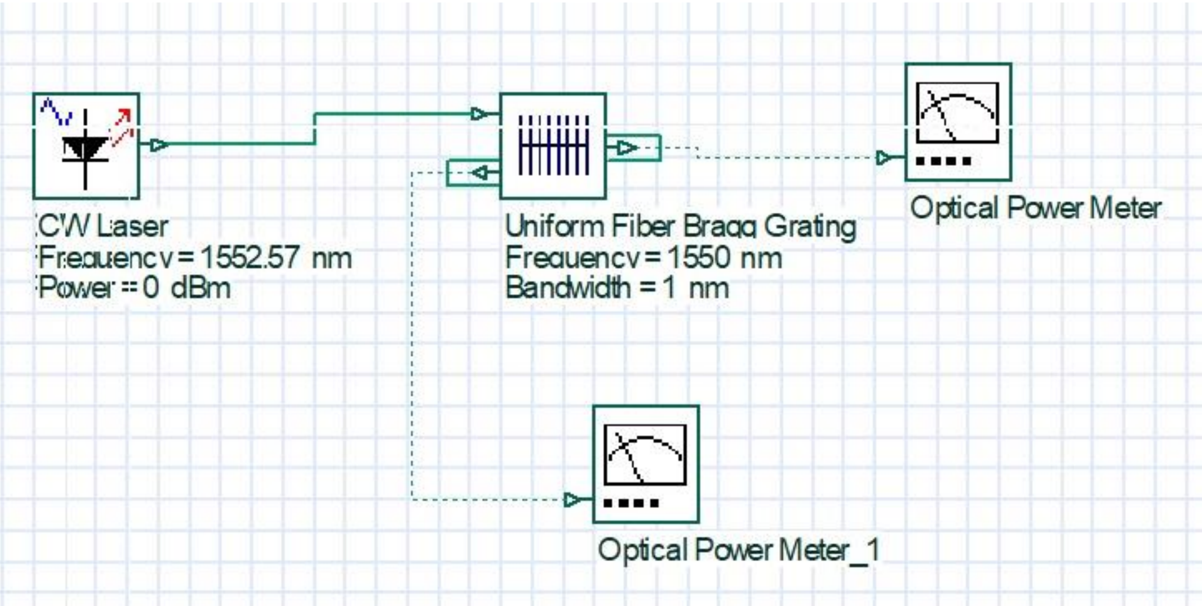


Fig: FBG response as function of strain

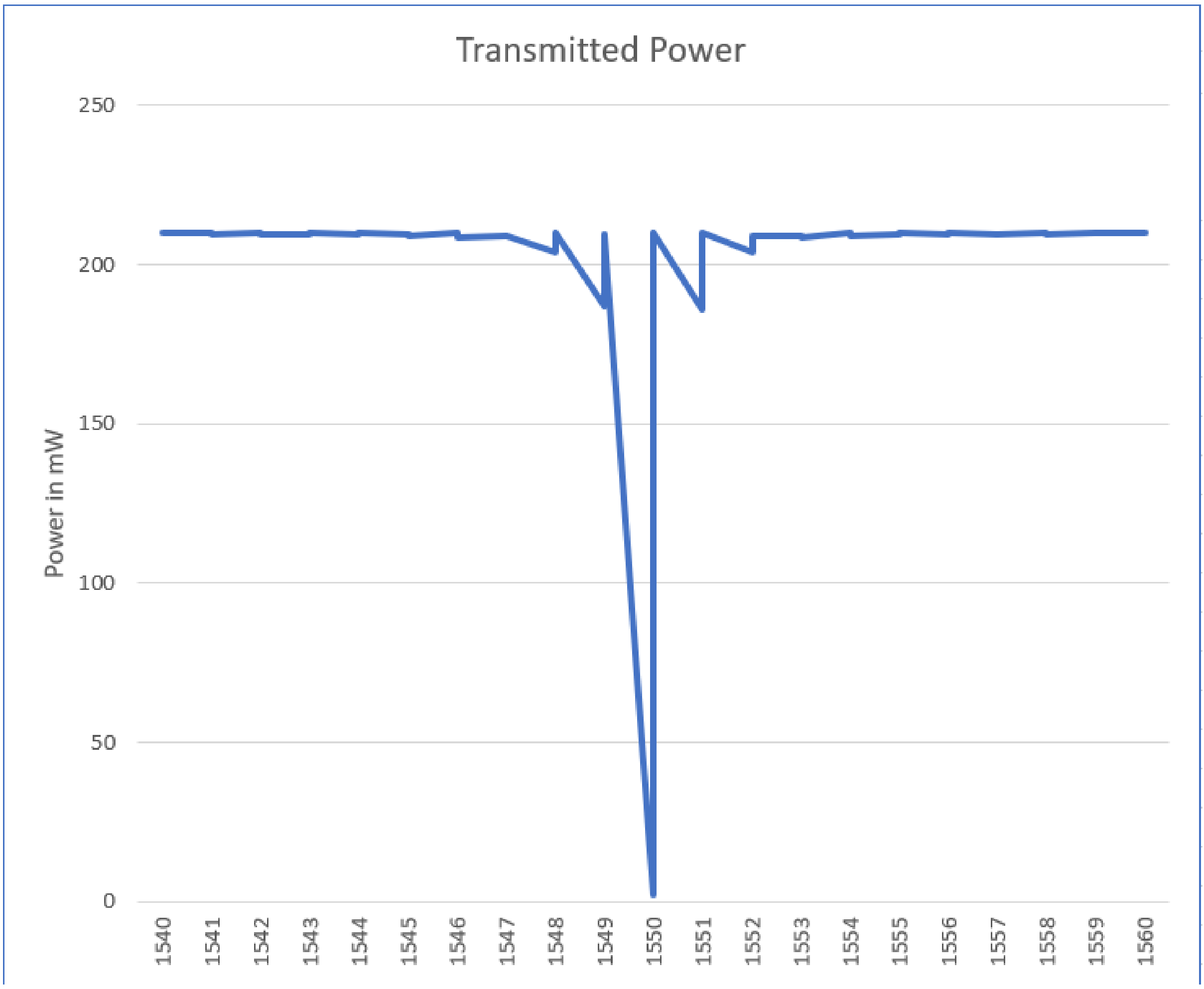
CIRCUIT DIAGRAM: -



OBSERVATION TABLE: -

Sl No.	Wavelength (in nm)	Input Power (in mW)	Reflected Power (in mW)	Transmitted Power (in mW)	Reflectivity	Transmittivity

GRAPH: -



RESULTS: -

Hence the characterization of FBG as an Optical filter has been studied.

EXPERIMENTS No. – 4

OBJECTIVE: To study the length dependence of attenuation in the given optical fiber.

SOFTWARE REQUIRED: - Opti-System, MS-Excel

In the Optisystem software following components are required: -

1. CW Laser
2. Optical Fiber
3. Photo-detector PIN
4. Optical power meter
5. Optical spectrum analyzer
6. Oscilloscope visualizer

THEORY: The efficient transmission of light at the operational wavelength(s) is the primary function of fiber optics needed for a range of applications (e.g. long-haul telecommunications, fiber lasers, optical delivery for surgical or biomedical applications). Reduction in the intensity of light as it propagates within the fiber is called "attenuation". The finite attenuation present in any optical fiber requires that fiber system design address degradation in signal strength through such approaches as signal amplification, interconnect optimization, fiber geometry design, and environmental isolation. An understanding of attenuation mechanisms and the potential for their minimization is, thus, of great importance in the efficient and economic use of fiber optics.

Any process that results in a reduction in the light intensity measured after propagation through a material contributes to the observed optical attenuation. In principle, all attenuation mechanisms can be traced back to the multi-length scale structure of the glass itself (e.g. atomic structure, point defects, second-phase inclusions) or structures arising from the fabrication process and/or optical design of the fiber (e.g. interfacial structure at the core-clad interface, uniformity of core clad structure along fiber length). Thus, the control of material structure (through composition, material processing, and fiber fabrication controls) is the primary means to reduce attenuation in the finished fiber. An understanding, however, of the underlying optical phenomena at work and their relationship to material composition and structure is needed.

MEASURING ATTENUATION: -

One of the standard ways of determining the attenuation through an optical fiber is to measure the value of optical power within the fiber at two locations separated by a distance L km and using the expression given by formula mentioned below. We can measure the power emanating from the light source but to know he optical power within the fiber we need to know the coupling efficiency into the fiber too. Since this is usually not known, one uses the method referred to as the 'cut back method'. In this technique, light is launched into the optical fiber and the power exiting a length L of the fiber is measured. Then without disturbing the input, the fiber is cut near the input end (about 1mfrom the input end) and the power exiting is again measured. Knowing the length of the fiber cut in this process we can estimate the attenuation coefficient of the fiber.

FORMULA: -

If P_i represents the input power and P_o is the output power after passing through an optical fiber of length L km.

Attenuation, A in dB = $10\log \frac{P_i}{P_o}$

Attenuation coefficient, α in dB/km = A/L= $\frac{10}{L} \log \frac{P_i}{P_o}$

CIRCUIT DIAGRAM FOR OPTISYSTEM:

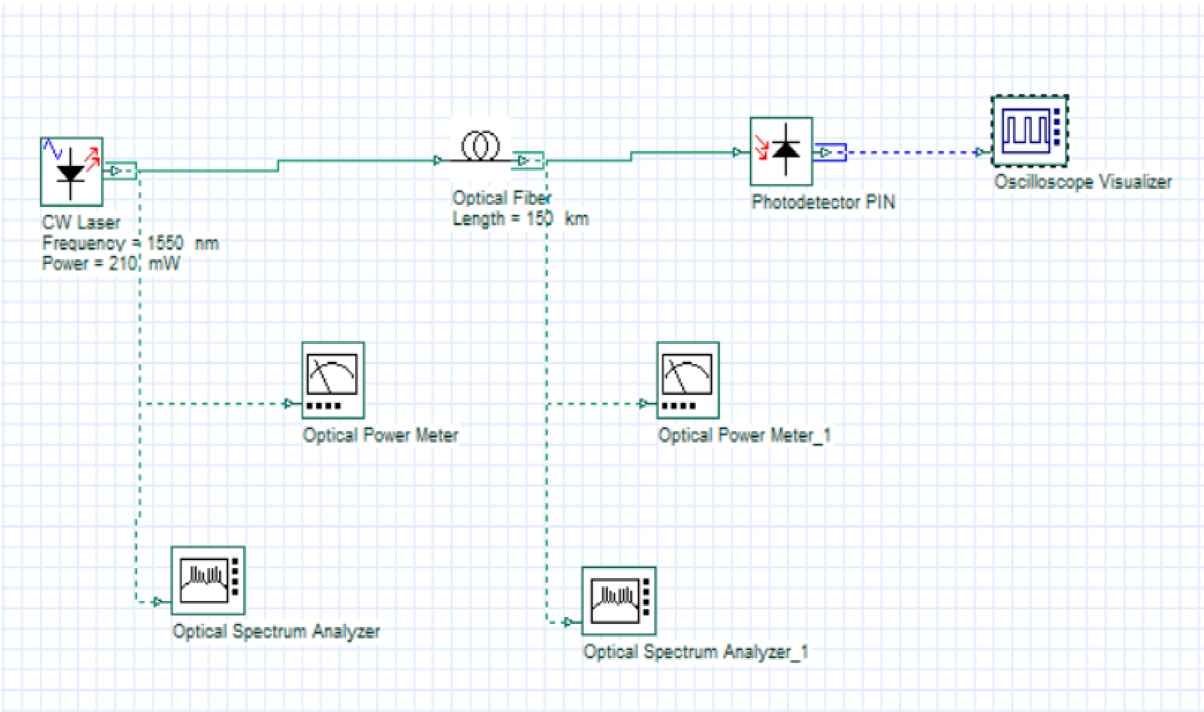


Figure: Schematic of the OptiSystem setup to determine attenuation of fiber as a function of length and wavelength.

SIMULATION PROCEDURE :

1. Run the simulation and record the following data:
   - ❖ Optical power levels (Both in mW and dBm) -> Both ends of the fiber.
   - ❖ Optical Spectrum -> Both ends of the fiber
   - ❖ Oscilloscope Visualizer Spectrum
2. Set a different fiber length and repeat the simulation and data recording.

OBSERVATION TABLES:

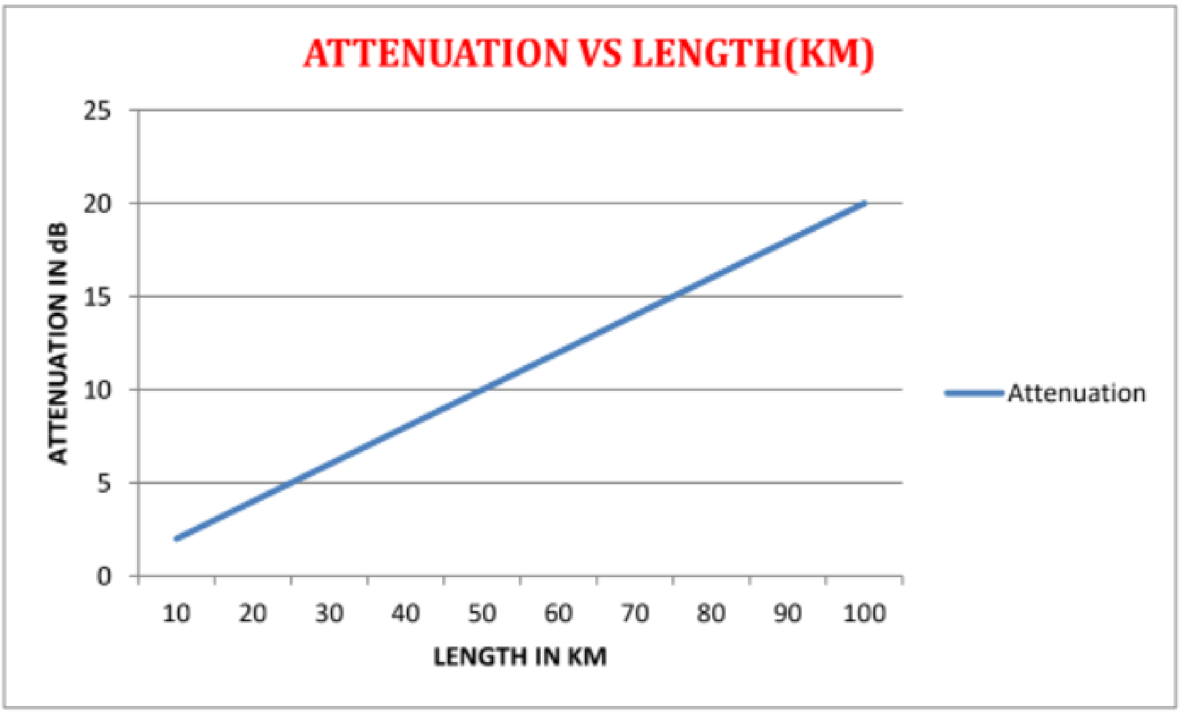
Table-1: Theoretical Attenuation of fiber as a function of length and wavelength.

Wavelength, λ (in nm)	Length, L (in Km)	Input Power, Pin (in mW)	Output Power, Pout (in mW)	Attenuation (in dB) A1 = 10 log (Pin/Pout)	Attenuation per km (A1/L)	Average
1550	0.5	1	0.977	?	?	?
1550	1.0	1	0.955			
1550	1.5	1	0.933			
1550	2.0	1	0.912			
1550	2.5	1	0.891			
1550	3.5	1	0.870			
1550	4.0	1	0.851			

Table-2: Practical Attenuation of fiber as a function of length and wavelength.

Wavelength, λ (in nm)	Length, L (in Km)	Input Power, Pin (in mW)	Output Power, Pout (in mW)	Attenuation (in dB) A1 = 10 log (Pin/Pout)	Attenuation per km (A1/L)	Average
1550	10	210	?	?	?	?
1550	20	210				
1550	30	210				
1550	40	210				
1550	50	210				
1550	100	210				
1550	150	210				

GRAPH: -



RESULTS: -

- ✓ Find the output optical power for the given input power and length.
- ✓ Show the output of the oscilloscope visualizer.

EXPERIMENTS No. – 5

OBJECTIVE: To check the characteristics of a 3-port Circulator at various wavelengths.

SOFTWARE REQUIRED: - Opti-System, MS-Excel

In the Optisystem software following components are required: -

1. CW Laser – 3
2. Circulator - 1
3. Optical Power Meter -3
4. Optical Spectrum Analyzer -6

THEORY:

Active components: -

1) Modulator, switch, and router

2) Optical-amplifier (fiber-amplifier, semiconductor amplifier)

3) Wavelength converter

4) Gain equalizer

5) Optical active devices, including optical sending and receiving module

Passive components: -

1) Optical passive devices, including optical fiber jumper, connector, plug, fixed attenuator, adapter, divider, isolator, coupler, dielectric film filter and optical fiber grating filter, optical switch, wavelength division multiplexing.
2) The word "passive" here refers to those devices do not require electrical-to-optical or optical-to-electrical conversion during its operation.
3) These devices are generally used to split and combine signals, or alter them in various other manners.

Optical Circulator: -

- An optical circulator is a nonreciprocal multiport passive device that directs light sequentially from port to port in only one direction.
- It is used to separate optical signal that travels in the opposite direction in an optical fiber e.g. to achieve bi-directional transmission over a single fiber.
- These devices are widely used in optical amplifiers, multiplexers, and optical sensor applications due to their high isolation of the input and reflected optical power and their low insertion loss.

CIRCUIT DIAGRAM FOR OPTISYSTEM: -

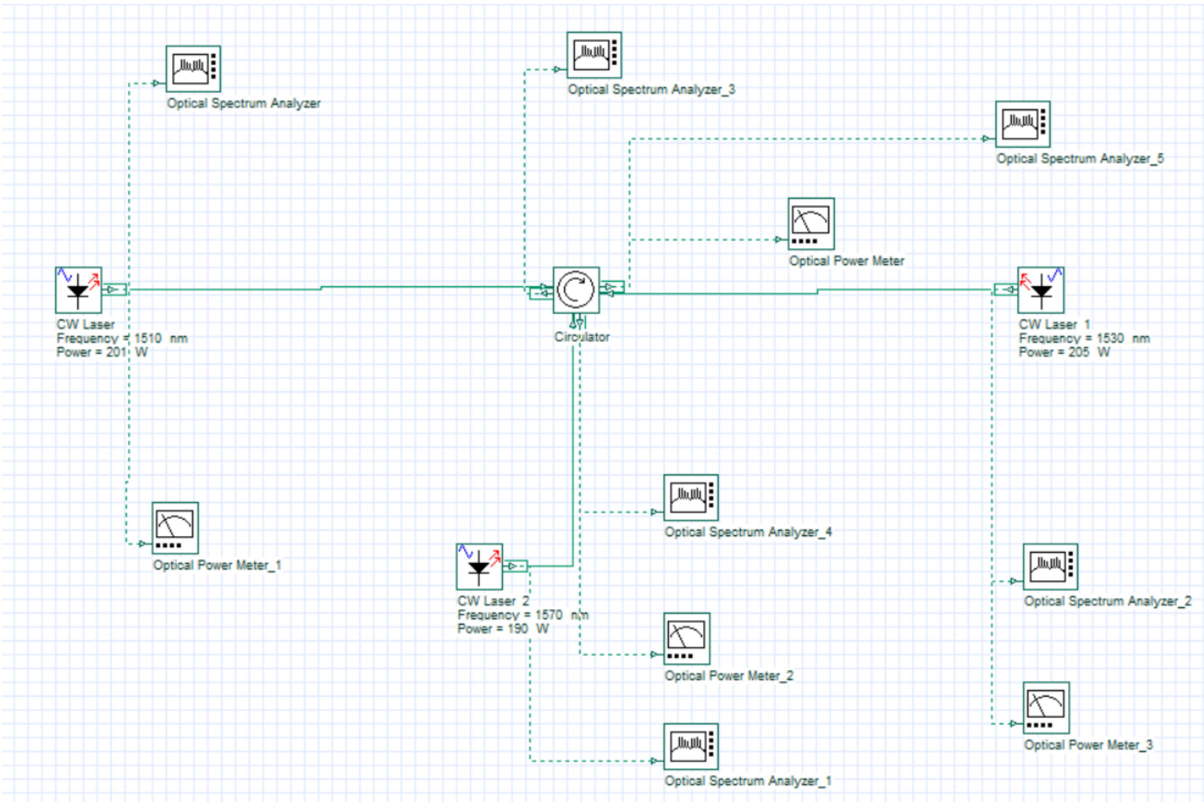


Figure: Schematic of the Optisystem to check the characteristics of the Optical circulator

SIMULATION PROCEDURE: -

Run the simulation and record the following data:

❖ Reflected power and Transmitted power -> Both ends

1. Set a different wavelength and repeat the simulation and data recording.
2. Record the input and output spectrum of the circulator:

- ➢ Input at port 1 – output at port -2
- ➢ Input at port 2 – output at port -3
- ➢ Input at port 3 – output at port -1

RESULT: -

Observe from the experiment that light entering any port exists from the next port with almost the same amount of power as there is very negligible reflection inside the circulator device which could be seen by the spectrum analyzer output.

EXPERIMENT NO. - 6

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

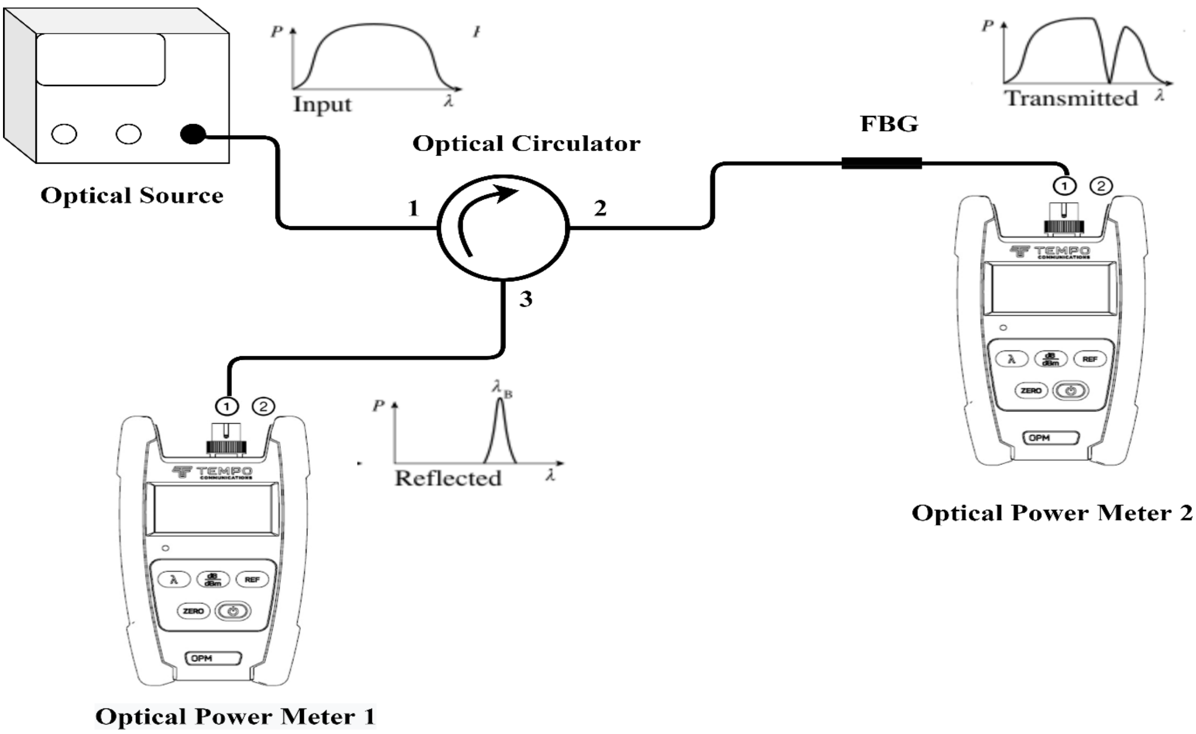
APPARATUS REQUIRED: - FBG, Broadband light source, Optical Circulator, Optical power meter, and connecting optical patch cables.

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: -

Wavelength (in nm)	Power (dBm)

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

EXPERIMENT NO. - 7

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

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

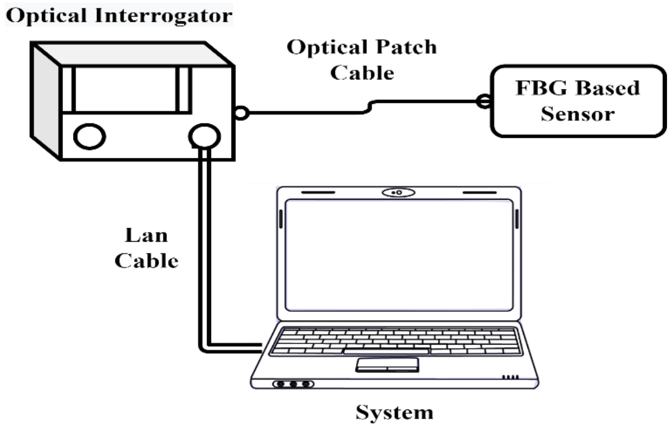
Where, α and ζ are the thermal expansion coefficient (0.55×10-6 $K^{-1}$for silica) and thermo-optic coefficient (8.6×10-6 $K^{-1}$for silica*)*, respectively. and pe is the effective strain-optic coefficient of the fiber.

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.

FBGs are by far the most successful optical sensors due to some of their principal advantages, such as:

1. They are small, lightweight, and able to withstand harsh environmental conditions for a long time.
2. These are immune to electromagnetic interferences.
3. They can be inscribed inside the fiber and can send sensing data from tens of kilometers.
4. 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: -

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

OBSERVATION TABLE: -

Strain or Temperature	Wavelength Shift (nm)	Power (dBm)

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

EXPERIMENTS No. – 8

OBJECTIVE: Design a wavelength division multiplexing (WDM) fiber optics link with the given component and determine the total loss in the system for each wavelength.

SOFTWARE REQUIRED: - Opti-System, MS-Excel

In the Optisystem software following components are required: -

1. CW Laser-4
2. WDM Mux 4×1
3. WDM D-MUX 1×4
4. Optical power meter
5. Optical spectrum analyzer

THEORY: -

Wavelength-division multiplexing (WDM) is a technology that multiplexes a number of optical carrier signals onto a single optical fiber by using different wavelengths (i.e., colors) of laser light. This technique enables bidirectional communications over a single strand of fiber, also called wavelength-division duplexing, as well as multiplication of capacity. The term WDM is commonly applied to an optical carrier, which is typically described by its wavelength, now a day it is the most widely used technology for high-capacity optical communication systems.

Figure 1 schematically shows a typical WDM transmission system. At the transmitter side, multiple optical transmitters – each emitting at a different wavelength – individually send signals, and these signals are multiplexed by a wavelength multiplexer (MUX). The multiplexed signals are then transmitted over one main transmission line (optical fiber cable). At the receiver side, the signals are de-multiplexed by a wavelength demultiplexer (DEMUX) and sent to multiple receivers.

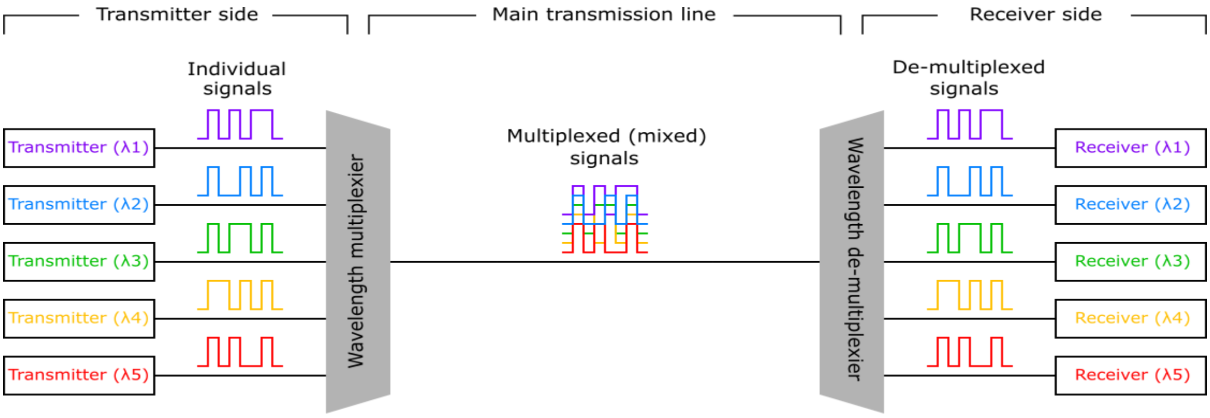
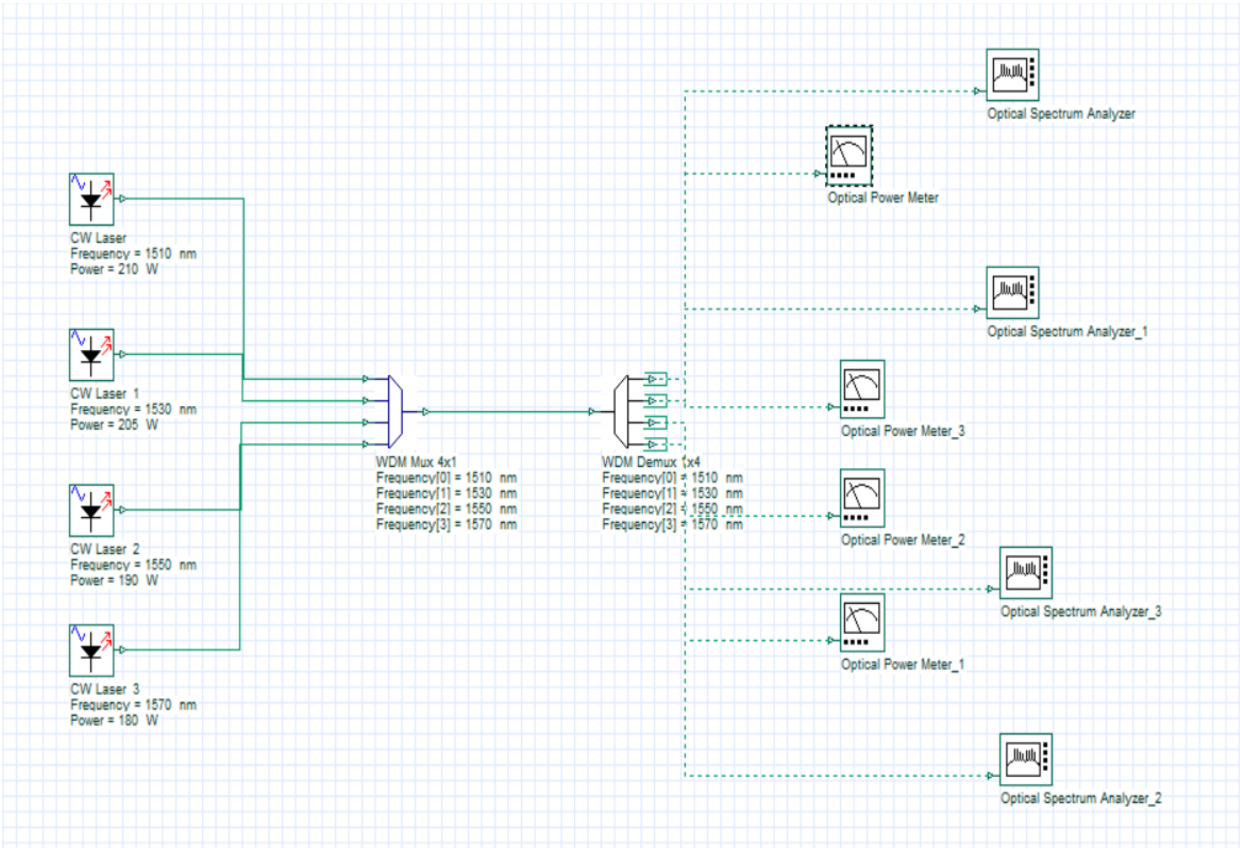


Fig: Schematic of WDM transmission system.

One primary advantage of using WDM technology is in reducing the number of fibers used in the main transmission line. The distance of an optical transmission line sometimes exceeds 1,000 km, and the cost of fiber cable manufacturing/deployment would become a serious issue if we need to install a high-fiber-count cable over a very long distance. Using WDM technology, (1) the number of fibers in an optical cable is reduced, and (2) the number of wavelength multiplexer/de-multiplexer basically remains the same no matter how long the transmission distance is. For that reason, WDM generally becomes advantageous as the transmission distance becomes longer.

CIRCUIT DIAGRAM: -



SIMULATION PROCEDURE: -

Run the simulation and record the data:

- ✓ Output of Optical Power (in dBm),
- ✓ Optical spectrum after Demux,
- ✓ and Insertion loss (in dB).

OBSERVATION TABLE: -

Wavelength, λ (in nm)	Input Power, Pin (in Watts)	Output Power, Pout (in Watts)	Insertion loss (in dB) I1 = -10 log (P_{out}/P_{in})

RESULT: -

Show the output power and spectrum of all the four laser inputs.

EXPERIMENT NO. – 9

OBJECTIVE: - Equalization of optical channel strength in a multi-wavelength fiber optic system using attenuators.

Design a multi-wavelength fiber optic system with the given components and equalize the optical channel strength (30 dBm) using optical attenuators so that all the channels have similar power levels.

SOFTWARE REQUIRED: - OptiSystem

Components required for Optisystem:

1. C W Lasers – 4 (P1 = 60 dBm, 1510 nm; P2 = 50 dBm 1530 nm; P3 = 40 dBm, 1550 nm; P4 = 70 dBm, 1570 nm)
2. WDM Mux 4x1 -1 (Channel Wavelength=1510, 1530, 1550, 1570 in nm)
3. WDM Demux 1x4 - 1
4. Optical Attenuator - 4
5. Optical power Meter - 4
6. Optical Spectrum Analyzer – 5

THEORY: -

An optical attenuator, or fiber optic attenuator, is a device used to reduce the power level of an optical signal, either in free space or in an optical fiber. Optical attenuators are commonly used in fiber-optic communications, either to test power level margins by temporarily adding a calibrated amount of signal loss, or installed permanently to properly match transmitter and receiver levels. Sharp bends stress optic fibers and can cause losses. If a received signal is too strong a temporary fix is to wrap the cable around a pencil until the desired level of attenuation is achieved. However, such arrangements are unreliable, since the stressed fiber tends to break over time.

Fixed Optical Attenuators: Fixed optical attenuators used in fiber optic systems may use a variety of principles for their functioning. Preferred attenuators use either doped fibers, or misaligned splices, or total power since both of these are reliable and inexpensive. Fixed optical attenuators in doped optical fiber usually have 1dB, 5dB, and 10dBetc.

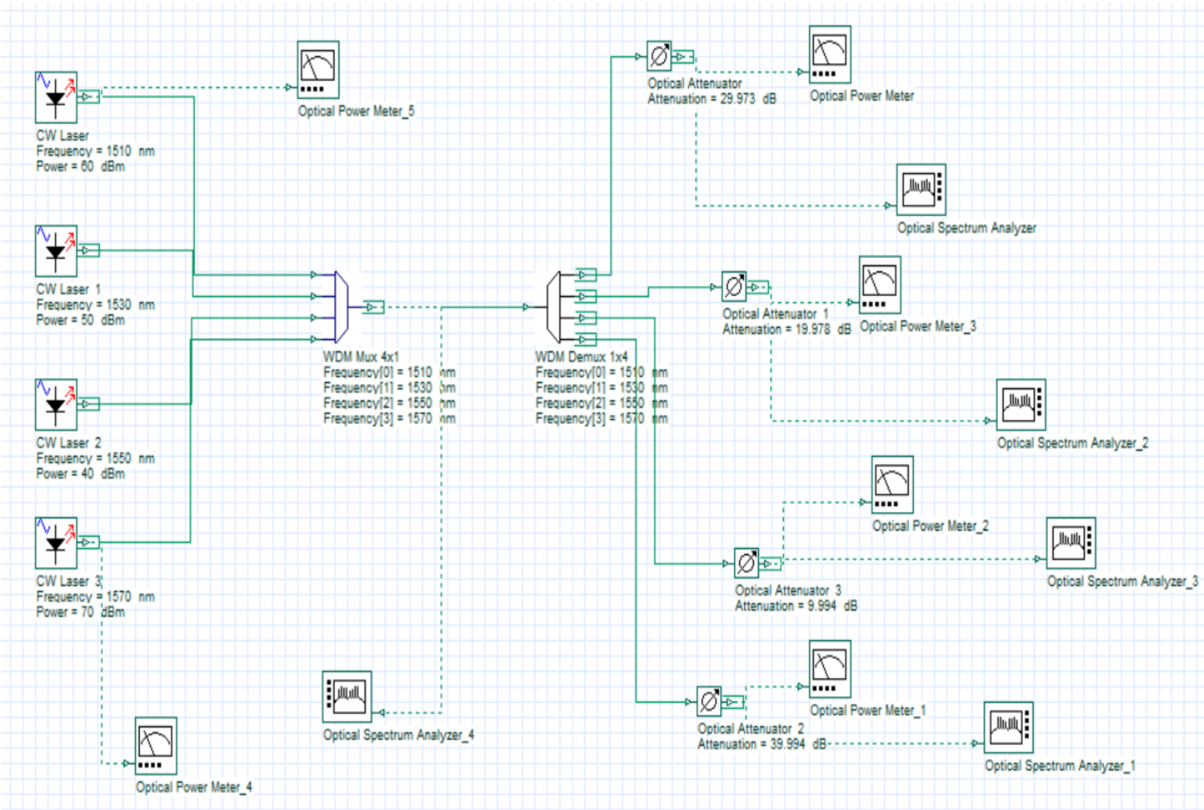
Variable Optical Attenuators: Variable optical test attenuators generally use a variable neutral density filter. Despite its relatively high cost, this arrangement has the advantages of being stable, wavelength insensitive, mode insensitive, and offering a large dynamic range. Other schemes such as LCD, variable air gap, etc. have been tried over the years, but with limited success. They may be either manually or motor controlled. Variable optical attenuators have an adjustable range from 0.5dB to 20dB, some have very high resolution i.e. 0.01dB or even

Working Principles of Fiber Optic Attenuators: Optical attenuators achieve the desired attenuation in optical fiber links in three different principles, which relatively are the gap-loss principle, absorptive principle, and reflective principle.

Optical Attenuator Applications:

- Test power level margin by temporarily adding a calibrated amount of signal loss.
- Installed permanently to properly match transmitter and receiver levels.

CIRCUIT DIAGRAM: -



SIMULATION PROCEDURE: -

Run the simulation and record the following data:

- ✓ Output of Optical Power (in dBm)
- ✓ Optical spectrum after Demux, and
- ✓ Attenuation (in dB).

OBSERVATION TABLE: -

Sl. No.	Wavelength (nm)	Input Power (dBm)	Attenuation (dB)	Output Power (dBm)

RESULT: -

Show the output spectrum of all the four attenuators, WDM mux, and de-mux.

EXPERIMENT NO. - 10

OBJECTIVE: -

(a). Familiarization with the hardware equipment and characterization of LED and LASER Diodes.

(b). Study of optical passive components like circulators, isolators, and attenuators

EQUIPMENTS REQUIRED: -

1. Scientech 2506Kit with Power Supply cord
2. Optical Fiber cable
3. Digital Multimeter/ Optical Power meter)

THEORY: -

LEDs and LASER Diodes are the commonly used sources in optical communication systems, whether the system transmits digital or analog signals. LEDs are formed from various doped semiconductor materials in the form of a P-N diode junction. When an electrical current passes through the junction in the forward direction, the electrical carriers give up energy proportional to the forward voltage drop across the diode junction which is emitted in the form of light. The amount of energy is relatively low for infrared or red LEDs. For green and blue LEDs which are produced from higher forward voltage materials, the amount of energy is greater. Since the device is being used in the forward-biased mode, once the voltage applied exceeds the diode forward voltage; the current through the device can rise exponentially.

Very high currents would damage the device which is why a current limiting resistor must be added in series with the LED when driven from a voltage source. It may be mentioned that in many low-cost, short-haul, and small bandwidth applications. The amount of light emitted by an LED is proportional to the amount of current passing through the device in the forward bias direction. As the current is varied, the output of the light will vary in a similar fashion. By modulating the current flowing through the LED, the light output can be modulated to produce an amplitude modulated optical signal which can be used to communicate information through free space (i.e. TV remote control).

If the voltage source is applied in the reverse direction, the P-N junction will block current flow until the voltage applied exceeds the device's ability to block the current. At that point, the device junction will break down, and if there is no current limit device in the circuit, the LED will be destroyed. The typical value of maximum reverse voltage is five volts.

Laser light is used for optical fiber communications for the simple reason that it is a single wavelength light source. Sunlight or the light emitted by a light bulb is a mixture of many different wavelengths of light. Because the light waves of such light are all out of phase with one another, they do not produce a very powerful beam. Laser beams, however, have a single wavelength, and so their waves are all in phase, producing very powerful light.

LASER Diodes are used in telecom, datacom , and video communication applications involving high speeds and long hauls. All single-mode optical fiber communication systems use LASERs in the 1300nm and 1550 nm windows. LASERs with very small line widths also facilitate the realization of wavelength division multiplexing (WDM) high-density communication over a single fiber.

The inherent properties of LASER diodes that make them suitable for such applications are high coupled optical power into the fiber (Typically greater than 1 mW), high stability of optical intensity, small line widths (less than 0.05 nm in special devices), high speed (several GHz) and high linearity (over a specified region suitable for analog transmission). Special LASERs also provide for the generation/ amplification of, optical signals within an optical fiber. These fibers are known as erbium-doped fiber amplifiers; LASER diodes for communication applications are available in the wavelength regions 650nm, 780nm, 850nm, 980nm, 1300nm, and 1550nm.

Even though a variety of LASER diode constructions are available there are a number of common features in all of them. We have selected a very simple device (650nm/2.5 mw) to demonstrate the functioning of a LASER diode.

Specifications of typical LASER diode at 650 nm:

Symbol	**Parameter**	**Typical Value**	**Unit**
P0	CW output power	2.5	mW
Iop	Operating current	30	mA
Wp	Wavelength to Peak Emission	650	Nm
MTTF	Mean time to failure	10,000	hrs

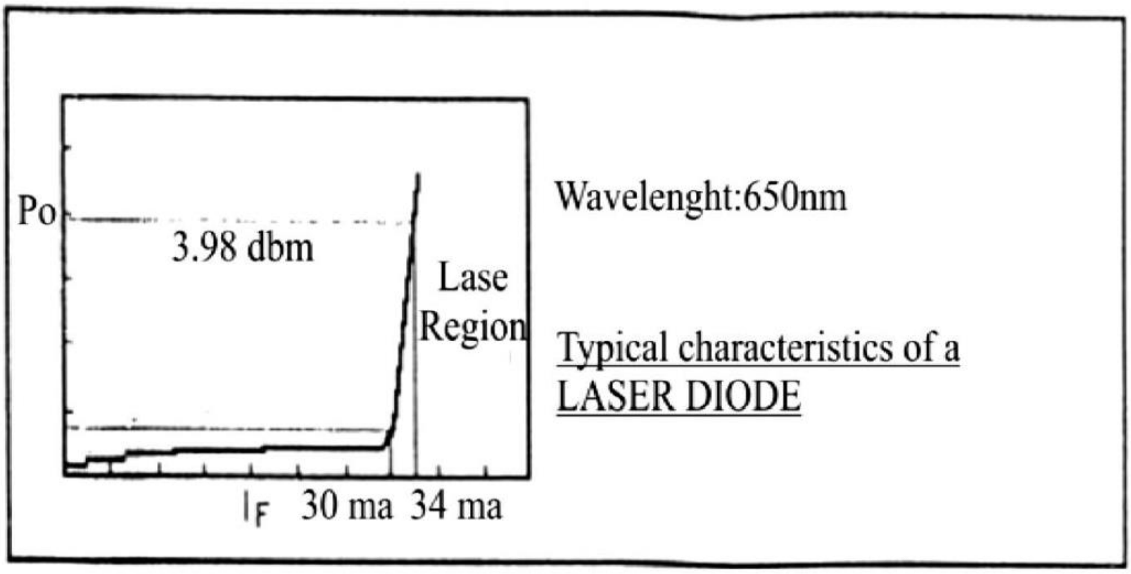


Fig. 10.1 Characteristics of a Laser diode

Monitor Photo Detector (MPD) Automatic Power Control and Automatic Current Control Modes of Operation:

A LASER diode has a built-in photodetector, which one can employ to monitor the optical intensity of the LASER at a specified forward current. This device is also effectively utilized in designing an optical negative feedback control loop, to stabilize the optical power of a LASER in the steep lasing region. The electronic circuit scheme that employs the monitor photodiode to provide negative feedback for the stabilization of optical power is known as the Automatic Power Control Mode (APC). If a closed-loop employs current control alone to set optical power then this mode is called the Automatic Current Control Mode (ACC).

The disadvantage of the ACC scheme is that the optical power output may not be stable at a given current due to the fact that small shifts in the lasing characteristics occur with temperature changes and aging. The disadvantage of the APC is that the optical feedback loop may cause oscillations, if not designed properly.

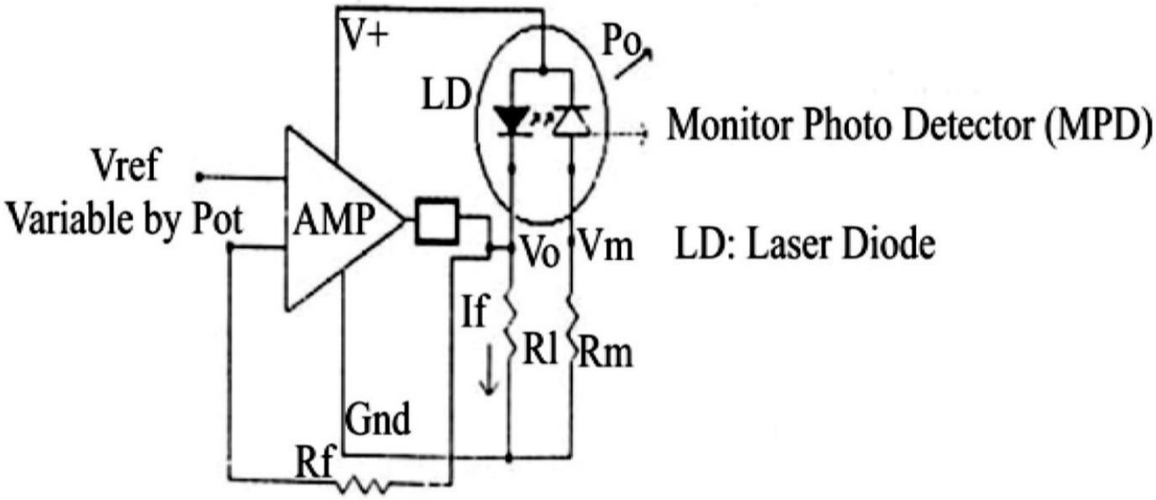


Fig. 10.2 Circuit diagram of MPD in APC/ACC mode

PROCEDURE: -

1. Connect the 2-meter PMMA FO cable to Po port of and couple the LASER light to FO PIN the power meter as shown.

2. Set DMM 1 to the 2000 mV range. On the RX Unit, connect the Wires marked Po to it. Turn it on. The power meter is now ready for use. Po = (Reading)/10 dBm.

3. Set DMM2 to the 200.0mV range and connect it between the VM and ground on the TX Unit.

4. Adjust the SET If knob to the extreme anticlockwise position to reduce IM to the minimum value. There will be a negligible offset voltage.

5. Change Po in suitable Steps and note the VM readings. Record up to the extreme clockwise position.

6. Plot the graph IM vs Po on a semi-log graph sheet IM = (VM)/ (100K).

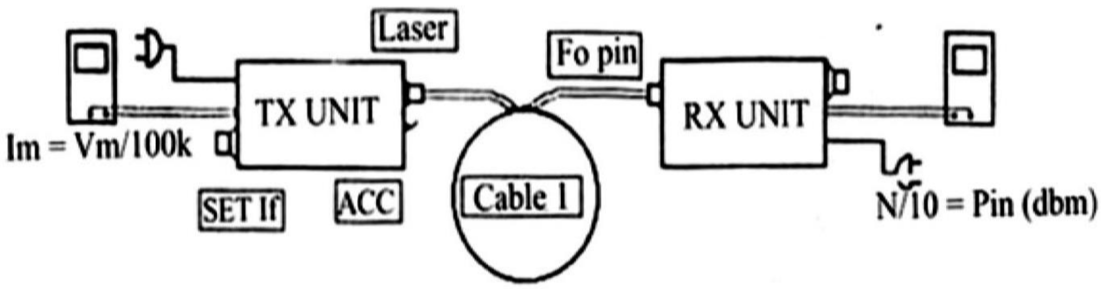


Fig. 10.3 Block diagram of Optical communication system using Laser source

OBSERVATION TABLE: -

Sr. No.	VL(mV)	IF = VL/100 (mA)	P0(dBm)
1			
2			
3			
4			

CONCLUSION: -

Hence we got familiar with some hardware optical instruments and also studied the characterization of LED and LASER source.

EXPERIMENT NO. - 10 (b)

OBJECTIVE: - Study of optical passive components like circulators, isolators, and attenuators

EQUIPMENTS REQUIRED: -

1. FOL-DUAL
2. FOL-Passive
3. One meter ST-ST glass fiber cable
4. Optical Power Meter

THEORY: -

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.

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.

The basic types of optical attenuators are fixed, step-wise variable, and continuously variable.

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, $\boldsymbol{B}$, 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,

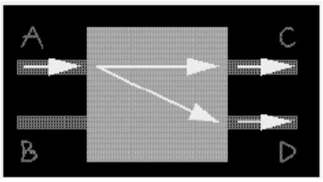
$$\beta = \nu \, B \, d$$

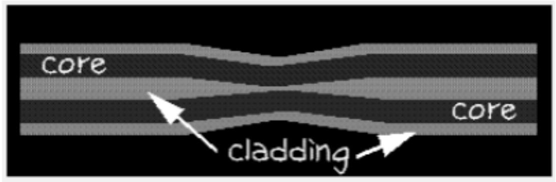
Where, ν is the Verdict constant of the material (amorphous or crystalline; solid, liquid, or gaseous) of which the rotator is made, and d is the length of the rotator. Specifically for an optical isolator, the values are chosen to give a rotation of 45 degrees.

An **optical coupler** is a device that splits the light. There are several types of Couplers:

- Directional coupler
- Star coupler

The four-port directional coupler, also denoted 2 x 2 coupler, is the simplest coupler.





The light arrives for instance at port A and is split between port C and D. In the most common case, 50% of the light power will go in C and D. Optical couplers are made by fusing and tapering two fibers together so that the cores are close enough to each other for optical coupling to occur. In practice,

- twist two fibers together
- Heat the in a furnace: the fibers are softened and they fuse.
-

The principle of optical couplers varies whether the fibers used are single-mode or multimode.

PROCEDURE: -

1. Make sure that the Intensity control 1 and Intensity Control 2 pots 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 post of the Laser Source: 1310nm on the FOL-DUAL module.

4. Gradually turn the Intensity Control 1 Pot 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 post to on of the post of the 3dB Attenuator on the FOL-PASSIVE module.

6. Connect the optical power meter to output post of the Attenuator/Isolator/Coupler.

RESULTS: -

1. The Attenuation for 3dB and 15dB attenuators is verified with 1310nm and 1550nm Laser source.
2. 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.
3. The couplers are symmetric, that is, that the coupling is assured no matter which path is used for the injection. The couplers are wide band, that is to say that they have more or less the same characteristics on the two wavelengths. Coupler used is proved to be 50/50 coupler.