1. **<u>1310 nm Laser source for the Continuous Wave.</u>**

INTRODUCTUION:

A laser diode is a semiconductor device that produces high-intensity coherent light. LASER is an abbreviation for Light Amplification by Stimulated Emission of Radiation. The operation of this diode is based on stimulated emission.The P-N junction of a laser diodes are similar to that of an LED; but, unlike LEDs, the P-N junction of a laser diode emits coherent radiation.

Absorption of Energy: The laser diodes are made up of a p-n junction that contains both holes and electrons. (A hole indicates the lack of an electron under this context.) When a voltage is applied to the p-n junction, electrons gain energy and move to a higher energy level.Holes are formed in the excited electron's original position.

Spontaneous Emission: Excited electrons recombine with holes during their upper-state lifespan. The disparity in energy is converted into photons or electric radiation when electrons fall from a higher energy level to a lower energy level.LEDs use the same method to generate light. The disparity between the two energy ratios gives the energy of the released photon.

Stimulated Emission : We need more coherent photons from the laser diodes than those generated by spontaneous emission. A partially reflecting mirror is used on either side of the diode to capture photons emitted from spontaneous emission in the p-n junction before their concentration exceeds a threshold value.These trapped photons stimulate excited electrons to recombine with holes well before their recombination period. This causes the release of more photons that are in exact phase with the original photons, amplifying the output.When the photon concentration exceeds a certain threshold, they escape from the partially reflecting mirrors, producing vivid monochromatic coherent light

EQUIPMENT:

- FOL-DUAL module
- Optical Patch cords

WORKING PRINCIPLE:

The semiconductor junction laser is also called an injection laser because its pumping method is electron-hole injection in a p-n junction. The semiconductor that has been extensively used for junction is the Gallium Arsenide. The features of semiconductor lasers are

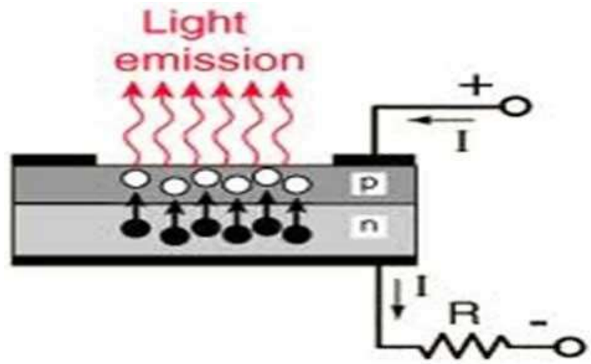
- Extreme mono chromaticity
- High directionality

Three basic transition process related to operation of Lasers are

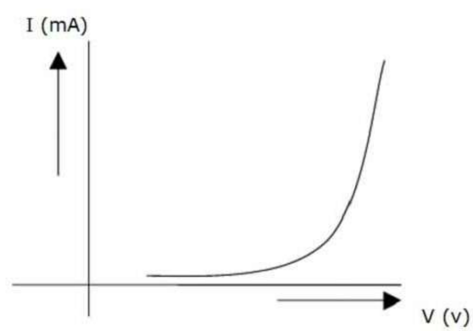
- Absorption
- Spontaneous emission
- Stimulated emission

The starting material is an n-type GaAS doped with silicon in the range of 2-4×10 18 cm -3.A p-type is grown on the wafer by the liquid-phase epitaxial process. The wafer is lapped to a thickness of 75 µm and surfaces are metalized. The wafer is then cleaved into slivers. The next step is to evaporate are flective coating onto one of the cleared facts of the silver so that the laser can emit from only one facet.

Working Principle Diagram:



Model Graph



2. THE SPLICING OF OPTICAL FIBER

INTRODUCTION: Splicing of optical fibers is a **technique used to join two optical fibers**. This technique is used in optical fiber communication, in order to form long optical links for better as well as long-distance optical signal transmission. **Splicers are basically couplers** that form a connection between two fibers or fiber bundles.

At the time of splicing two optical fibers, the geometry of the fibers, their proper alignment and mechanical strength must be taken into consideration.

Working principle

Fusion Splicing

This technique of splicing gives the permanent connection between the two optical fiber cables and gives a longer life with less attenuation. The two cores of fiber cables are joined or fused electrically or thermally. That means an electric device or an electrical arc is used to fuse the two fiber optic cables and produces a connection between them. This technique is very costly and works for a longer period.

Mechanical Splicing

This technique doesn't require a fusion splicer to join the optical fiber together. It uses index matching fluid to hold and align the single or more fiber cables assembled in a place to join them together. The mechanical splicing acts as a junction to join the optical cables more precisely.

SMF cleaver

Optical fiber splicer

When the optical fiber cables are joined together to pass the light from one to another, the loss of light will be low if we use the mechanical splicing technique. That means insertion loss, splicing loss will be nearly 0.3dB. But it produces high back reflection when compared to fusion splicing. It is very easy to repair and install for both multimode and single-mode optical fiber cable

3. Wavelength measurement using Michelson interferometer

In the Michelson interferometer, coherent beams are obtained by splitting a beam of light that originates from a single source with a partially reflecting mirror called a beam splitter. The resulting reflected and transmitted waves are then re-directed by ordinary mirrors to a screen where they superimpose to create fringes. This is known as interference by division of amplitude.

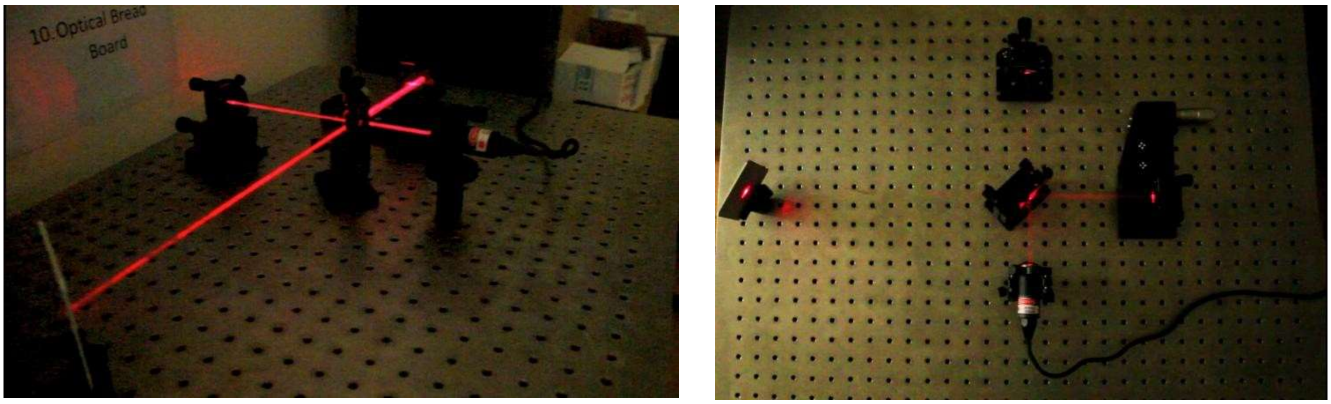
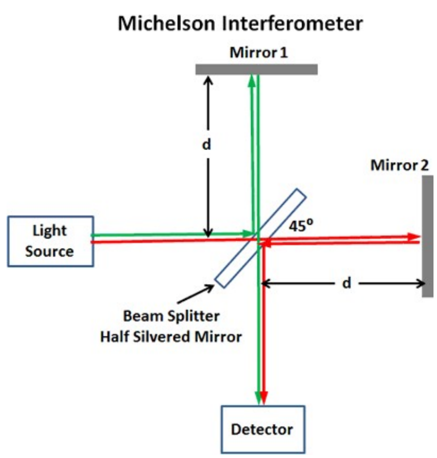


Fig: Optical Bread Board



The wavelength is calculated using,

$$\lambda = (2d/N)\Delta nm$$

4. V-I Characteristics of Laser Diode (FOL-CWDM Module)

AIM:

To study the Voltage-Current (V-I) and Light output-Current (L-I) characteristics of the CWDM laser diode sources and to determine the threshold current of the laser diode.

INTRODUCTION:

A laser diode does not emit light at every value of forward current. Below a certain injection current, called the threshold current (I_th), the device predominantly emits spontaneous (LED-like, incoherent) light of low intensity. Once the injection current exceeds the threshold current, population inversion is achieved inside the active region and stimulated emission dominates, causing the optical output power to rise sharply and near-linearly with current. The V-I and L-I characteristics together describe the electrical behaviour of the diode junction and the optical behaviour of the laser action, and are the primary parameters used to characterize any laser source before it is used in a communication link.

EQUIPMENT:

- FOL-CWDM trainer module with 1510 nm / 1530 nm / 1550 nm / 1570 nm CWDM laser diode sources
- 1.5 GHz InGaAs PIN photodetector module
- Optical patch cords
- PC with FOL-CWDM GUI software (VI Characteristics mode) / USB 2.0 interface

SPECIFICATIONS (as per FOL-CWDM module):

- CWDM Laser diode wavelengths: 1510 nm, 1530 nm, 1550 nm, 1570 nm (1.25 Gbps modules, in-built isolator)
- Threshold current (I_th): 10 mA typical
- Output power: ~0.7 mW at I_th + 30 mA; ~1.4 mW at ~58 mA
- Operating voltage: 1.1 V typical
- Detector: 1.5 GHz InGaAs PIN photodiode, responsivity typical 0.9 A/W (9/125 µm fiber), spectral range 1250-1600 nm, reverse voltage 30 V max

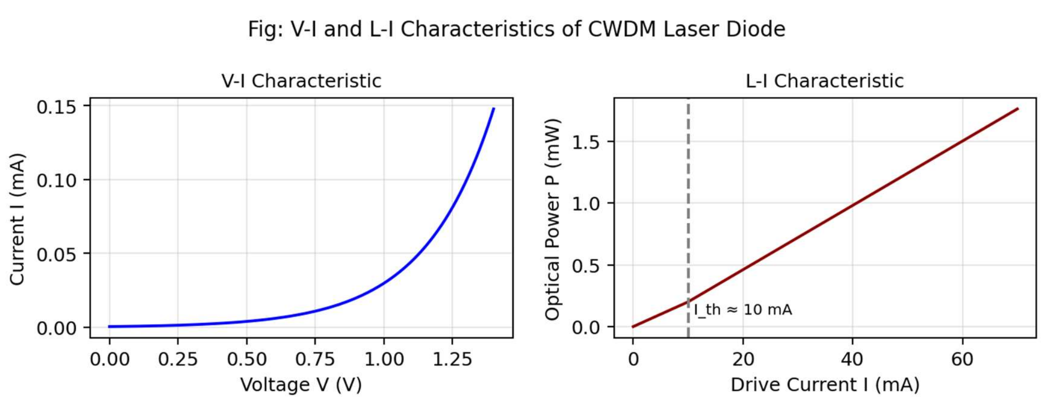


Fig 4.1: Typical V-I and L-I characteristics of a laser diode

PROCEDURE:

- Connect the selected CWDM laser source output to the InGaAs PIN detector input using an optical patch cord.
- Launch the FOL-CWDM GUI software and select 'VI Characteristics' mode.
- Switch ON the laser power supply and select the required source wavelength (1510/1530/1550/1570 nm).
- Increase the laser drive current in small steps (e.g. 0-70 mA) starting from zero, and note the corresponding forward voltage (V) and the detected optical power / photocurrent at each step.
- Tabulate the readings and plot two graphs: (i) Current (I) vs Voltage (V), and (ii) Optical output power (P) vs drive Current (I).
- From the L-I graph, identify the knee point where the slope changes sharply — this corresponds to the threshold current I_th of the laser diode.
- Repeat the procedure for the other CWDM wavelengths and compare the threshold currents.

OBSERVATION TABLE:

S.No.	Drive Current I (mA)	Forward Voltage V (V)	Optical Power P (mW)
1	0		
2	10		
3	20		
4	30		
5	...		

MODEL GRAPH:

The V-I curve of the laser diode follows the standard forward-biased p-n junction diode characteristic — negligible current until the turn-on voltage is reached, after which current rises steeply. The L-I curve remains near-flat (spontaneous emission only) below I_th, and rises sharply and near-linearly once the current exceeds I_th, marking the onset of lasing action.

RESULT:

The V-I and L-I characteristics of the CWDM laser diode were plotted and the threshold current of the laser source was determined from the L-I graph.

5. Digital Modulation in Optical Fiber Communication

AIM:

To study digital (ON-OFF Keying) modulation of a laser source and to demonstrate transmission and recovery of a digital signal over an optical fiber link using the FOL-CWDM trainer.

INTRODUCTION:

In optical fiber communication, information is transmitted by varying (modulating) the intensity of the light emitted by a laser or LED source in accordance with an electrical data signal, and recovering the data at the receiver end using a photodetector. The simplest and most widely used technique is digital intensity modulation, in which the laser is switched between two current levels corresponding to logic '1' (above threshold, laser ON, high optical output) and logic '0' (below threshold or off, low/negligible optical output). This is commonly called On-Off Keying (OOK). The FOL-CWDM module supports digital modulation of its laser sources with a maximum modulation frequency of 5 MHz, in addition to internal and external modulation modes.

EQUIPMENT:

- FOL-CWDM trainer module (laser source with digital modulation input)
- Function generator (for external digital modulating signal)
- 1.5 GHz InGaAs PIN photodetector module
- Optical patch cords, CRO (oscilloscope)

WORKING PRINCIPLE:

A digital electrical bit pattern is applied to the modulation input of the laser diode driver circuit. The driver biases the laser diode above threshold for a '1' bit and below threshold (or at a much lower current) for a '0' bit, so that the optical output intensity follows the electrical data pattern. This intensity-modulated light is launched into the optical fiber, propagates to the receiving end, and is converted back to an electrical signal by the InGaAs PIN photodetector, whose output current is proportional to the received optical power. The recovered electrical waveform is observed on a CRO and compared with the original transmitted data to verify signal fidelity, extinction ratio and any timing distortion introduced by the link.

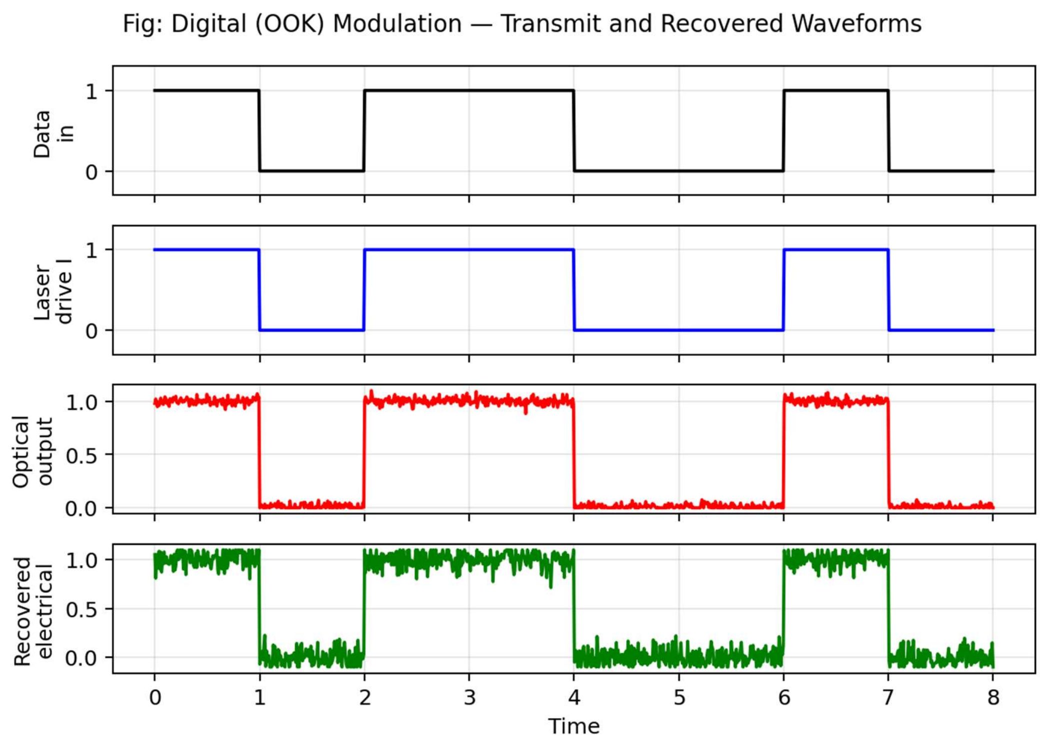


Fig 5.1: Digital (OOK) modulation — transmit and recovered waveforms

PROCEDURE:

- Set the FOL-CWDM software / hardware to 'External Modulation' or 'Internal Modulation' mode as required.
- Apply a digital bit pattern (square wave / pseudo-random bit sequence) from the function generator to the laser modulation input, or select internal modulation from the GUI.
- Connect the laser output to the PIN photodetector through the optical fiber patch cord.
- Observe the transmitted (electrical input) and received (recovered electrical output) waveforms simultaneously on the CRO.
- Vary the modulation frequency (up to 5 MHz) and note the maximum frequency at which the received waveform remains a faithful replica of the transmitted data.

- Record the extinction ratio (ratio of optical power for logic '1' to logic '0') and any observed pulse distortion.

OBSERVATION:

S.No.	Modulation Frequency (MHz)	Transmitted waveform	Received waveform (Remarks)
1	0.1	Square wave	Clean recovery
2	1	Square wave	
3	5	Square wave	

RESULT:

Digital (OOK) modulation of the laser source was performed and the transmitted digital data was successfully recovered at the receiver, confirming correct operation of the optical transmit-receive link over the range of modulation frequencies tested.

6. Wavelength Division Multiplexing (WDM) — CWDM MUX / DEMUX Characterization

AIM:

To study the principle of Coarse Wavelength Division Multiplexing (CWDM) and to characterize the multiplexer (MUX) and demultiplexer (DEMUX) of the FOL-CWDM module.

INTRODUCTION:

Wavelength Division Multiplexing (WDM) is a technique that allows multiple optical signals of different wavelengths to be transmitted simultaneously over a single optical fiber, thereby multiplying the transmission capacity of the fiber without laying additional cable. Coarse WDM (CWDM) uses widely spaced channels (typically 20 nm apart) compared to Dense WDM (DWDM), making the associated optical components simpler and less costly. At the transmitting end, a multiplexer (MUX) combines several individual wavelength channels onto one fiber; at the receiving end, a demultiplexer (DEMUX) separates the combined signal back into its individual wavelength channels for detection.

EQUIPMENT:

- FOL-CWDM module with 4-channel CWDM MUX and DEMUX (center wavelengths 1510/1530/1550/1570 nm)
- CWDM laser sources (4 channels), InGaAs PIN detector
- Optical patch cords, PC with FOL-CWDM GUI software

SPECIFICATIONS (4-channel CWDM MUX/DEMUX):

- Center wavelengths: 1510 nm, 1530 nm, 1550 nm, 1570 nm
- Channel spacing: 20 nm ; Passband @ 0.5 dB: ITU ± 6.5 nm
- Insertion loss @ MUX / DEMUX port: ≤ 2.9 dB
- Adjacent channel isolation: ≥ 30 dB ; Non-adjacent channel isolation: ≥ 40 dB
- Maximum optical power handling: 300 mW
- Overall system band: C + L band (1525 nm - 1610 nm); transmission direction 1→2, 2→3

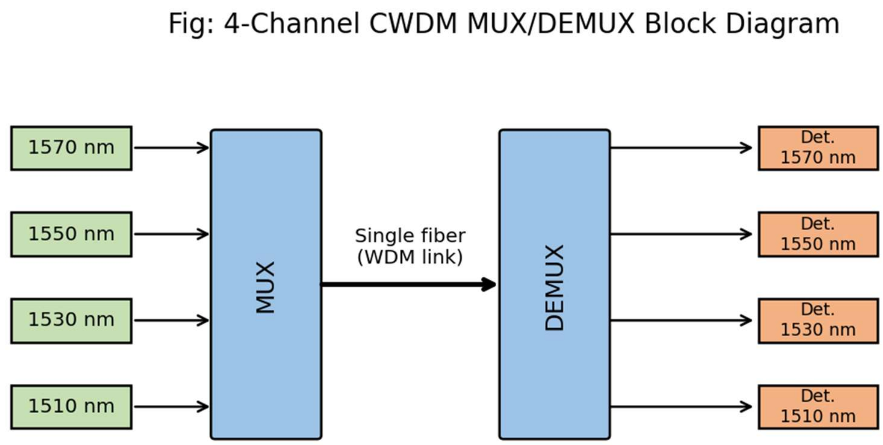


Fig 6.1: 4-channel CWDM MUX/DEMUX block diagram

PROCEDURE:

- Connect each of the four CWDM laser sources to the corresponding input port of the MUX.
- Connect the common output of the MUX to the input of the DEMUX (directly, or via the fiber spool provided) to simulate a single-fiber WDM link.
- Switch ON one laser source (channel) at a time and measure the optical power at the corresponding DEMUX output port (through-channel) as well as at the adjacent and non-adjacent DEMUX output ports.
- Compute the insertion loss of the through channel and the isolation (crosstalk suppression) at adjacent and non-adjacent channels for each source wavelength.
- Repeat by switching ON all four sources simultaneously and verify that each DEMUX output port recovers only its designated channel wavelength.

FORMULAE:

$$\text{Insertion Loss (dB)} = 10 \log_{10} (P\_in / P\_out)$$

$$\text{Channel Isolation (dB)} = 10 \log_{10} (P\_through\text{-}channel / P\_crosstalk\text{-}channel)$$

OBSERVATION TABLE:

Source λ (nm)	MUX out power (dBm)	DEMUX through-port power (dBm)	Insertion Loss (dB)	Adjacent channel isolation (dB)
1510				
1530				
1550				
1570				

RESULT:

The 4-channel CWDM multiplexer and demultiplexer of the FOL-CWDM module were characterized; the insertion loss and channel isolation obtained were verified against the specified values (insertion loss ≤ 2.9 dB, adjacent isolation ≥ 30 dB, non-adjacent isolation ≥ 40 dB).

7. Fiber Bragg Grating (FBG) Characterization

AIM:

To study the principle of a Fiber Bragg Grating and to determine its central (Bragg) wavelength, 3 dB bandwidth and side-lobe suppression ratio using the FOL-CWDM module.

INTRODUCTION:

A Fiber Bragg Grating (FBG) is formed by introducing a periodic variation of the refractive index along the core of an optical fiber. When broadband light is launched into the fiber, the grating reflects a narrow band of wavelengths centered on the Bragg wavelength (λ_B) — determined by the grating period and effective refractive index — while transmitting all other wavelengths. Because of this wavelength-selective reflection, FBGs are widely used for add/drop wavelength filtering in WDM systems, gain flattening, dispersion compensation and sensing applications.

EQUIPMENT:

- FOL-CWDM module with in-built Fiber Bragg Grating (central wavelength 1550 nm) and three-port optical circulator
- Broadband / CWDM laser source(s), InGaAs PIN detector
- Optical patch cords, PC with FOL-CWDM GUI software

SPECIFICATIONS (Fiber Bragg Grating):

- Central wavelength: 1550 ± 0.5 nm
- Bandwidth @ 3 dB: 0.02 - 5 nm
- Side-lobe suppression ratio (SLSR): > 15 dB
- Reflectivity: > 90%

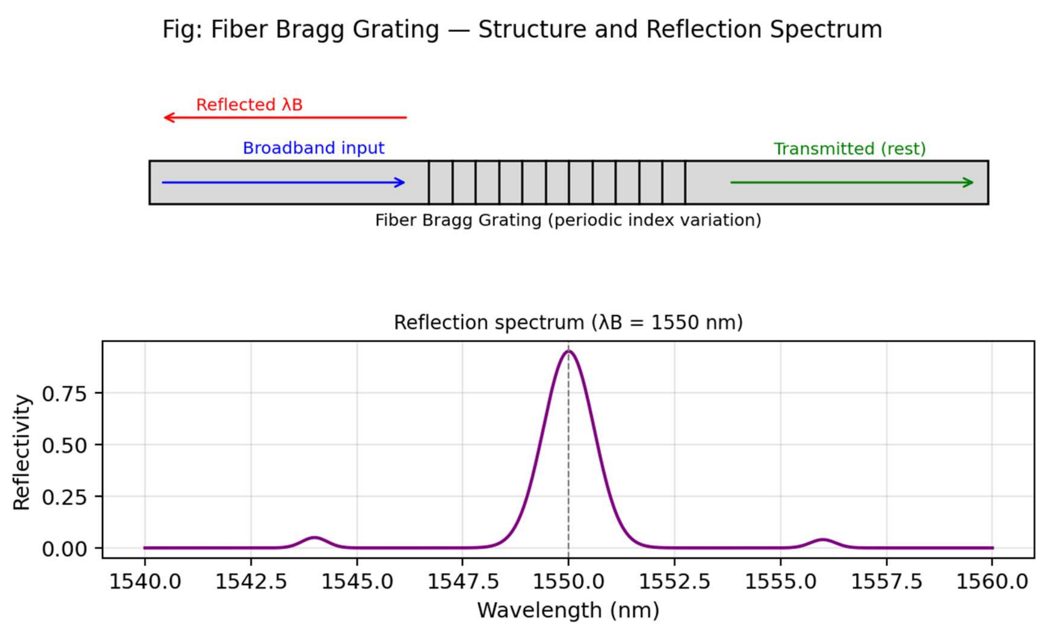


Fig 7.1: FBG structure and reflection spectrum

PROCEDURE:

- Connect the CWDM source to port 1 of the three-port optical circulator; connect port 2 of the circulator to the Fiber Bragg Grating.

- Connect port 3 of the circulator to the PIN detector to capture the light reflected back by the FBG (the circulator directs light from port 1 to port 2, and any light reflected back into port 2 is redirected to port 3).
- Sweep / select the source wavelength across the CWDM channels (or use the tunable source, if provided) and record the reflected optical power detected at port 3 for each wavelength.
- Plot reflected power versus wavelength to obtain the reflection spectrum of the grating.
- From the plotted spectrum, identify the peak (central / Bragg wavelength), measure the 3 dB bandwidth (the wavelength span where reflected power falls to half of the peak value), and note the level of the side lobes relative to the main peak to determine the SLSR.

OBSERVATION TABLE:

S.No.	Source Wavelength (nm)	Reflected Power at Port 3 (dBm)
1	1545	
2	1548	
3	1550	
4	1552	
5	1555	

RESULT:

The reflection spectrum of the Fiber Bragg Grating was obtained; the measured central wavelength, 3 dB bandwidth and side-lobe suppression ratio were verified against the specified values (λ_B = 1550 ± 0.5 nm, bandwidth 0.02-5 nm, SLSR > 15 dB, reflectivity > 90%).

8. Optical Circulator Characterization

AIM:

To study the working of a three-port polarization-independent optical circulator and to verify its directional (non-reciprocal) transmission and isolation properties.

INTRODUCTION:

An optical circulator is a non-reciprocal, multi-port passive device that routes light entering any port out of the next port in sequence, while blocking transmission in the reverse direction. In a standard three-port circulator, light entering port 1 exits (almost entirely) from port 2, light entering port 2 exits from port 3, and there is very high isolation between port 1 and port 3 in the reverse direction. This directional property makes circulators essential building blocks for add/drop multiplexing with fiber Bragg gratings, bidirectional transmission over a single fiber, and optical amplifier / sensor interrogation systems.

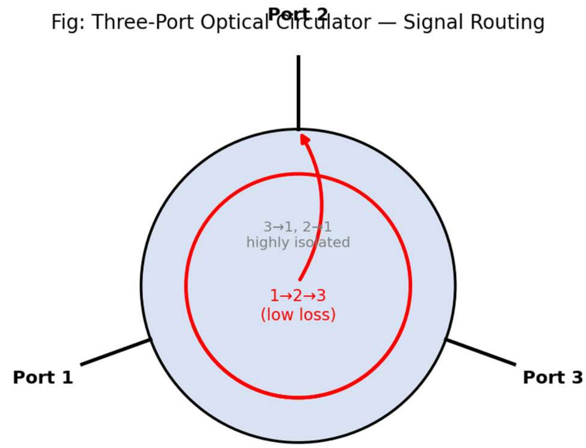


Fig 8.1: Three-port optical circulator — signal routing

EQUIPMENT:

- FOL-CWDM module with in-built three-port, polarization-independent optical circulator
- CWDM laser source, InGaAs PIN detector
- Optical patch cords, PC with FOL-CWDM GUI software

PROCEDURE:

- Connect the laser source to port 1 of the circulator and the PIN detector to port 2; measure the transmitted optical power (Port 1 → Port 2).
- Move the detector to port 3 (with the source still on port 1) and measure the leakage power (Port 1 → Port 3) to determine the isolation between ports 1 and 3.
- Repeat by connecting the source to port 2 and measuring the output at port 3 (Port 2 → Port 3), and the leakage from port 2 back to port 1.
- Calculate the insertion loss for each 'forward' path (1→2, 2→3) and the isolation for each 'reverse' path (1→3, 2→1) using the insertion-loss formula given in Experiment 6.

OBSERVATION TABLE:

Path	Input Power (dBm)	Output Power (dBm)	Insertion Loss / Isolation (dB)
Port 1 → Port 2 (forward)			
Port 1 → Port 3 (reverse / isolation)			
Port 2 → Port 3 (forward)			
Port 2 → Port 1 (reverse / isolation)			

RESULT:

The directional transmission characteristics of the three-port polarization-independent optical circulator were verified: light injected at a given port was found to couple predominantly to the next port in sequence, with high isolation observed in the reverse direction, confirming the non-reciprocal behaviour of the device.