Optical Communication Laboratory (ECC 17201)

Lab Manual

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Optical Communication Lab Manual(ECC 17201)

List of Hardware experiments:

1. Study of setting up an analog and digital link using optical fiber.
2. Measurement of numerical aperture of the plastic fiber provided using 660 nm wavelength.
3. Study of Frequency modulation and demodulation using Optical fiber.
4. Study of pulse width modulation and demodulation technique using Optical fiber
5. Study of Characteristics of LASER diode.
6. Study of I-V Characteristics of Fiber optic LED and Photodetector.
7. Measurement of bending loss and propagation loss in the optical fiber cable.
8. Setting up Fiber Optics voice link using Frequency Modulation.

List of Software Experiments:

9. Plot the transcendental equations for the TE modes in a symmetric step index planner waveguide.
10. Plot the transcendental equations for the TM modes in a symmetric step index planner waveguide.
11. 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’.
12. Plot the refractive index profiles for different values of α in a graded index fiber with a index profile of

$$n^2(r) = n_1^2[1 - 2\Delta(r/a)^\alpha],\ \ 0<r<a\ .$$

13. Write a program to study the modes of a step index cylindrical core optical fiber.

Safety Instructions

- Read the following safety instructions carefully before operating the product.

- To avoid any personal injury or damage to the product or any products connected toit.

Do not operate the instrument if you suspect any damage within.
The instrument should be serviced by qualified personnel only.

For your Safety:
Use proper Mains cord:

- Use only the mains cord designed for this product.
- Ensure that the mains cord is suitable for yourcountry.

Ground the Instrument:

- This product is grounded through the protective earthconductor of the mains cord.
- To avoid electric shockthe grounding conductor must be connected to theearth ground.
- Before making connections to the inputterminals, ensure that the instrument is properlygrounded.

Observe Terminal Ratings:

- To avoid fire or shock hazards, observe all ratings andmarks on the instrument.

Use only the proper Fuse: Use the fuse type and rating specified for this product.

Use in proper Atmosphere: Please refer to operating conditions given in themanual.

- **Do not operate in wet / damp conditions.**

- **Do not operate in an explosive atmosphere.**

- **Keep the product dust free, clean and dry.**

DO’S AND DON’TS

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 equipments
- Do not leave the table without prior permission from the teacher.

Experiment 1

Objective 1(a): Setting up Fiber Optic Analog Link
Study of a 650nm fiber optic analog link in this experiment you will study the relationship between the input signal and received signal.

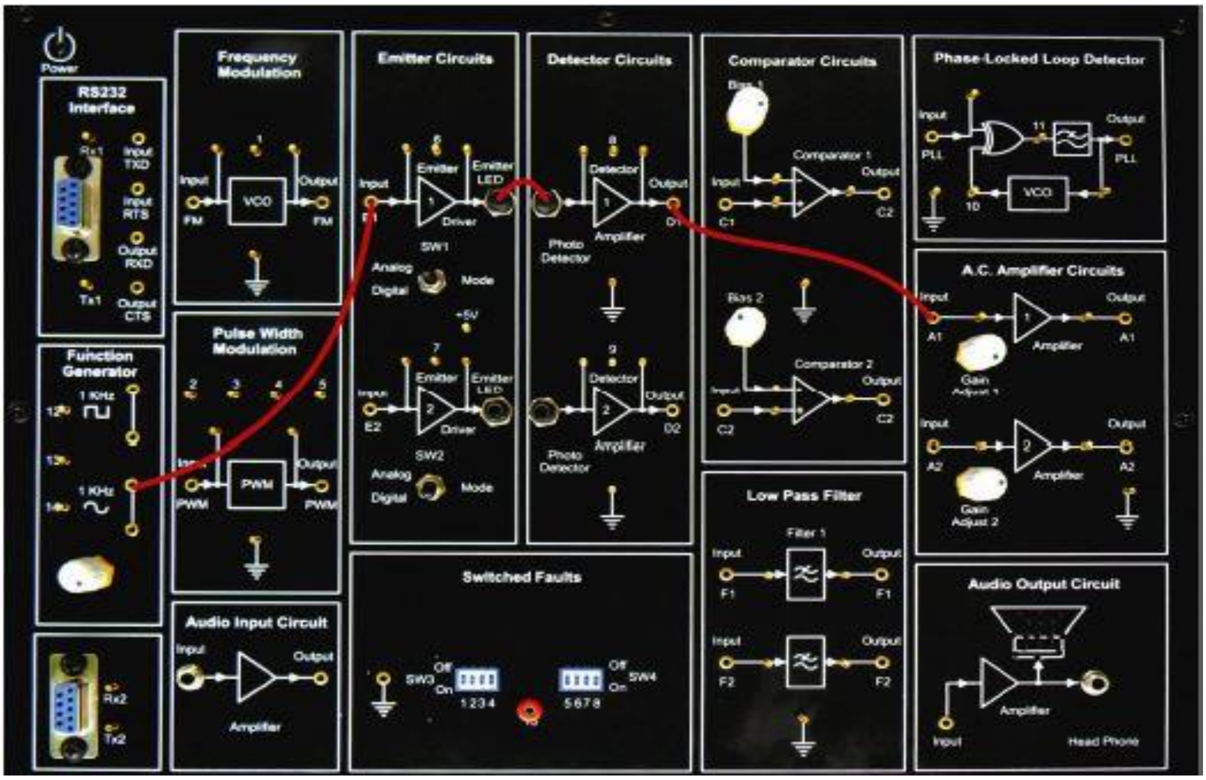
Equipments Required:

- Scientech 2502 Kit with Power Supply cord
- Optical Fiber cable
- Digital Storage Oscilloscopewith necessary connecting probe

Theory:

Fiber Optic Links can be used for transmission of digital as well as analog signals. Basically, a fiber optic link contains three main elements, a transmitter, an optical fiber and a receiver. The transmitter module takes the input signal in electrical form and then transforms it into optical (light) energy containing the same information. The optical fiber is the medium, which carries this energy to the receiver. At the receiver, light is converted back into electrical form with the same pattern as originally fed to the transmitter.

Connection Diagram:



Procedure:

● Connect the Power Supply cord to the main power plug & to TechBook Scientech 2502.
● Ensure that all switched faults are ‘Off’.
● Make the following connections as shown in next figure
• Connect the 1 KHz sine wave output to emitter l's input.
• Connect the Fiber Optics cable between emitter output and detectors input.
• Detector l's output to AC amplifier 1 input.
● On the board, switch emitter l's driver to analog mode.
● Switch ON the Power Supply of TechBook and Oscilloscope.
● Observe the input to emitter 1 with the output from AC amplifier 1 and note that the two signals are same.

Observation Table:

S. No.	f_{in}	V_{in}	V_{out}

Results and Discussions:

Questions:

1. What is meant by index profile?
2. What is the drawback of multimode Fibers?
3. What is Fiber optics?

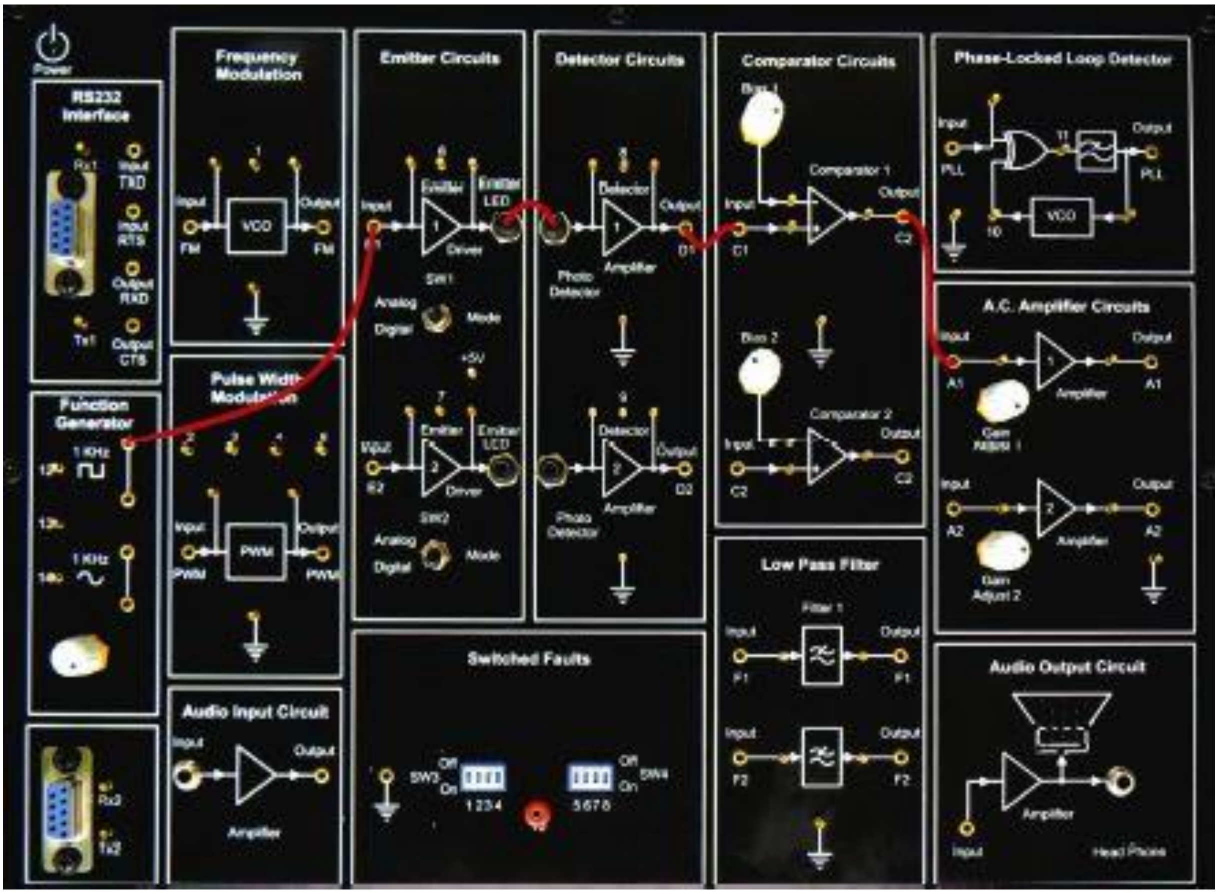
Objective 1(b): Setting up Fiber Optic Digital Link
In this experiment you will study the relationship between the input signal and received signal.

Equipments Required:
● Scientech 2502 Kit with Power Supply cord
● Optical Fiber cable
● Digital Storage Oscilloscopewith necessary connecting probe

THEORY:

In the experiment no. 1 (a), we have seen how analog signal can be transmitted and received using LED, fiber and detector. The same LED can be configured for the digital applications to transmit binary data over fiber. Thus basic elements of the link remain same even for digital applications.

Connection Diagram:



Procedure:

- Connect the Power Supply cord to the main the Power Supply to the board.
- Ensure that all switched faults are 'Off'.
- Make the following connections as shown in next figure.
- Connect the 1 KHz square wave output to emitter l's input.
- Connect the fiber optic cable between emitter output and detectors input.
- Detector 1's output to comparator 1's input.
- Comparator l's output to AC amplifier l's input.
- On the board, switch emitter 1's driver to digital mode.
- Switch ON the Power Supply of TechBook and Oscilloscope.
- Monitor both the inputs to comparator 1. Slowly adjust the comparators bias preset, until DC Level on the input (TP13) lays mid way between the high and low level of the signal on the positive input (TP14).
- Observe the input to emitter 1 (TP 5) with the output from AC amplifier 1 (TP28) and note that the two signals are same.

Observation Table:

S. No.	**f_{in}**	**V_{in}**	**V_{out}**

Results and Discussions:

Questions:

1. Why single mode Fibers are used for long distance transmission?
2. What is optical Fiber?
3. What is step index profile?

Experiment 2

Objective: Study of numerical aperture of optical fiber.
The objective of this experiment is to measure the numerical aperture of the plastic fiber provided with the kit using 660 nm wavelength LED.

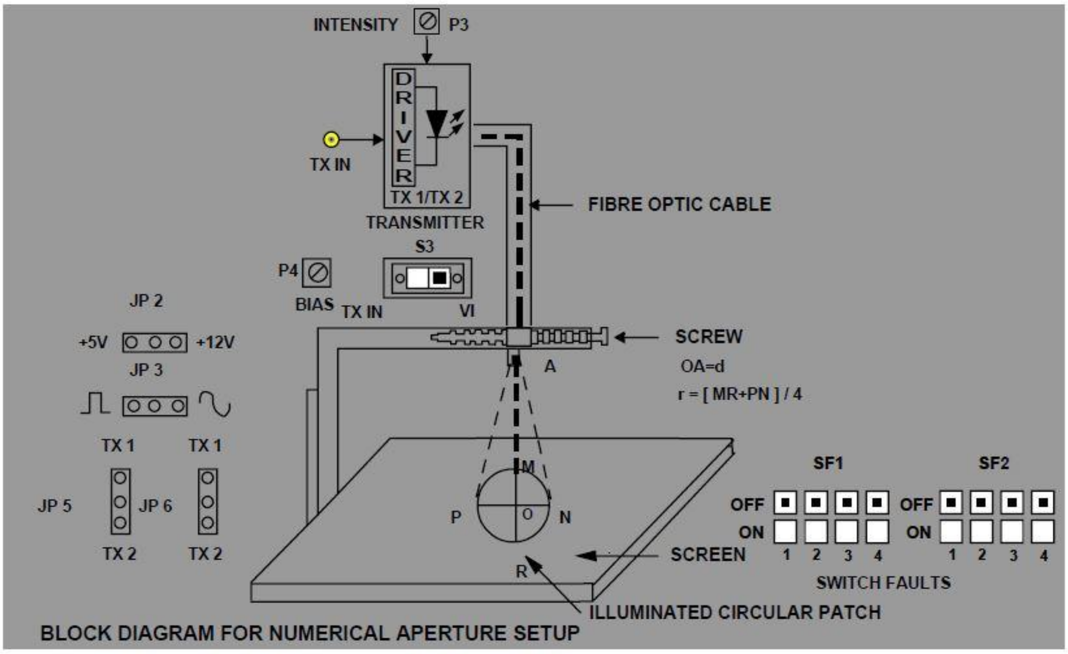
Equipments Required:

- Link-A kit.
- 1 Meter Fiber cable.
- NA JIG.
- Steel Ruler.
- Power supply.

Theory:
Numerical aperture refers to the maximum angle at which the light incident on the fiber end is totally internally reflected and is transmitted properly along the fiber. The cone formed by the rotation of this angle along the axis of the fiber is the cone acceptance of the fiber. The light ray should strike the fiber end within its cone of acceptance, else it is refracted out of the fiber core.

Considerations in NA measurement:
It is very important that the optical source should be properly aligned with the cable and distance from the launched point and the cable is properly selected to ensure that the maximum amount of optical power is transferred to the cable.
This experiment is best performed in a less illuminated room.
Measurement of Numerical Aperture
Measurement of the Numerical Aperture (NA) of the fiber

Block diagram for Numerical Aperture Set-up:



BLOCK DIAGRAM FOR NUMERICAL APERTURE SETUP

PROCEDURE:

- Connect the power supply cables with proper polarity to kit. While connecting this, ensure that the power supply is OFF. Do not apply any TTL signal from Function Generator. Make the connections as shown in block diag.
- Keep all the switch faults in OFF position.
- Keep Pot P3 fully Clockwise Position and P4 fully anticlockwise position.
- Slightly unscrew the cap of LED SFH756V (660 nm). Do not remove the cap from the connector. Once the cap is loosened, insert the fiber into the cap. Now tight the cap by screwing it back. Keep Jumpers JP2 towards +5V position, JP3 towards sine position, JP5 & JP6 towards TX1 position.
- Keep switch S3 towards VI position.
- Insert the other end of the fiber into the numerical aperture measurement jig. Hold the white sheet facing the fiber. Adjust the fiber such that its cut face is perpendicular to the axis of the fiber.
- Keep the distance of about 10 mm between the fiber tip and the screen. Gently tighten the screw and thus fix the fiber in the place.
- Now adjust Pot P4 fully Clockwise Position and observe the illuminated circular patch of light on the screen.
- Measure exactly the distance d and also the vertical and horizontal diameters MR and PN indicated in the block diagram.
- Mean radius is calculated using the following formula. r = (MR + PN) / 4
- Find the numerical aperture of the fiber using the formula. NA = sin max = r / d + r Where max is the maximum angle at which the light incident is properly transmitted through the fiber.

Observation Table:

S. No.	d (in cm)	r (in cm)	NA

Results and Discussions:

Questions:-

1) What is numerical aperture?
2) What is the expression for numerical aperture?
3) What is the S.I. unit of numerical aperture?

Experiment 3

Objective: Study of Frequency modulation and demodulation using Optical fiber

Equipments Required:

- Scientech 2502 Kit with Power Supply cord
- Optical Fiber cable
- Digital Storage Oscilloscopewith necessary connecting probe

Theory:

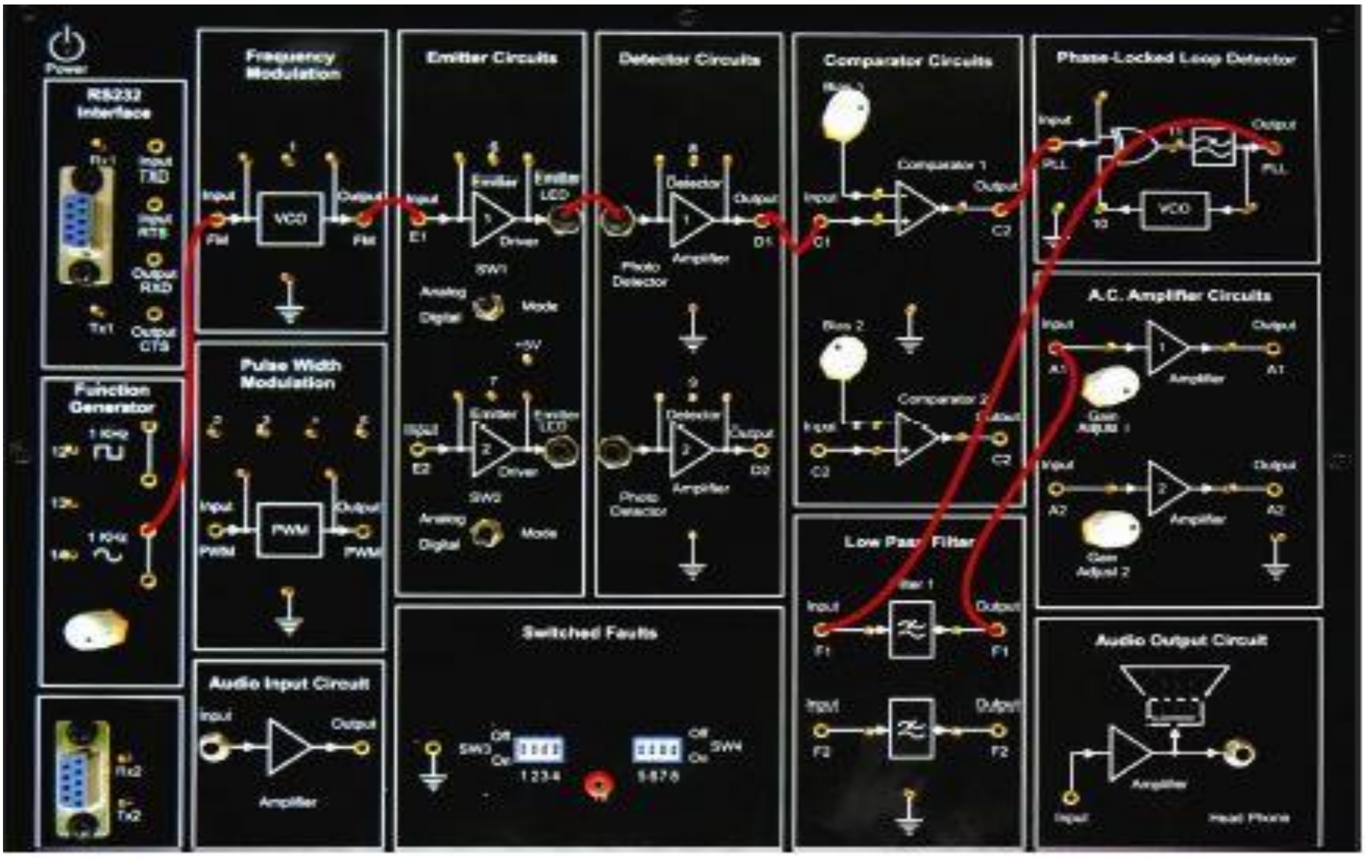
FREQUENCY MODULATION: It is a type of modulation in which the frequency of the high frequency (Carrier) is varied in accordance with the instantaneous value of the modulating signal.Consider a sine wave signal Vm(t) with pulse Vm(t) = B• sin(w•t) and another sine wave Vc(t) with upper Ω pulse: Vc(t) = A • sin(Ω•t) The signal Vm(t) is called modulating signal, the signal Vc(t) is called carrier signal. Vary the frequency of the carrier Vc(t) in a way proportional to the amplitude of the modulating signal Vm(t). You obtain a Vm(t) frequency modulated diagonal, which can be expressed by the relation: Vm(t) = A • sin [Θ(t)] with Θ(t) instantaneous angle function of Vm(t).

The instantaneous pulse Ω(t) of the FM signal by definition: Ω(t) = Ω + K• Vm(t) with hΩ = carrier pulse K= modulation sensitivity

The instantaneous angle Ω (t) to be used as subject of the sine to obtain the mathematical operation of the FM signal, is detected by integrating $\Omega(t)$: $\Theta(t) = \int\Omega(t)\,dt$ In the case of modulating sine wave signal [Vm (t) = B•sin (w•t)], $\Theta(t)$ it results: $\Theta(t) = \Omega\cdot(t) - (K\cdot B/w)\cdot\cos(w\cdot t)$ The expression of the frequency modulated signal Vm (t) becomes: $Vm(t) = A\cdot\sin[\Omega\cdot(t) - (K\cdot B/w)\cdot\cos(w\cdot t)]$

Frequency Deviation ΔF andModulation Index MF:
The instantaneous frequency F(t) of the carrier modulated by a sine wave, results:
$F(t) = \Omega(t)/2\pi = \Omega/2\pi + K\cdot B\cdot\sin(w\cdot t)$
and oscillates between a minimum Fmin and a maximum value Fmax: $Fmin = \Omega/2\pi - K\cdot B/2\pi$ $Fmax = \Omega/2\pi + K\cdot B/2\pi$
The frequency deviation ΔF represents the maximum shift between the modulated signal frequency, over and under the frequency of the carrier:
$\Delta F=(Fmax–Fmin)/2$
We define as modulation index m_f the ratio between ΔF and the modulating frequency f: $m_f = \Delta F/f$

Connection Diagram:



Procedure:

● Connect the Power Supply cord to the main power plug & to TechBook Scientech 2502.

● Ensure that all switched faults are 'Off'.

● Make the following connections as shown in next figure

• Connect Function Generator 1 KHz sine wave signal to frequency modulator input.

• Frequency modulator output TP2 to the emitter 1 input at TP5.

• Connect the optic fiber between the emitter 1 circuit and the detector 1 circuit.

• Detector 1 output TP10 to comparator 1 input at TP14.Comparator 1 output TP15 to the PLL detector input at TP23.

• PLL detector output at TP26 to the low pass filter 1 input at TP19

• Low Pass Filter 1 output TP20 to A C amplifier 1 input at TP27

● Switch emitter l's driver to digital mode. This ensures that fast changing digital signal applied to the drivers input causes the emitter LED to switch quickly between 'On' & 'Off' states.

● Turn the 1 KHz preset in the Function Generator block to fully anticlockwise (Zero amplitude) position.

● Switch ON the Power Supply of the TechBook and Oscilloscope.

● Monitor the output of the voltage controlled oscillators (VCO) in the frequency modulator block TP2. Note that the frequency of this digital signal is at present constant, since the modulating 1 KHz sine wave has zero amplitude.

● Examine the output of detector 1 (TP10 and check that the transmitted digital pulses are successfully detected at the receiver).

● With the help of dual trace Oscilloscope monitor both inputs to comparator1. Now adjust the bias 1 preset until the bias input at TP13 is halfway between the top and bottom of the square wave on TP14. You will remember that the function of the comparator is to clean up the square wave after its transmission through the fiber optic link.

● The output of comparator 1 drives the input of the PLL detector which produces a signal whose average level is proportional to the frequency of the digital stream. This average level is then extracted by low pass filter 1, and amplified by AC Amplifier1 to produce the original analog signal at the amplifiers output TP28. Examine TP28 and note that the output voltage is zero. This is expected since there is currently no modulating voltage in the transmitter.

● While monitoring the input to the frequency modulator block TP1 and the output from AC amplifier 1 TP 28 turn the 1KHz preset to its fully clockwise maximum amplitude) position. Note that the modulating 1 KHz signal now appears at the amplifiers output. If necessary, adjust the amplifiers gain, adjust 1preset until the two monitored signal are equal in amplitude.

● In order to fully understand how this frequency modulation transmitter/ receiver system works, examine the inputs and outputs of all functional blocks within the system, using an Oscilloscope.

Observation:

Results and Discussions:

Questions:

1. How the FM signal is generated?
2. What are the various detection techniques of FM signals?
3. Why FM is used for short distance communication?

Experiment 4

Objective: Study of pulse width modulation and demodulation technique using Optical fiber

Equipments Required:

- Scientech 2502 Kit with Power Supply cord
- Optical Fiber cable
- Digital Storage Oscilloscopewith necessary connecting probe

Theory:

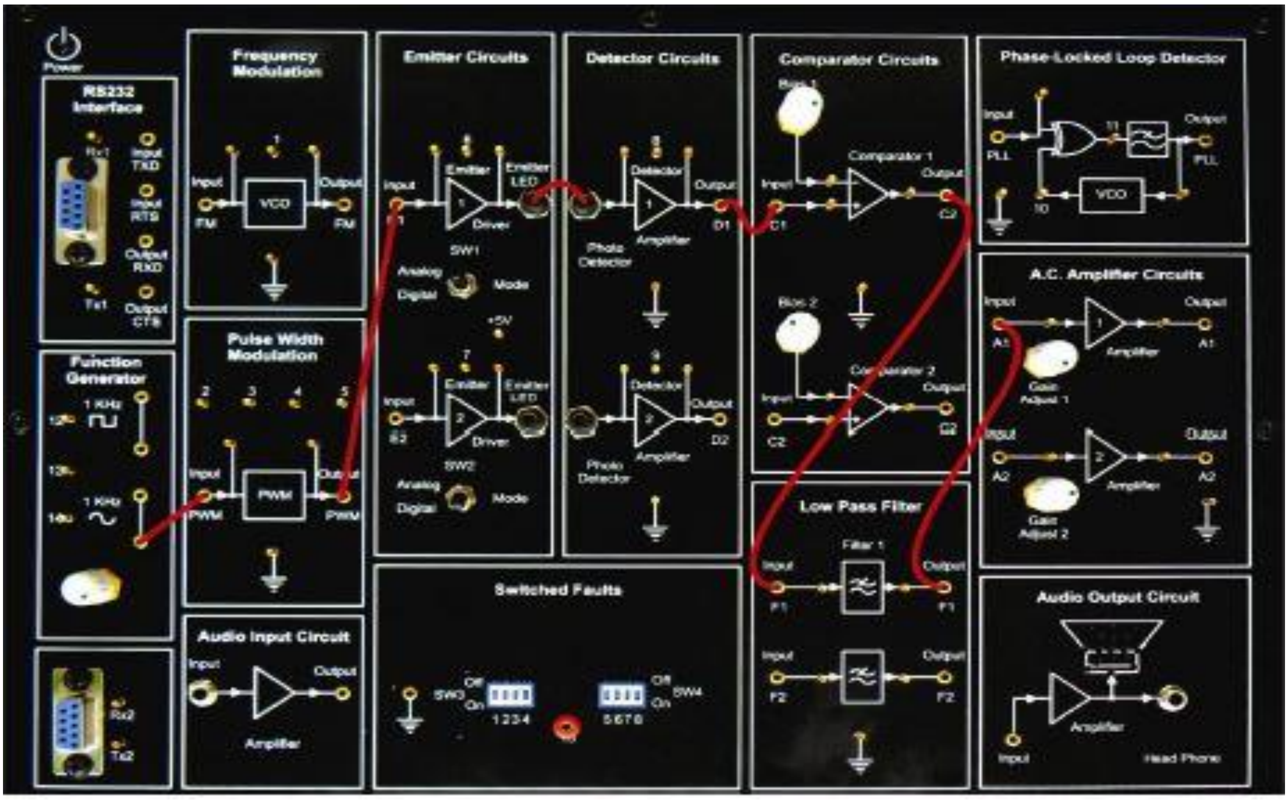
Pulse Width Modulation:

This technique of modulation controls the variation of duty cycle of the square (With some fundamental frequency) according to the input modulating signal. The amplitude variation of the modulating signal is reflected in to ON period variation of square wave. Hence, it is also called as technique of V to T conversion.

Pulse Width Demodulation:

The input signal is pulse width modulated, so the ON time of the signal is changing according to the modulating signal. In this demodulation technique during the time of PWM signal is changing according to the modulating signal. In demodulation technique, the PWM signal is applied to an Integrator, whose output then Filtered to obtain original signal. Thus at the output we get the original modulating signal extracted from PWM wave. Fiber optic transmitter and receivers are used to transmit and receive PWM signal respectively.

Connection Diagram:



Procedure:

● Connect the Power Supply cord to the main power plug & to TechBook Scientech 2502.

● Ensure that all switched faults are set to ‘Off’.

● Make the following connections as shown in next figure.

• FG' s 1KHz sine wave signal to the Pulse width modulator input TP3

• Pulse width modulator output TP4 to emitter 1 input TP5

• Connect the optic fiber between the emitter 1 circuit and detector 1 circuit.

• Detector 1 output TP10 to comparator & input at TP14.

• Comparator 1 output TP15 to LPF 1 at TP19.

LPF 1 output TP20 to A C amplifier 1 input at TP27.

● Switch emitter 1’s driver to digital mode. This ensures that fast changing digital signals applied to the drivers input because the emitter LED to switch quickly between ‘On’ & ‘Off’ states.

● Turn the 1 KHz preset of Function Generator block to fully anticlockwise (zero amplitude) position.

● Switch ON the Power Supply of the TechBook and Oscilloscope.

● Monitor the output of the pulse width modulator block TP4. Note that the pulse width of this digital signal is at present constant, since the modulating 1 KHz sine wave has zero amplitude.

● Examine the output Detector TP10 and check that the transmitted digital pulse is successfully detected at the receiver.

● Monitor both inputs' comparator 1 TP13 & TP14 and if necessary, slowly adjust the comparator's bias preset, until the DC Level on the negative input TP13 lies midway between the high and low level of the signal on the positive input TP14.

● The average level of comparator l's output is extracted by LPF 1 and then amplified by AC amplifier which also removes the DC offset. Since, the average level of the comparator output is proportional to the pulse width, the original analog signal appears at the amplifiers output TP28. Examine TP28 and note that the output voltage is zero. This is expected since there is currently no
modulating voltage at the transmitter.

● While monitoring the input to the pulse width modulator block TP3 and the output from AC amplifier 1 TP28 turn the 1 KHz preset to its fully clockwise (maximum amplitude position). Note that the modulating 1 KHz signal now appears at the amplifiers output. If necessary, adjust the amplifiers gain adjust 1 preset until the two monitored signals are equal in amplitude.

● In order to fully understand how this pulse width modulation transmitter/ receiver system works, examine the inputs and outputs of all functional blocks within the system using an Oscilloscope.

Observation:

Results and Discussions:

Questions:

1. What is PWM?
2. What is the advantage of using PWM in communication systems?
3. What is the function of comparator circuit?

Experiment 5

Objective: Study of Characteristics of LASER Diodes
(i) Optical Power (Po) of LASER Diode vs LASER Diode Forward Current (IF)
(ii) Monitor photodiode current (IM) vs LASER Optical Power Output (Po)

Equipments Required:
- Scientech 2506Kit with Power Supply cord
- Optical Fiber cable
- Digital Multimeter/ Optical Powermeter

Theory:
LEDs and LASER Diodes are the commonly used sources in optical communication systems, whether the system transmits digital or analogue signals. In the case of analogue transmission, direct intensity modulation of the optical sources is possible provided the optical output from the source can be varied linearly as a function of the modulating electrical signal amplitude. LEDs have a linear optical output with relation to the forward current over a certain region of operation. It may be mentioned that in many low-cost, short-haul and small bandwidth applications. LEDs at 660nm, 850nm, and 1300nm are popular. While direct

intensity modulation is simple to realize, higher performance is achieved by fm modulating the base-band signal prior to intensity modulation.

LASER Diodes are used in telecom, data com 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 realization of wavelength division multiplexing (WDM) for 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 analogue transmission). Special LASERs also provide for 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**
P_0	CW output power	2.5	mW
Iop	Operating current	30	mA
W_p	Wavelength to Peak Emission	650	Nm
MTTF	Mean time to failure	10,000	hrs

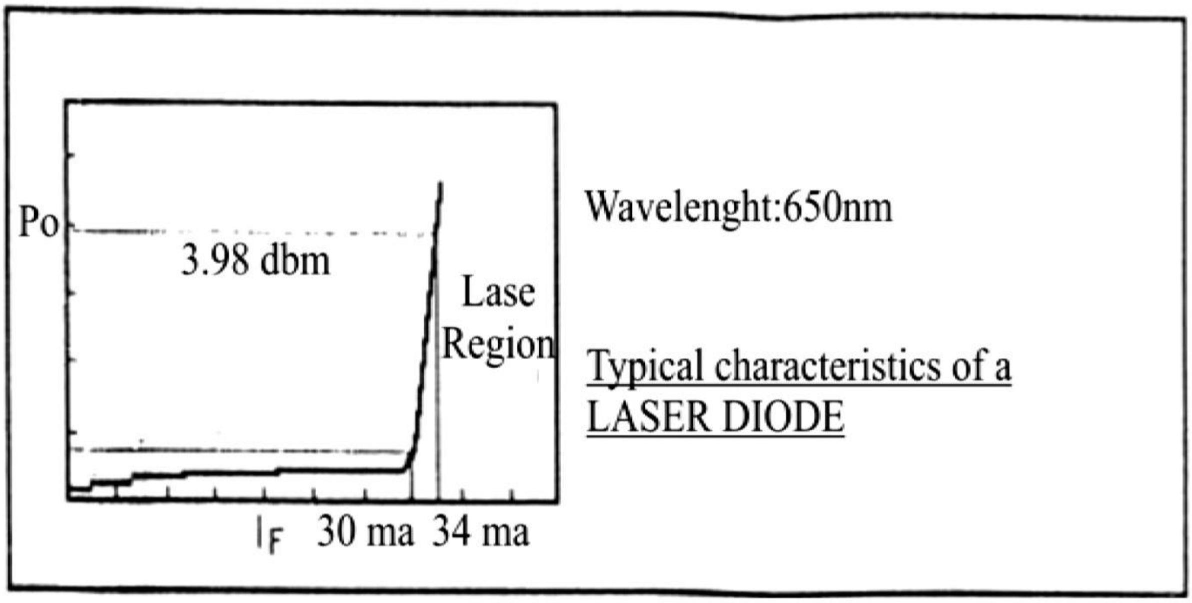


Fig. 5.1 Characteristics of a Laser diode

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

A LASER diode has a built in photo detector, 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 a negative feedback for 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 ACC scheme is that the optical power output may not stable at a given current due to the fact that small shifts in the lasing characteristics occur with temperature changes and ageing. The disadvantage of the APC is that the optical feedback loop may cause oscillations, if not designed properly.

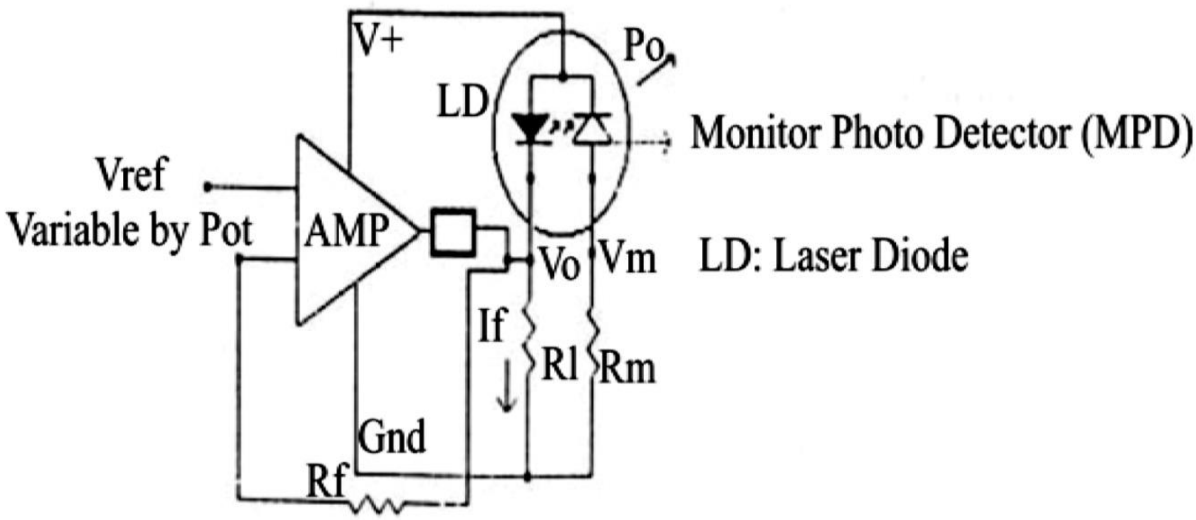


Fig. 5.2 Circuit diagram of MPD in APC/ACC mode

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).

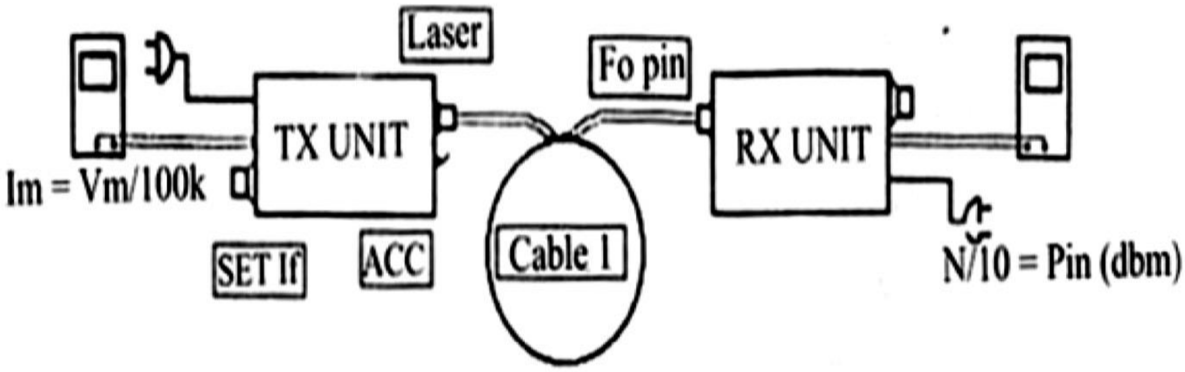


Fig. 5.3 Block diagram of Optical communication system using Laser source

Observation:

Sr. No.	**V_L(mV)**	**$I_F = V_L/100$ (mA)**	**P_0(dBm)**
01.			
02.			
03.			
04.			

Results and Discussions:

Question:

1. What are the applications of the LASER Diodes?

2. What is the LASER operation window for single mode optical fiber communication systems?

3. What is the LASER principle?

Experiment 6

Objective: Study of I-V Characteristics of Fiber optic LED and Photodetector.

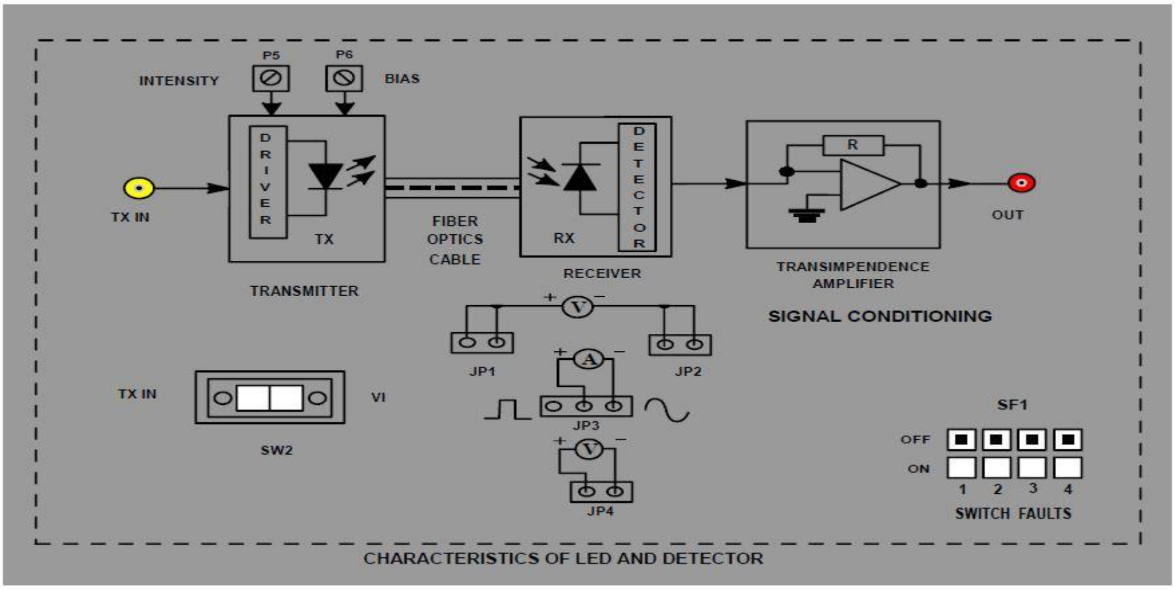
Equipments Required:

- Fiber Link – C
- 15 cm fiber cable
- Multimeter
- Jumper to crocodile connectors
- Power Supply

THEORY:

In optical fiber communication system, electrical signal is first converted into optical signal with the help of E/O conversion device as LED. After this optical signal is transmitted through optical fiber, it is retrieved in its original electrical form with the help O/E conversion device as photodetector. Different technologies employed in chip fabrication lead to significant variation in parameters for the various emitter diodes. All the emitters distinguish themselves in offering high output power coupled into the plastic fiber. Data sheets for LEDs usually specify electrical and optical characteristics, out of which are important peak wavelength of emission, conversion efficiency (usually specified in terms of power launched in optical fiber for specified forward current), optical rise and fall times which put the limitation on operating frequency, maximum forward current through LED and typical forward voltage across LED. Photodetectors usually comes in variety of forms like photoconductive, photovoltaic, transistor type output and diode type output. Here also characteristics to be taken into account are response time of the detector which puts the limitation on the operating frequency, wavelength sensitivity and responsively.

Connection Diagram:



Procedure:

Refer to the block diagram & carry out the following connections and settings.

- Connect the power supply with proper polarity to the kit link-C and switch it on.
- Keep all the switch faults in OFF position.
- Keep switch SW2 towards VI position.
- Keep the bias pot P6 at maximum fully clockwise position.
- Keep intensity control pot P5 at minimum fully anticlockwise.
- Connect Current meters to jumpers JP3 & JP4.
- Connect voltmeter between jumpers JP1 & JP2.
- Slightly unscrew the cap of SFH756V (660nm). Do not remove the cap from the connector. Once the cap is loosened, insert the 15 cm fiber into the cap. Now tighten the cap by screwing it back.
- Insert the other end of optical fiber into detector SFH 250V until it is seated, then lightly tighten the fiber optic locking cinch nut.
- P5 is used to control current flowing through the LED to get the VI characteristics of LED, rotate P5 slowly and measure forward current and corresponding forward voltage through LED and also measure current through detector, Take number of such readings for various current values and plot VI characteristics graph for the LED.
- For each reading taken above, find out the power, which is product of Iand V. This is the electrical power supplied to the LED. Data sheets for the LED specify optical power coupled into plastic fiber when forward current was 10mA as 200mW. This means that the electrical power at 10mA current is converted into 200mW of optical energy. Hence, the efficiency of the LED comes out to be approx. 1.15%.
- With this efficiency assumed, find out optical power coupled into plastic optical fiber for each of the reading. Plot the graph of forward current v/s output optical power of the LED.
- Similarly, by assuming that transmitted power reaches receiver without any loss plots the received power v/s receiver current.

Observation:

V_f	I_f
1	
1.5	
2	
2.5	
3	
3.5	
4	

Results and Discussion:

I-V Characteristics of Fiber optic LED and Photodetector have been studied successfully.

Question:

1. What are the applications of the LED?

2. What is a LED made of?

3. What is the difference between photodiode and photodetector?

4. What are the disadvantages of LED lights?

Experiment 7

Objective: Measurement of bending loss and propagation loss in the fiber.

Experiment 7(A):
The objective of this experiment into study bending loss

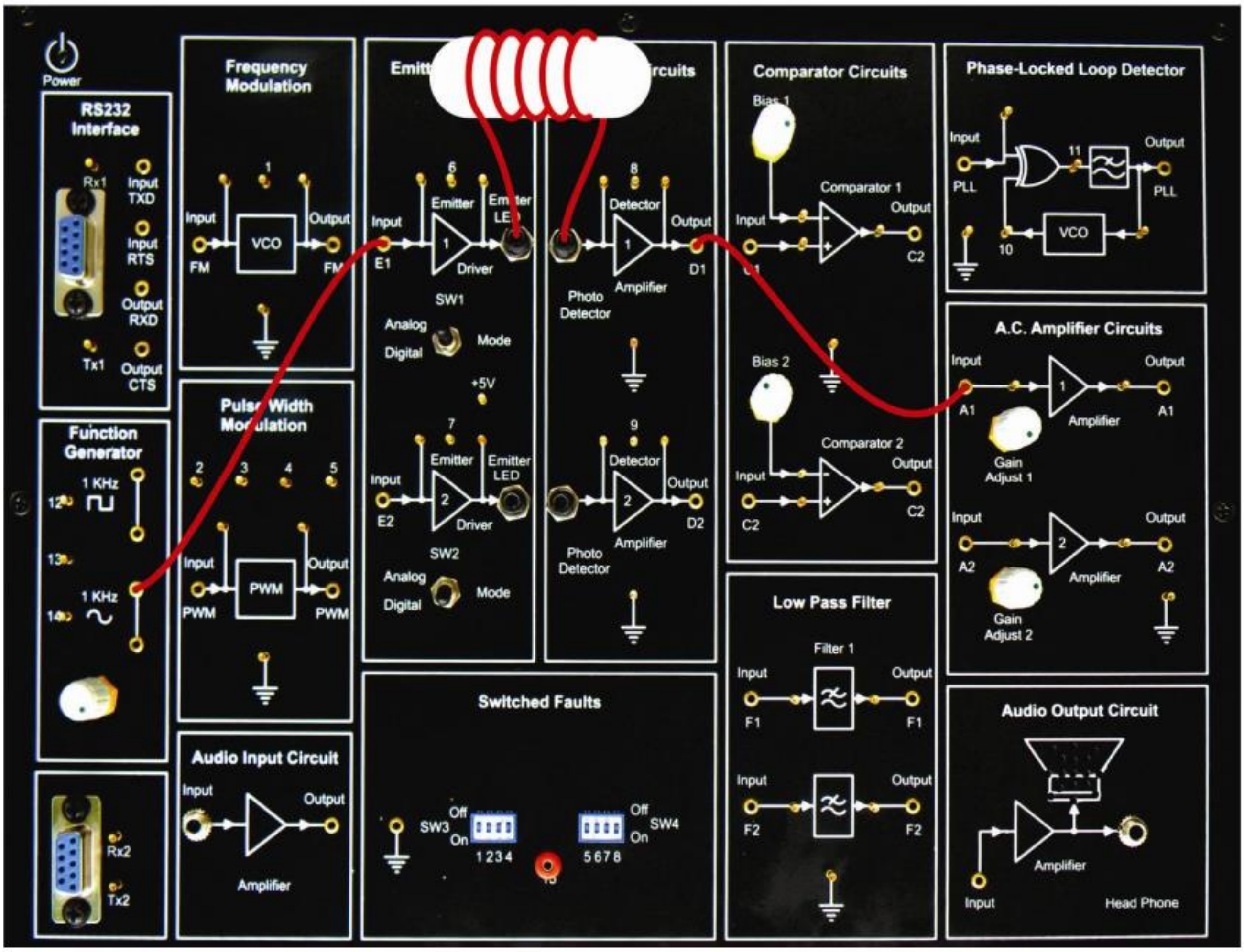
Equipments Required:

- Scientech 2502 TechBook with Power Supply cord
- Optical Fiber cable
- Cathode ray Oscilloscope with necessary connecting probe
- Mandrel

Theory:

Optical fibres exhibit additional propagation losses by coupling light from core modes to cladding modes when they are bent. Typically, these losses rise very quickly once a certain critical bend radius is reached. This critical radius can be very small (a few millimeters) for fibers with robust guiding characteristics (high numerical aperture), whereas it is much larger (often tens of centimeters) for single-mode fibers with large mode areas. Generally, bend losses increase strongly for longer wavelengths, although the wavelength dependence is often strongly oscillatory due to interference with light reflected at the cladding/coating boundary, and/or at the outer coating surface. The increasing bend losses at longer wavelengths often limit the usable wavelength range of a single-mode fiber. For example, a fiber with a single-mode cut-off wavelength of 800 nm, as is suitable for operation in the 1-μm region, may not be usable at 1500 nm, because they would exhibit excessive bend losses. Note that even without macroscopic bending of a fiber, bend losses can occur as a result of microbends, i.e., microscopic disturbances in the fiber, which can be caused by imperfect fabrication conditions. Microbend is an imperfection in the optical fiber which was created during manufacturing. Microbending can cause extrinsic attenuation, a reduction of optical power in the glass. In multimode fibers, the critical bend radius is typically smaller for higher-order transverse modes. By properly adjusting the bend radius, it is possible to introduce significant losses for higher-order modes without affecting the lowest-order mode. This can be useful e.g. for the design of high-power fiber amplifiers and fiber lasers where a higher effective mode area can be achieved when using a fiber with multiple transverse modes

Connection Diagram:



Procedure:

- Connect Power Supply cord to the main power plug & to TechBookScientech 2502.
- Make the connections as shown in next figure.

• Function Generator 1 KHz sine wave output to input socket of emitter Circuit via 4 mm lead.

• Connect 0.5 m optic fiber between emitter output and detectors input.

• Connect Detector output to amplifier input socket via 4mm lead.

● Switch 'On' the Power Supply of the TechBook and Oscilloscope.

● Set the Oscilloscope channel 1 to 0.5 V/ Div and adjust 4-6 div amplitude byusing X 1 probe with the help of variable pot in Function Generator Block at input of Emitter.

- Observe the output signal from detector (TP8) on CRO
- Adjust the amplitude of the received signal as that of transmitted one with the help of gain adjusts potentiometer in AC amplifier block
- Note this amplitude and name it V_1.
- Wind the fiber optic cable on the mandrel and observe the corresponding ACamplifier output on CRO, it will be gradually reducing, showing loss due tobends.

Observation:

Loss in dB: $20\, log \frac{V_1}{V}$

Results:

The Observed bending Loss is: ________dB

Questions:

- What is the reason of bending losses?
- What is the function of cladding?
- What are the various types of losses in fiber?

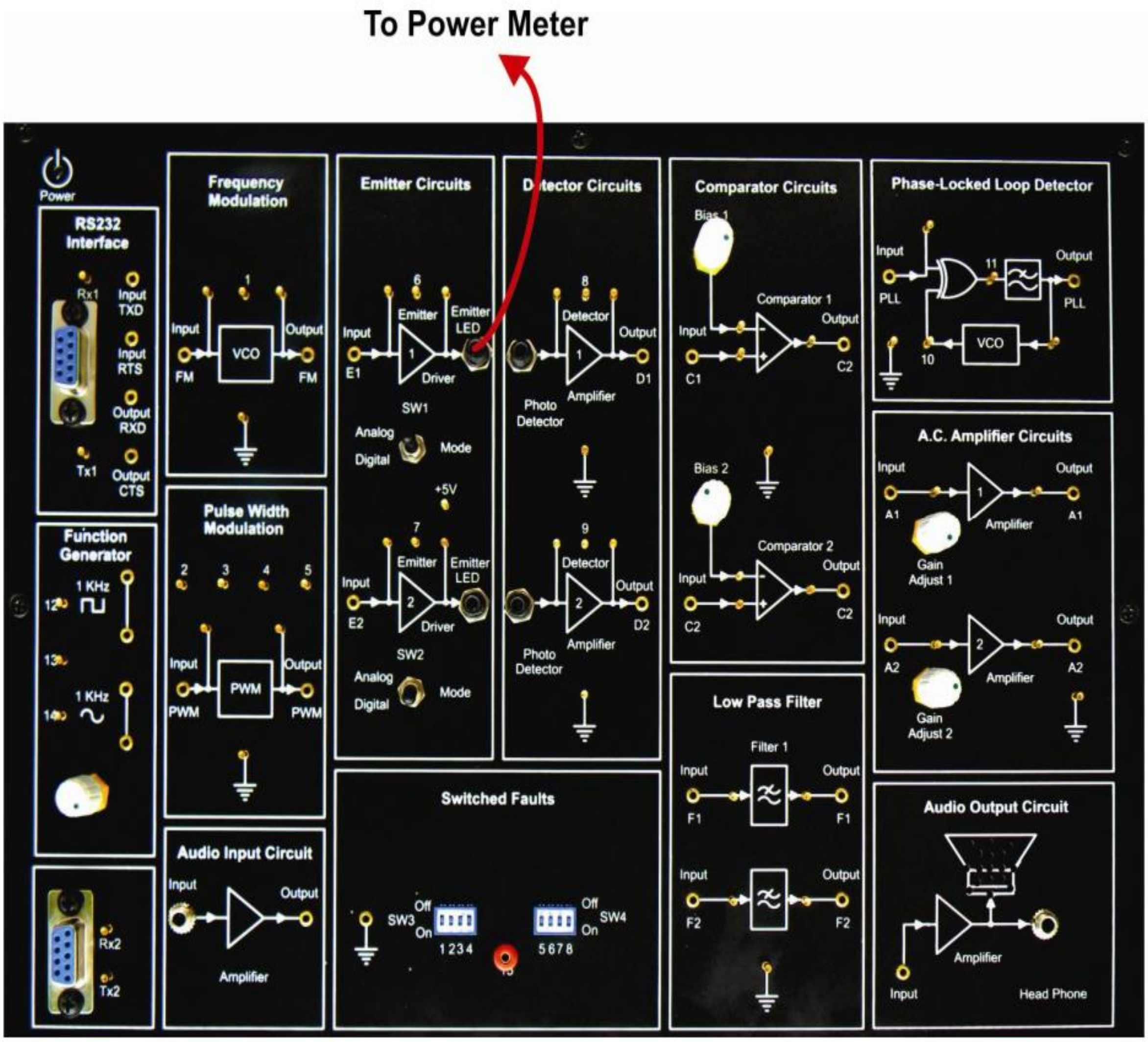
Experiment 7(B):

To measure propagation loss in optical fiber using optical power meter.

Equipments Required:

- Scientech 2502 TechBook with Power Supply cord
- Optical Fiber cable
- Cathode ray Oscilloscope with necessary connecting probe
- Power Meter Scientech 2551 with Power Supply cord

Connection Diagram:



Procedure:

- Connect the Power Supply cord to mains supply and to the TechBookScientech 2501.
- Keep the mode switch in emitter 1 circuit in analog mode
- Connect the 0.5m fiber cable in between the emitter LED & I/P of power meter.
- Switch on the instrument Optical Fiber Communication & power meter (Keep the wavelength switch in 660 nm, position). Note the reading in power meter.
- Replace the 0.5m fiber cable with the 1m cables without disturbing any setting. Again note the reading in power. This reading will be lesser then the previous one, indicating that the propagation loss increases with increase in length.
- Perform the same experiment with emitter 2.

Observation:

Propagation Loss = $10\log\frac{P_{out}}{P_{in}}$

Results:

Propagation loss is = ________dB

Question:

1. What is dB loss in cable?
2. What causes loss in fiber optics?
3. What is the difference between dBm and dBW?
4. What is absorption loss in optical fiber?

Experiment 8

Objective: Setting up Fiber Optics voice link using Frequency Modulation.

The objective of this experiment is to demonstrate voice transmission through optic fiber using FM.

Theory:-

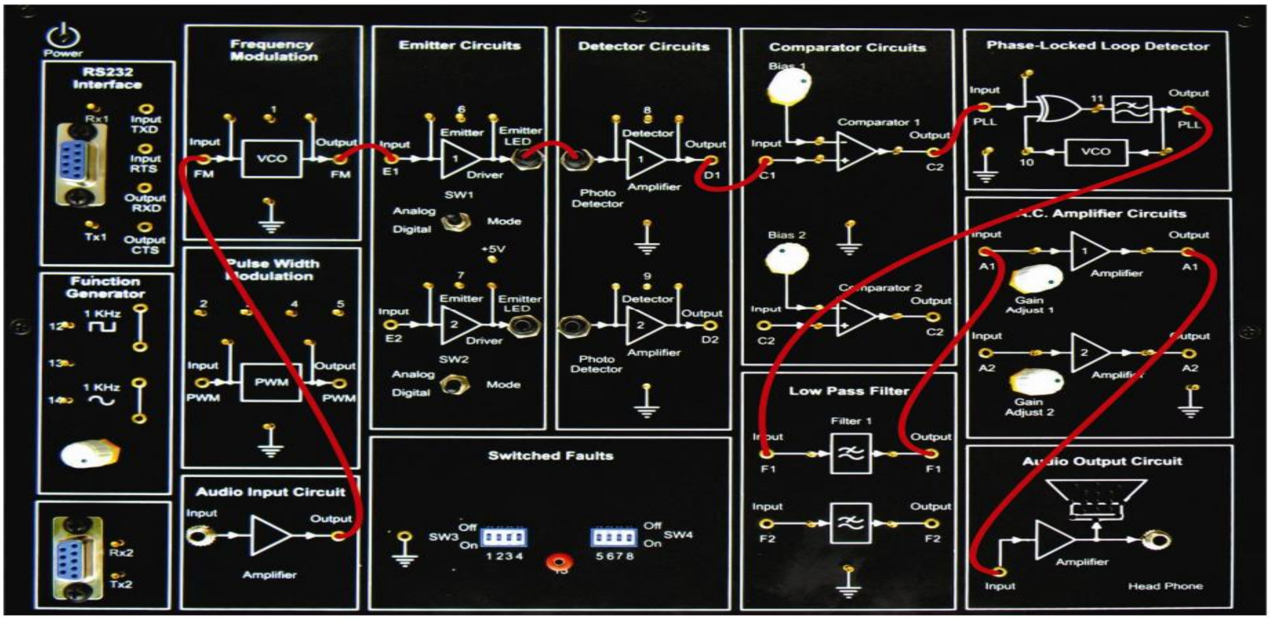
The human voice consists of sound made by a human being using the vocal folds for talking, singing, laughing, crying, screaming, etc. Its frequency ranges from about 50Hz to 12KHz.In that voice signal converting electrical signal using microphone transducer. And this electrical signal used in electronic circuits in voice communication. After doing all process the electrical signal converting voice signal again using speakers.

The heart of the transmitter is a light source. The major function of a light source is to convert an information signal from its electrical form into light. Today's **fiber-optic communications** systems use, as a light source, either **light-emitting diodes** (LEDs) or **laser diodes** (LDS). Both are miniature semiconductor devices that effectively convert electrical signals into light. They need power-supply connections and modulation circuitry. All these components are usually fabricated in one integrated package. Transistor based driver circuit need for this type LEDs.

Equipments Required:

- Scientech 2502 Kit with Power Supply cord
- Optical Fiber cable
- DSO with necessary connecting probe

Connection Diagram:



Procedure:

- Connect the Power Supply cord to the main power plug & to TechBook Scientech 2502.
- Ensure that all switched faults are 'Off'.
- Make the following connections as shown in next figure.
- Connect Function Generator 1 KHz sine wave signal to frequency modulator input.
- Frequency modulator output TP2 to the emitter 1 input at TP5.
- Connect the optic fiber between the emitter 1 circuit and the detector 1
- Detector 1 output TP10 to comparator 1 input at TP14.
- Comparator 1 output TP15 to the PLL detector input at TP23.
- PLL detector output at TP26 to the low pass filter 1 input at TP19
- Low Pass Filter 1 output TP20 to A C amplifier 1 input at TP27
- Switch emitter l's driver to digital mode. This ensures that fast changing digital signal applied to the drivers input causes the emitter LED to switch quickly between 'On' & 'Off' states.
- Turn the 1 KHzpreset in the Function Generator block to fully anticlockwise (Zero amplitude) position.
- Disconnect the 1 KHz sine wave output from input of F M block.
- Make the following additional connections as shown in next figure without disturbing previous setting.
- Plug the Microphone in the input of Audio input block.
- Output of Audio input block to input of FM block.
- Output of AC Amp block to the Power Supply.
- Speak in the Microphone and listen the same in the speaker / Headphone.

Observation:

Result& Discussion:

Questions:

- What is the drawback of FM modulation in terms of bandwidth requirement?
- How the FM signals are generated?
- What is the function of AC amplifier?

Experiment 9

AIM: Plot the transcendental equations for the TE modes in a symmetric step index planar waveguide.

TE modes of a symmetric step index planar waveguide is given by

$\tan\left(\frac{k*a}{2}\right) = (\gamma/k)$ For symmetric mode

$\cot\left(\frac{k*a}{2}\right) = -(\gamma/k)$ For anti-symmetric mode

OR

$\xi \tan \xi = \left[\left(\frac{V}{2}\right)^2 - \xi^2\right]^{1/2}$ For symmetric mode

$-\xi \cot \xi = \left[\left(\frac{V}{2}\right)^2 - \xi^2\right]^{1/2}$ For anti-symmetric mode

(i) Plot $\xi \tan \xi$ and $-\xi \cot \xi$ versus ξ (Range 0 to 8) for $\frac{V}{2} = 2$ *and* $\frac{V}{2} = 5$ for TE.

How many TE modes can exist for the given waveguide structure.

(ii) Calculate no. of TE Mode for n_1=1.49, n_2=1.485, a = 3 and 15 μm, λ= 0.8 μm.

(iii) Find Exact value of β for n_1=1.49, n_2=1.485, a = 3 μm and 15 μm, λ= 0.8 μm.

Here

$V = \frac{2\pi a}{\lambda}\sqrt{n_1^2 - n_2^2}$ and $= \frac{K*a}{2} = (K_0^2 n_1^2 - \beta^2)^{1/2}\left(\frac{a}{2}\right)$, $k=(k_0^2 n_1^2-\beta^2)^{1/2}$, $\gamma=(\beta^2-k_0^2 n_2^2)^{1/2}$

Theory

The simplest optical waveguide structure is the step-**index planar waveguide**. The slab waveguide, shown in Fig. 9.1, consists of a high-index dielectric layer surrounded on either side by lower index material. The slab is infinite in extent in the yz-plane, and finite in the x direction. The index of refraction of the guiding slab, n_f, must be larger than that of the cover material, n_c, or the substrate material, n_s , in order for total internal reflection to occur at the interfaces. If the cover and substrate materials have the same index of refraction, the waveguide is called **"symmetric",** otherwise the waveguide is called **"asymmetric."** The symmetric waveguide is a special case of the asymmetric waveguide.

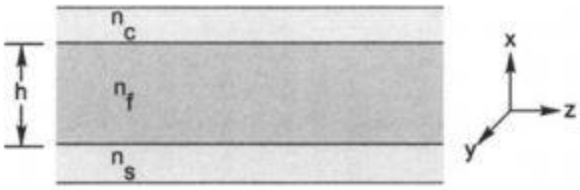


Figure 9.1. The planar slab waveguide consists of three materials, arranged such that the guiding index (n_f), is larger than the surrounding substrate (n_s) and cover (n_c) indices.

The slab waveguide is clearly an idealization of real waveguides, because real waveguides are not infinite in width. However, the one-dimensional analysis is directly applicable to many real problems, and the techniques form the foundation for further understanding. We will begin by solving the wave equation using boundary conditions for the slab waveguide structure. This will lead naturally to the concept of **modes**.

In **TE modes**, the electric field vector is everywhere transverse and perpendicular to the waveguide axis.

Apparatus and components

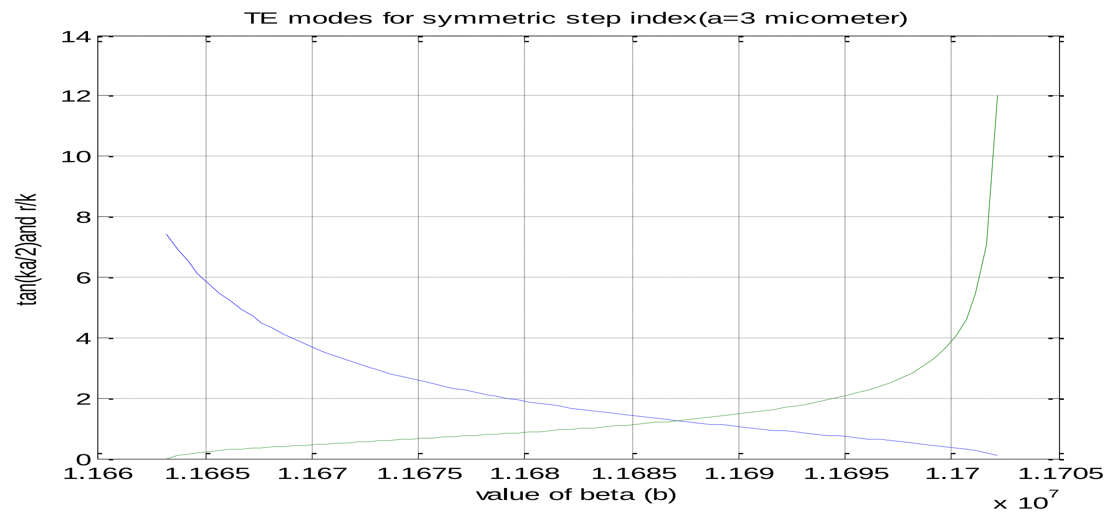
Software –Mat lab 1.11

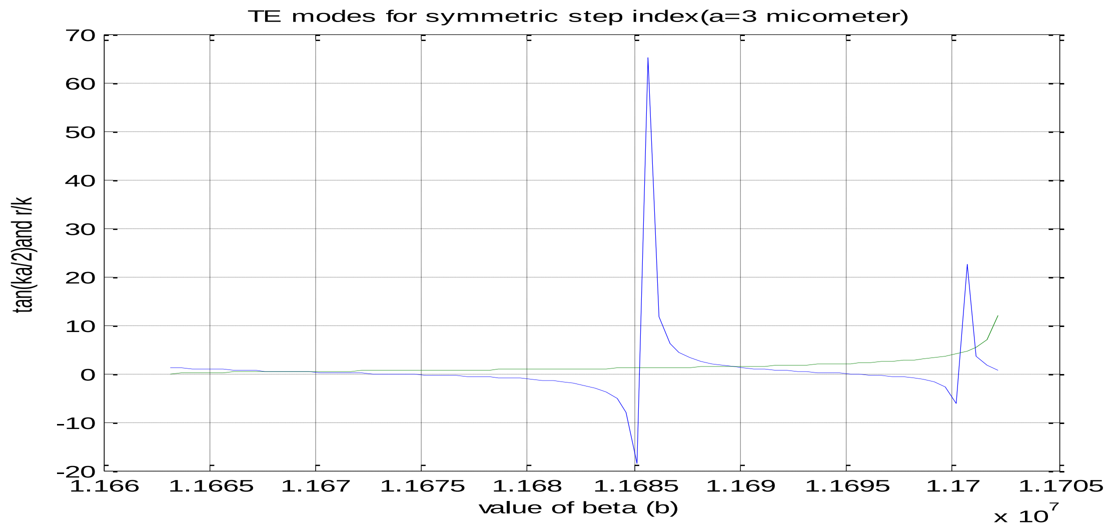
Procedure:-

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.

Observation table

Graph:





RESULT:

(1) The number of points of intersection for a = 3 µm is 1(As observed from graph). So total number of modes is 1 for a = 3 µm.

(2) The number of points of intersection for a = 15 µm is 5(As observed from graph). So total number of modes is 5 for a = 15 µm.

Question

1) What is Step index planar waveguide?
2) What is mode in optical domain?
3) What is TE & TM mode?

Experiment 10

AIM: Plot the transcendental equations for the TM modes in a symmetric step index planarwaveguide.

TM modes of a symmetric step index planner waveguide is given by

$$\xi \tan \xi = \left(\frac{n_1}{n_2}\right)^2 \left[\left(\frac{V}{2}\right)^2 - \xi^2\right]^{1/2}$$ For symmetric TM mode

$$-\xi \cot \xi = \left(\frac{n_1}{n_2}\right)^2 \left[\left(\frac{V}{2}\right)^2 - \xi^2\right]^{1/2}$$ For anti-symmetric TM mode

1) Plot $\xi \tan \xi$ and $-\xi \cot \xi$ versus ξ(Range 0 to 8) for $\frac{V}{2} = 2 \; and \; \frac{V}{2} = 5$.

2) Discuss how many TM modes exist for the given waveguide structure. Then use the formulae and plot the graph. Also Plot b versus V.

Apparatus and components

Software –MATLAB tool

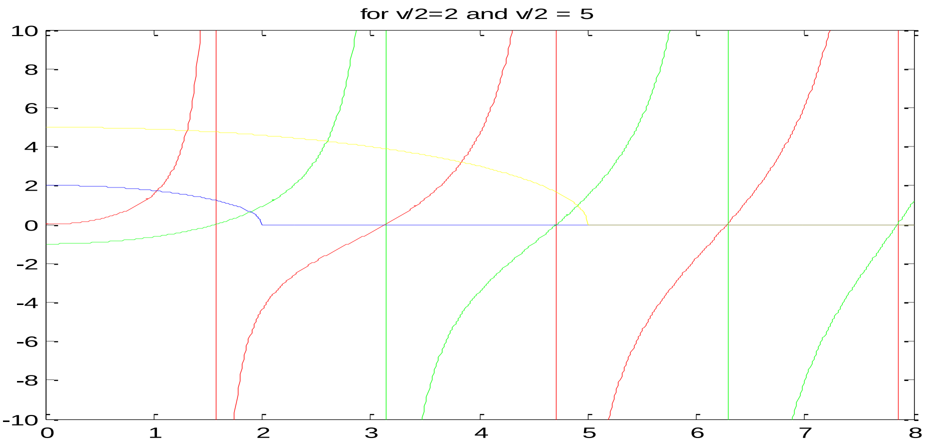
Procedure:-

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.

Observation table

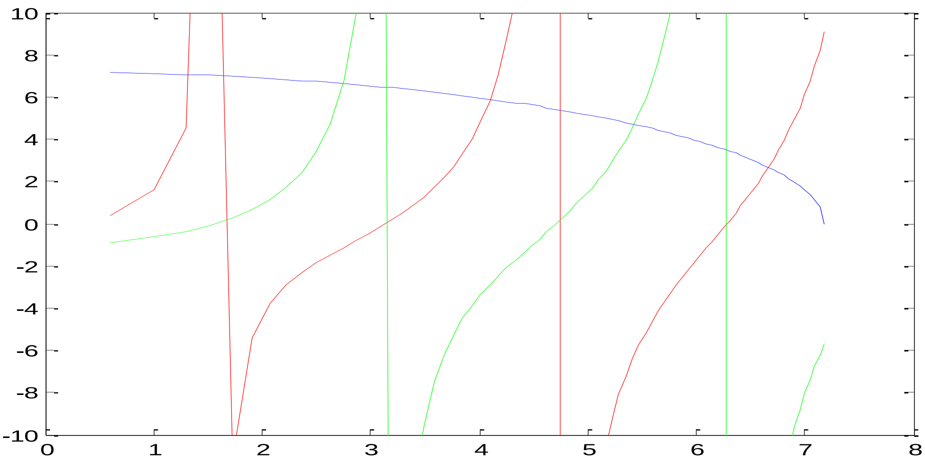
Graph

(a)



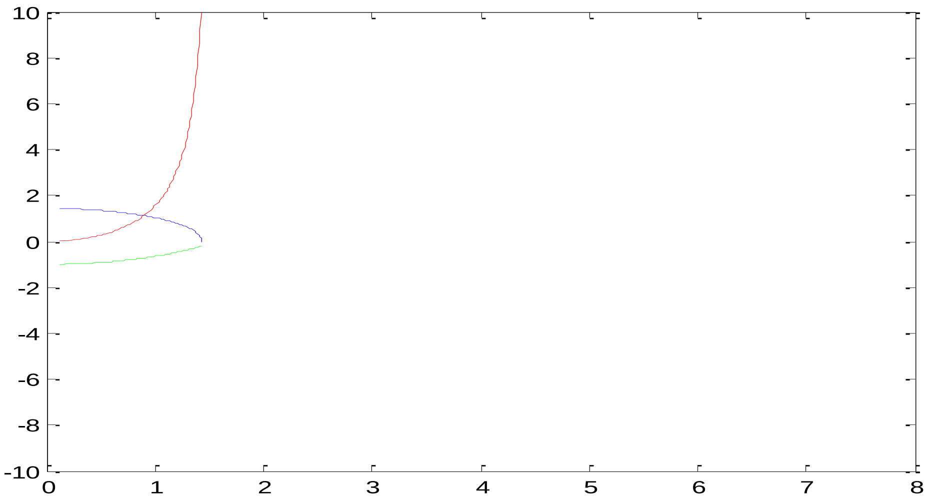
for v/2=2 and v/2 = 5
10
8
6
4
2
0
-2
-4
-6
-8
-10
0
1
2
3
4
5
6
7
8

(b)



10
8
6
4
2
0
-2
-4
-6
-8
-10
0
1
2
3
4
5
6
7
8

(C)



Result:

(1) The number of points of intersection for a = 3µm is1 . hence number of modes is 1 for a = 3µm.(graph c)

(2) The number of intersection for a=15µm is 5. Hence number of modes is 5.(graph b)

(3) The number of intersection for v/2 =2 is 2 and number of intersection of v/2=5 is 4.

Question

1) What is Step index planar waveguide?
2) What is mode in optical domain?
3) What is TE & TM mode?

Experiment 11

MATLAB program to plot the normalized index b, against the normalized freq. V, for three values of symmetric coefficient ‘a’ and for the first three values of ‘v’. (Values of a=0, a=10 and a=∞ may be used). 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.

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

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

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

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

Apparatus and components

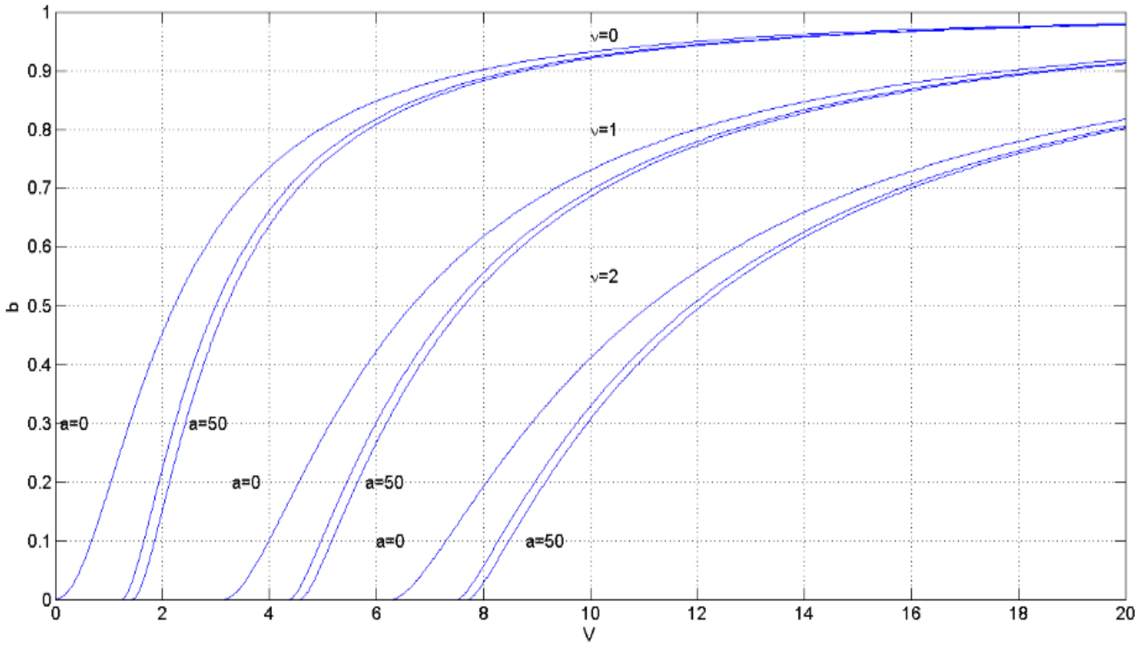
Software –MATLAB

Procedure:-

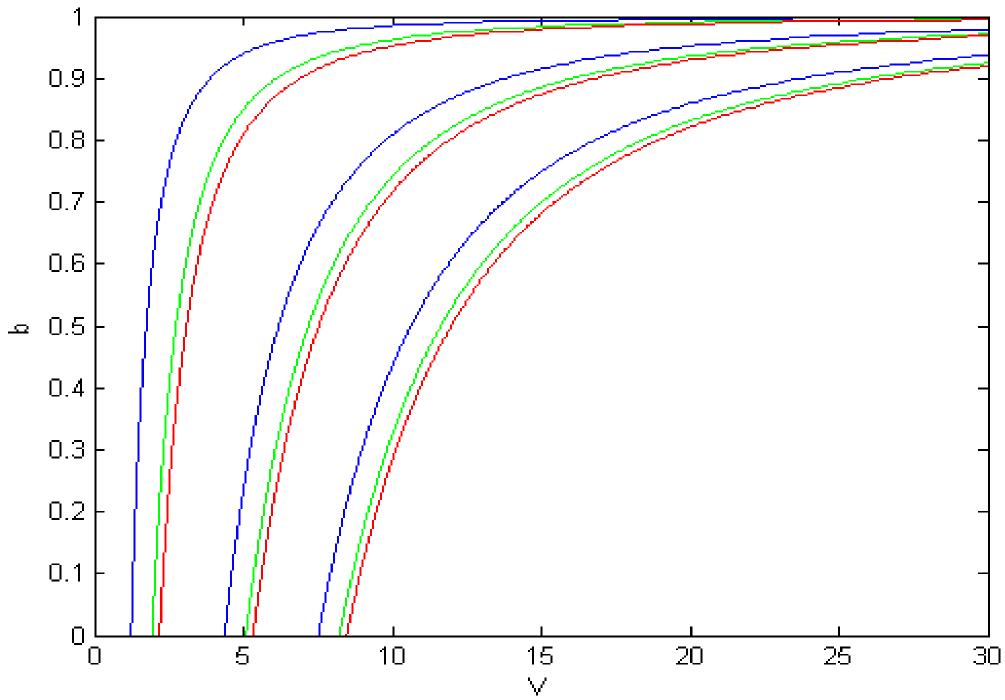
1) Mat lab coding has to be done to plot those equations.

2) Plot all the three questions and solve it with the help of the given values.

Result



or



Questions:-

1) What is V number?
2) How it is related to core and cladding R.I.?
3) What is the relation between V number and modes?

Experiment 12

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

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

$$=n_1^2[1 - 2\Delta],\ \ r>a$$

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

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

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

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

Theory

In optics, the **refractive index** or **index of refraction** of a material is a dimensionless number that describes how fast light propagates through the material. It is defined as

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

In optics, the **numerical aperture** (**NA**) of an optical system is a dimensionless number that characterizes the range of angles over which the system can accept or emit light.

A **refractive index profile** is the distribution of refractive indices of materials within an optical fiber. Some optical fiber has a step-index profile, in which the core has one uniformly-distributed index and the cladding has a lower uniformly-distributed index. Other optical fiber has a graded-index profile, in which the refractive index varies gradually as a function of radial distance from the fibercenter. Graded-index profiles include power-law index profiles and parabolic index profiles.

Apparatus and components

Software –Mat lab 1.11

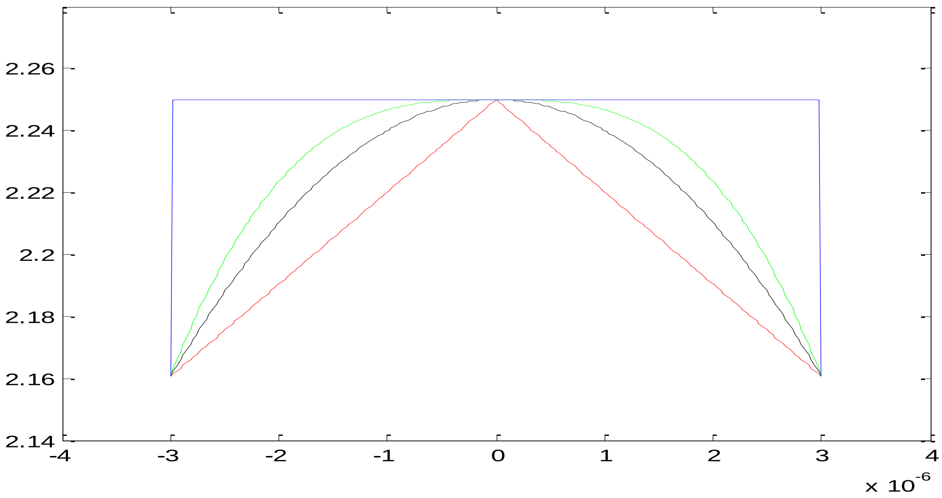
Procedure:-

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.

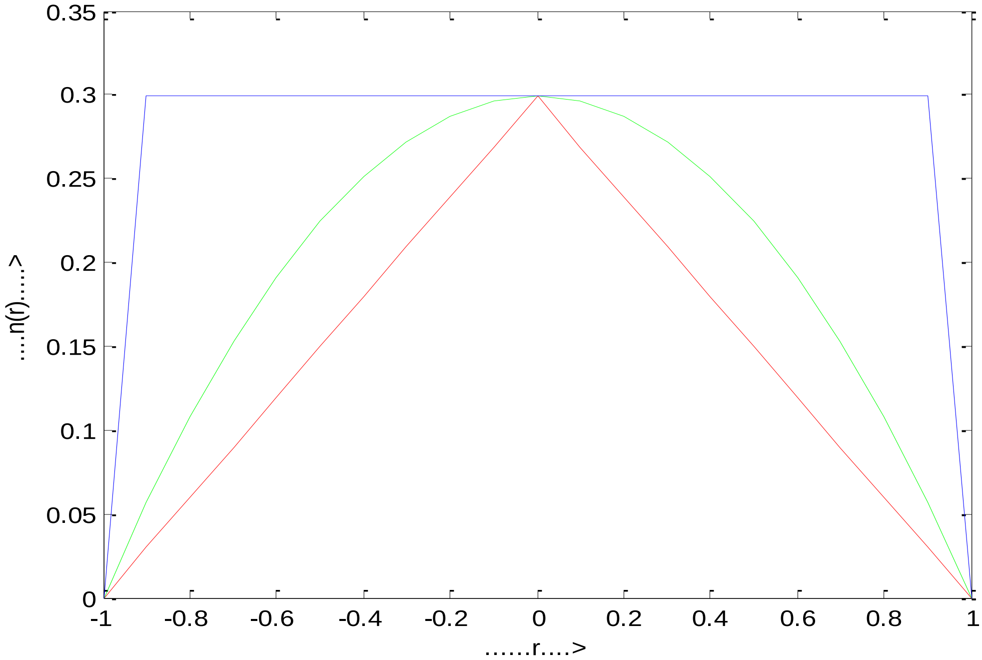
Observation table

Graph

(a)



(b)



Result:

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

(2) The value of n(r) is constant for l r/al >1.

Experiment 13

To study of Modal analysis for a step index cylindrical core fiber is given by following eigen-value equation (LP mode):

$$V(1-b)^{1/2}\frac{J_1\left[V(1-b)^{1/2}\right]}{J_0\left[V(1-b)^{1/2}\right]} = Vb^{1/2}\frac{K_1\left[Vb^{1/2}\right]}{K_0\left[Vb^{1/2}\right]} \text{(for l=0 } LP_{01} mode\text{)}$$

Theory

$$\Delta \equiv \frac{n_1 - n_2}{n_1} \ll 1$$

The assumption of Δ given by equation above is called as the weakly **guiding approximation** because of the fact that under such an approximation, light energy would not be confined or guided inside any medium but would be almost uniformly distributed in the entire medium. When the difference between the core and cladding refractive indices becomes very small, there results a substantial amount of light energy that lies in the cladding. As this difference further decreases, more and more light energy spreads into the cladding. In other words, the light guiding capability of the fiber gets weaker and the structure hence becomes weakly guiding in nature. Therefore for most of the practical fibers, this weakly guiding approximation is well applicable and is thoroughly justified because for these fibers, the difference between the core and cladding refractive indices is very small. In other words, the fields in a practical optical fiber are almost transverse in nature and it can be shown that they are **linearly polarized**. This means that the field patterns shown in figure below no longer remain so as far as direction is concerned. That is, the fields do show the same intensity variation patterns but they all are now polarized linearly with the same linearity, i.e. all the fields have same polarization orientations. These polarizations may be either vertical or horizontal as shown in the figure below:

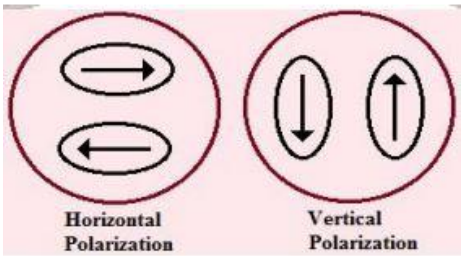


Figure 13.1 Polarizations of the Linearly Polarized modes

Apparatus and components

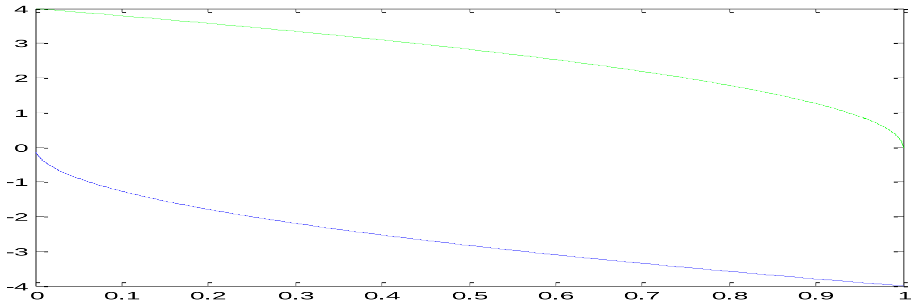
Software –MATLAB

Procedure:-

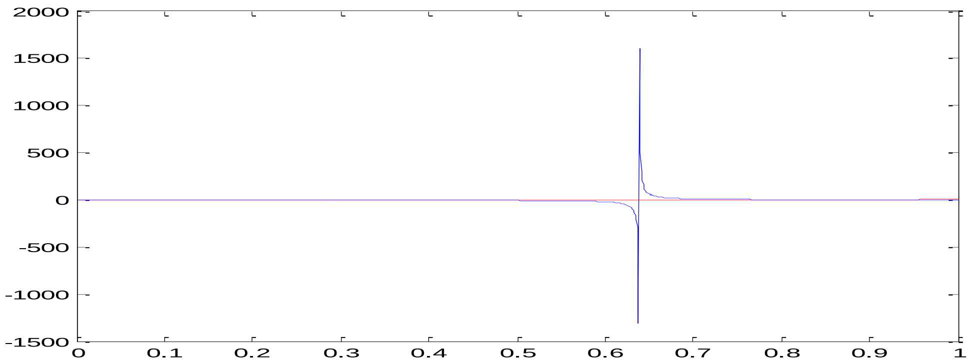
1) Mat lab coding has to be done to plot those equations.
2) Plot all the three questions and solve it with the help of the given values.

Graph

(a)



(b)



Result:

Number of LP modes for (v=4) = 5

LP01,LP02,LP11,LP12,LP21

Questions:-

1) What is weakly guiding approximation?
2) What is linearly polarized mode?
3) How are both related? Explain with suitable reasons.