GOVERNMENT COLLEGE OF ENGINEERING KANNUR

DEPARTMENT OF ELECTRONICS & COMMUNICATION ENGINEERING

LAB MANUAL

SEMESTER 7 - B.TECH
ECL 411 - ELECTROMAGNETICS LAB

GOVERNMENT COLLEGE OF ENGINEERING KANNUR

Mangattuparamba Parassinikadavu P.O, Kannur - 670563, Kerala, India

Vision

A globally renowned institution of excellence in engineering, education, research and consultancy.

Mission

To contribute to the society by providing quality education and training, leading to innovation, entrepreneurship and sustainable growth.

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GOVERNMENT COLLEGE OF ENGINEERING KANNUR
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Department Vision

A supreme center for quality education, research and consultancy in Electronics and Communication Engineering

Department Mission

To impart knowledge in the field of Electronics and its related areas with a focus on developing the required competencies and virtues for the sustainable development of the society

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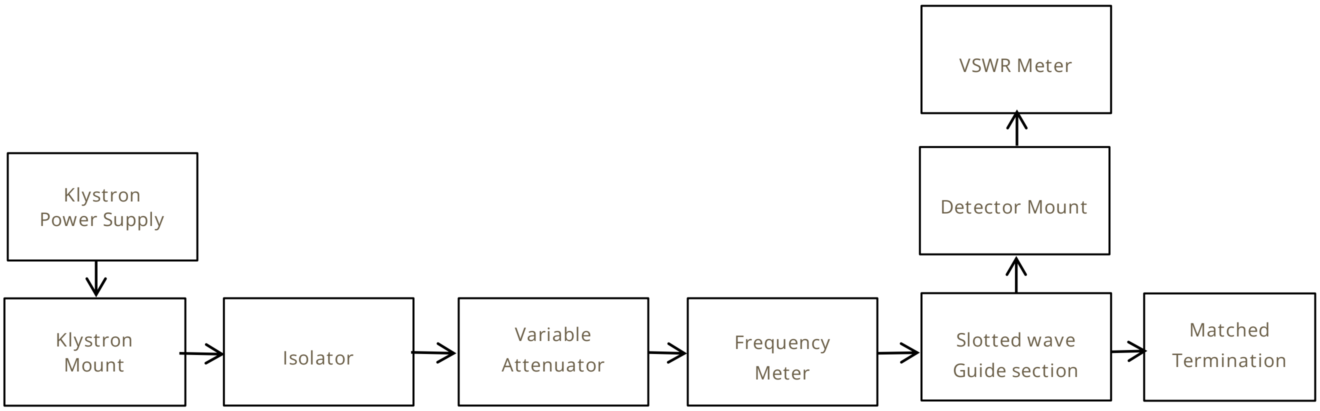
Set up for microwave measurement



Microwave Test Bench

PART A EXP. No. 1	Familiarization of Microwave Components
DATE:	

Aim:

To familiarize with the important microwave components and equipment used in the laboratory.

Theory

A microwave test bench is an experimental set up consisting of various microwave components and instruments such as microwave source, waveguides, waveguide Tees, frequency meter, variable attenuator, horn antenna, power supply for the microwave sources, VSWR meter, etc.

Waveguides:

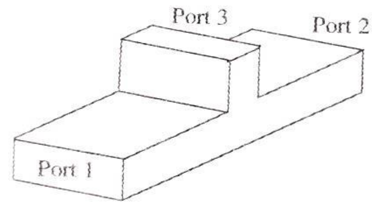
Waveguides are rectangular or circular shaped metallic tubes used to guide electromagnetic waves in microwave frequencies. It confines the electric and magnetic fields within the space of waveguide. Each waveguide has a definite cut off frequency, the lowest of which is called dominant mode. The cut off frequency of a rectangular waveguide is given by

$$f_{c_{mn}} = \frac{1}{2\sqrt{\mu\varepsilon}}\sqrt{\left(\frac{m}{a}\right)^2 + \left(\frac{n}{b}\right)^2}$$

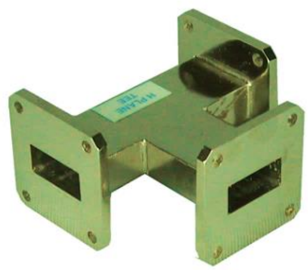
Where m and n modes of wave propagation and a and b are waveguide dimensions.

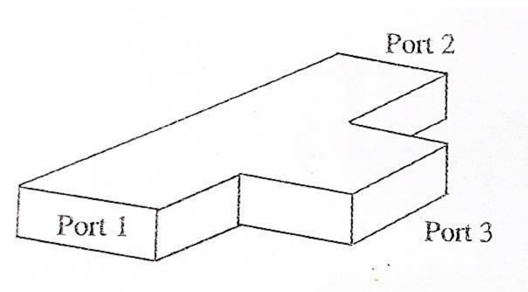
Waveguide Tees: Tees are used to connect waveguides for branching out the microwave signals. Commonly used microwave junctions are E-plane Tee, H-plane Tee, Magic Tee (hybrid Tee) directional coupler and circulator.

E-plane Tee: It is a T-shaped waveguide in which the axis of its side arm is parallel to the electric field of the main branch. A rectangular slot is made on the broader dimension of a waveguide and a side arm is attached Port 1 and Port 2 are

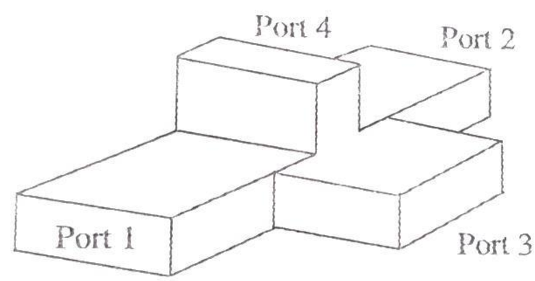


E-plane Tee





H-plane Tee



Magic Tee

Directional Coupler

collinear arms and Port 3 is the side arm. E arm is also called series arm.

H-plane Tee: The side arm of H-plane Tee is parallel to H-field of the main arm. All the three arms of H-plane Tee lie in the plane of magnetic field. H-arm is also called parallel arm. Waves enter through the side arms split into two and leave through main arm with equal magnitude and phase. If two input waves in phase are fed into main arm ports, the waves leave the side arm will be additive and in phase.

Magic Tee: A magic Tee (hybrid Tee) is a combination of E-plane Tee and H-plane Tee. It has a series arm and a parallel arm. Rectangular slots are cut both along the width and breadth of a long waveguide and side arms are attached as shown in Figure. Port 1 and Port 2 are collinear arms, Port 3 is the H-arm (parallel arm) and Port 4 is the E-arm (series arm). This four-port hybrid Tee junction combines the properties of both H-plane Tee and E-plane Tee.

When power enters through the Port 1 and Port 2, the field leaving the parallel arm is proportional to the phasor sum of two input fields and field leaving the series arm is proportional to phasor difference of two input fields. When waves of equal amplitude and phase enter parallel and series arms, the E-field gets canceled in one of the collinear arms and gets added in the other arm. The energy applied to parallel arm gets divided equally between Port 1 and Port 2 in phase. Energy applied to series arm gets divided between Port 1 and Port 2 but in opposite phase. There is no direct transmission between series and parallel arms since they are symmetrical and perpendicular to each other.

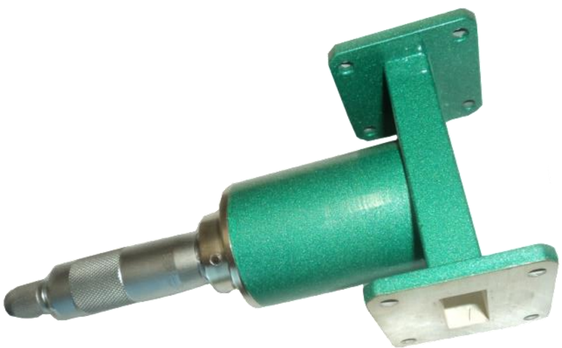
Directional coupler: A directional coupler is a hybrid waveguide which couples power in an auxiliary waveguide in one direction. It is a four-port device with one port terminated with a matched load.

Directivity of the directional coupler is defined as the ratio, expressed in dB, of the power output in the coupled auxiliary arm to the power flowing through the uncoupled auxiliary arm. Ideally, directivity is infinite since the power in the uncoupled auxiliary arm should be zero.

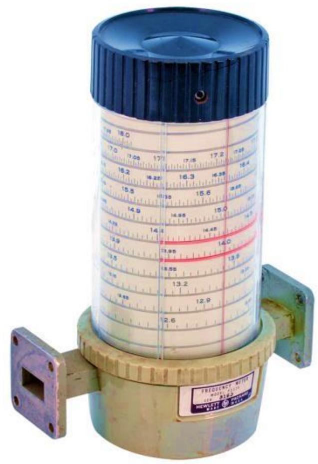
Coupling factor is defined as the ratio, expressed in dB, of the power entering the main arm to the power coupled in the auxiliary arm.

Directional Couple

Slotted Waveguide Section



Frequency Meter with Micrometer



Direct reading type Frequency Meter

Variable Attenuator

Matched Termination

Circulator: It is a multi-port waveguide junction in which power may flow from Nth port to (N + 1)th port in one direction. Although there is no restriction on the number of ports, microwave circulators with four ports are commonly used. Main application of circulator is as a duplexer to isolate transmission and receiver sections in radar. Circulator can be used as an isolator by connecting external termination. Isolator is a device used to isolate the microwave source from the rest of the circuitry. The wanes kept inside it manage the transmission of the waves only in one direction.

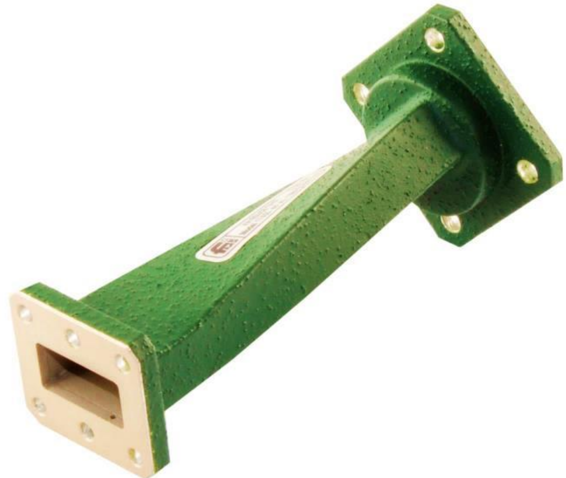
Slotted waveguide section: It is used to sample the standing wave in the waveguide. A narrow longitudinal slot with ends tapered provides smoother impedance transformation. The slot is usually of several long wavelengths. The location of the slot is such that it does not disturb the field in the waveguide.

A probe is inserted in the holder mounted on a movable carriage on the section. A scale is attached to the slotted section to measure the distance moved by the probe.

Frequency meter: A frequency meter is used to measure the frequency of the microwave inside the waveguide. It consists of a calibrated tunable cavity. The calibration of frequency is done in two ways. In one type of frequency meter, frequency can be read directly since the meter is calibrated in frequency while in other type it is calibrated in micromete. From the chart supplied by the manufacturer, the frequency can be determined.

Attenuator and matched termination: The attenuators are passive devices which control power levels in microwave system by absorption of the signal and to isolate source from the rest of the equipment. Fixed and variable attenuators are used in microwave circuitry. The attenuator is calibrated to read the attenuation level.
Matched termination is used to terminate waveguide transmission line operating at low average power. Matched load is used in the measurement of reflection coefficient and VSWR.

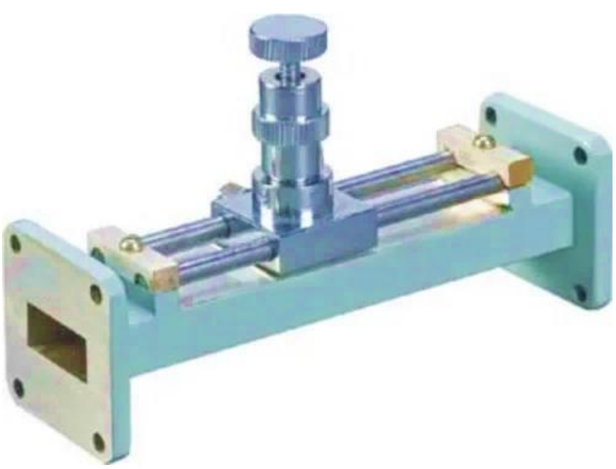
Bend



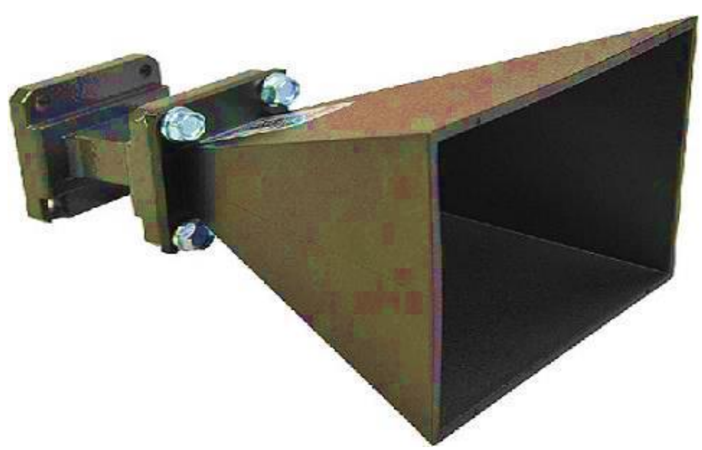
Twist

Tunable Detector Mount

PIN Modulator



Slide Screw Tuner



Pyramidal Horn Antenna

Phase shifter:

Phase shifter consists of a piece of waveguide and a dielectric material placed inside the waveguide parallel to electric vector of TE mode. When the piece of dielectric material moves from edge of waveguide towards the centre of the waveguide, phase of the field changes.

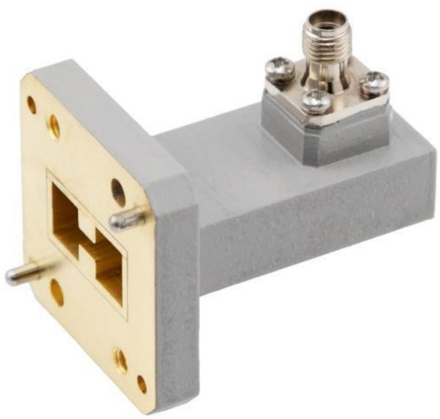
Waveguide bends and twists: The direction of waveguide is changed using bends and twists. If the bend is in the broader dimension, it affects H-field. Otherwise it affects E-field.

Tunable detector mount: A detector mount is a simple and easy to use instrument for detecting microwave power with the help of a suitable detector. It consists of a crystal detector mounted on a section of a waveguide and shorting plunger for matching purpose. The output from the crystal is given to a measuring instrument.

Tunable probe: A tunable probe is meant for exploring the energy of the electromagnetic field in a suitably fabricated section of waveguide. The depth of penetration into a waveguide section is adjustable by the knob of the probe. The tip picks up the RF power from the line and it is rectified by crystal detector, which is then fed to the VSWR meter or indicating instrument.

Slide screw tuner: A slide screw tuner is used for changing the penetration and position of a screw in the slot provided in the centre of the waveguide. This consists of a section of waveguide flanged on both ends and a thin slot is provided in the broad wall of the waveguide. A carriage carrying the screw is provided over the slot.

PIN modulators: PIN modulators are designed to modulate the continuous wave output of Gunn oscillators. It is operated by the square pulses derived from the UHF connector of the Gunn power supply. These consist of a PIN diode mounted inside a section of waveguide flanged on its both ends. A fixed attenuation vane is mounted inside at the input to protect the oscillator.



Waveguide to Coaxial Adapter

Tunable Probe

Gunn Power Supply

VSWR Meter

Antennas: A microwave pyramidal horn antenna is an antenna that consists of a flaring metal waveguide shaped like a horn to direct radio waves in a beam. Horns are widely used as antennas at UHF and microwave frequencies, above 300 MHz. Waveguide horns are used as feed horns as radiators for reflectors and lenses and as a pickup antenna for receiving microwave power.

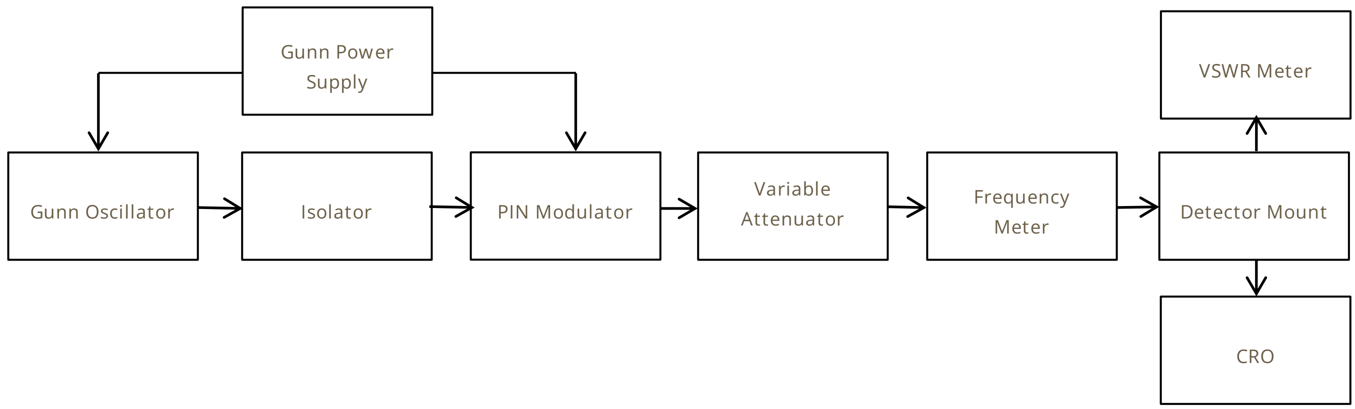
Waveguide to coaxial adapter: In certain situations, electromagnetic wave needs to be tapped from the waveguides for measurement or transmission using coaxial cables. Waveguide to coaxial adapter is used for that purpose.

Klystron and Gunn power supplies: The power supplies are specially designed to energize the klystron tube and Gunn oscillator. It provides highly stabilized bias voltages to the electrodes of the tube since the variation in the bias voltages will affect the frequency of operation.

VSWR meter: VSWR meter measures the standing wave ratio in a transmission line. It is a low noise tuned amplifier voltmeter calibrated in dB. A square wave modulated output is needed to use VSWR meter as the metering device.

Result:
Familiarized with various microwave components and equipment.

Experimental Set up



Tabular column

Sl No.	Voltage (Volts)	Current (Ampere)

PART A EXP. No. 2	**Gunn Diode Characteristics**
DATE:	

Aim

To study Gunn oscillator and to plot V-1 characteristics and hence measure V_T & I_P

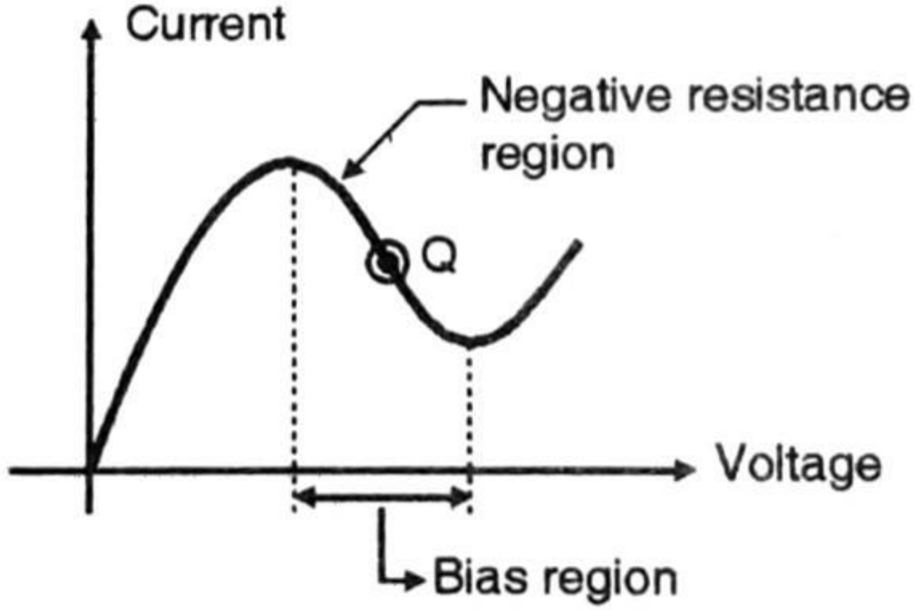
Theory:

Gunn effect is the periodic fluctuations of current passing through the N-type GaAs specimen when the applied voltage exceeds a certain critical value (typically, 2 to 4 kV/cm). Basic mechanism involved in the operation of bulk N-type GaAs devices is the transfer of electrons from the lower conduction valley (L-valley) to upper subsidiary valley (U-valley). The current becomes a fluctuating function of time whose period of oscillation is inversely proportional to the specimen length and closely equal to the terminal time of electrons between the electrodes.

Depending on the material parameters and operating conditions, a Gunn oscillator can be made to oscillate in any of the four frequency modes.

1. Domain mode = 10^7 can/s)
2. Delayed domain mode (10^6 cm/s << 10^7 cm/s)
3. Quenched domain mode (f_L> 2 x 10^7 cm/s)
4. Limited space charge accumulator (LSA) mode

Limited space charge accumulator (LSA) mode: This is the most important mode of operation for Gunn oscillator and this mode gives high power with high efficiency. The RF frequency and RF voltage are so chosen that the domains do not have sufficient time to form while the field is above threshold. As a result, most of the the domains are maintained in the negative conductance state during a large part of the voltage cycle. Frequency of operation is upto 100 GHz. Operation depends on external circuit (high Q-resonator is required for LSA mode).



VI Characteristics of Gunn Diode

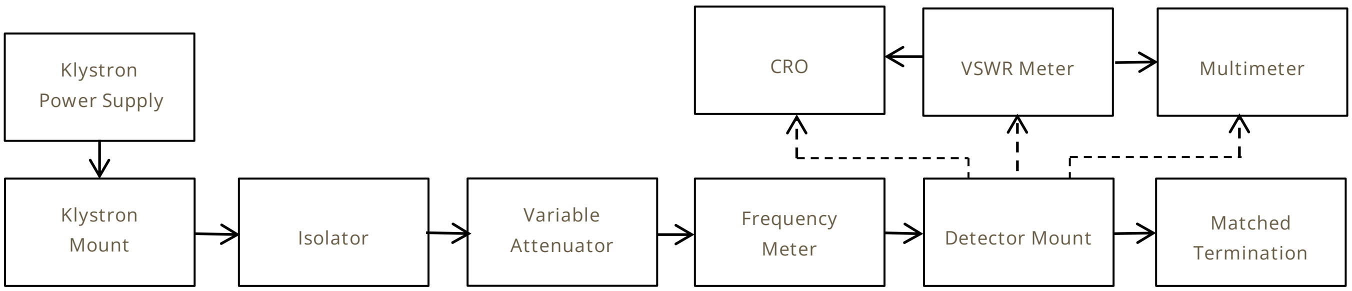
Procedure

1. Set the components and equipment as shown.
2. Initially set the variable attenuator at maximum position.
3. Keep the following arrangement in Gunn power supply.
   (a) Gunn bias knob-fully anti-clockwise.
   (b) PIN bias knob-fully anti-clockwise.
   (c) Meter switch - OFF
4. Switch ON Gunn power supply and cooling fan.
5. Turn the meter switch of Gunn power supply to voltage position.
6. Measure the Gunn diode current corresponding to various voltage controlled by Gunn bias knob through the panel meter and meter switch. Do not exceed the bias voltage above 10 V.
7. Plot the voltage and current readings on the graph.
8. Measure the threshold voltage. Never keep the Gunn bias knob position at threshold position more than 10 Sec. Take reading as fast as possible.

Result

Studied the V-I Characteristics of Gunn oscillator.

Experimental Set up



Tabular column

Mode	Ripple Voltage	Frequency	Power (dB)	Power (mW)
1				
2				
3				

PART A EXP. No. 3	**Mode Characteristics of**

DATE:	**Reflex Klystron**

Aim:

To study the characteristics of a reflex klystron, plot mode characteristics and hence compute ETR & ESR.

Equipment required:

Klystron power supply, klystron mount, isolator, frequency meter, variable attenuator, detector mount, matched load, VSWR meter, multimeter, CRO, cables.

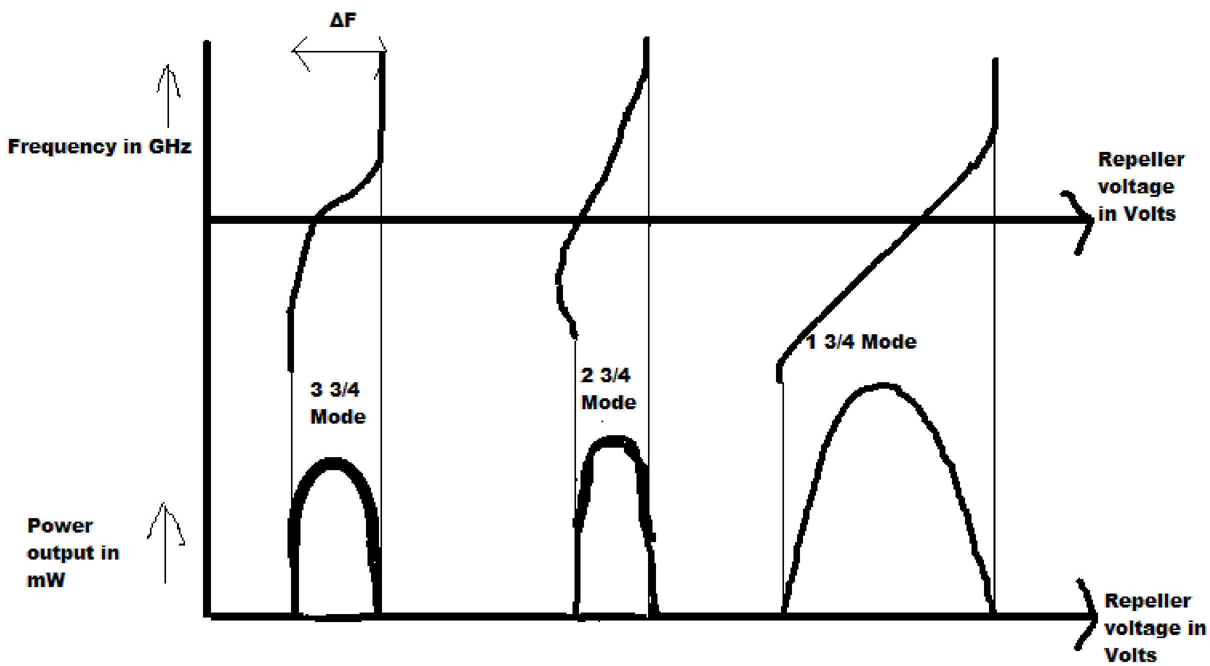
Theory:

Reflex klystron is a low power microwave oscillator. It has an electron gun consisting of a filament surrounded by a cathode and a focusing electrode.

Reflex klystron makes use of velocity modulation to transform a continuous electron beam into microwave power. Electron beam is accelerated towards the resonator cavity which has high positive voltage applied to it. Resonator acts as the anode. Electrons further move towards the repeller electrode which is at high negative potential. Because of negative, potential electrons never reach the repeller electrodes and get repelled back to the resonator. If conditions are all well, returning electrons give more energy to the gap than they take it and thus oscillations get sustained. The RF potential existing in the resonator either due to input frequency or cavity resonance, controls the velocity of electrons leaving the cavity to repeller. Fast electrons come closer to the repeller than slow ones and take longer time to return to resonator gap. The slower ones do not go closer to the repeller and hence they may catch up the faster ones on return journey. As a result, returning electrons group together in bunches. As the electron bunches pass through resonator, they interact with voltage at resonator grids.

The frequency is primarily determined by the dimension of resonator cavity.

Observations



method changing frequency is called mechanical tuning. Frequency can be varied Hence by changing the volume of resonator, frequency can be varied. This by adjusting repeller voltage also. This method is called electronic tuning.

If the bunches pass the grid at such time that the electrons are slowed down by the voltage, energy delivered to the resonator, bunches will give maximum energy to the cavity and thus the klystron will oscillate. Maximum retardation happens when gap voltage is positive maximum. The transit time of the electrons in repeller space is T = n + 3/4 where n is any integer, n determines the mode of klystron.

Mode characteristics: Output power depends on the repeller voltage. Lower the mode number, higher is the power output. Maximum power for any mode will be obtained if the repeller voltage gives the required value of transit time. On either side of optimum value of repeller voltage, power output falls. The variations of the output with respect to repeller voltage give the mode characteristics.

Procedure:

1. Switch ON the cooling fan for klystron tube.
2. Arrange the microwave bench set up as shown in Figure.
3. Set the variable attenuator at maximum position.
4. Set the beam voltage at minimum and repeller voltage at maximum position.
5. Switch ON the power supply.
6. Switch ON the HT.
7. Switch the mode selection HT to current mode.
8. Wait for 10 mA in the indication.
9. Set the modulation to CW mode.
10. Switch the mode selection knob to beam voltage and set the beam voltage.
11. Switch the mode selection knob to repeller voltage.
12. Take the probe connection from the detector mount and connect it to the CRO. 13. Reduce the repeller voltage and obtain first mode on CRO.
14. Obtain the frequency corresponds to the mode by tuning the frequency meter.
15. Measure the power of each mode using VSWR meter.
16. Vary the repeller voltage to obtain other models. Normally 3 to 4 modes are obtainable with the available range of reflector voltage with the klystron power supply.

17. Repeat Step 14 and Step 15 for getting mode 2 and mode 3.
18. Plot the mode characteristics on a graph sheet with mod of reflector voltage, VR along x-axis and frequency in GHz along y-axis.
19. Plot other set of characteristics with mod of reflector voltage, |VR| along x-axis and power output in mW along y-axis.

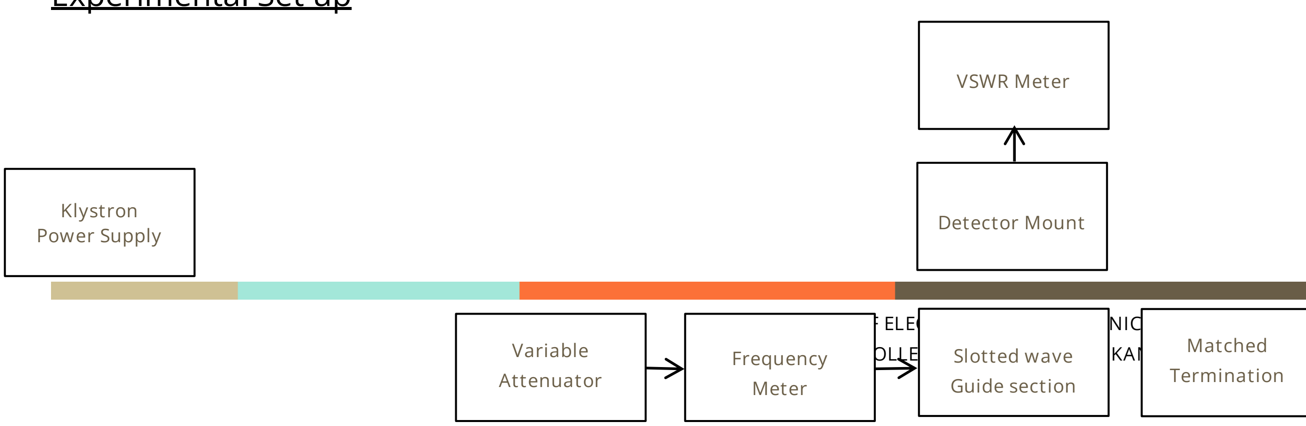
20. Before switching OFF the supply, keep the beam voltage at minimum position and repeller voltage at maximum position.

Result:

Studied the characteristics of a reflex klystron.

1. ESR
2. ETR

Experimental Set up



Tabular column

PART A EXP. No. 4	Frequency and Wavelength Measurements
DATE:	

Sl No.	f_o (GHz)	$1/\lambda_o^2$	λ_g	f_o

Aim:

To determine the frequency and wavelength in a rectangular waveguide and to verify the relation between λ_o, λ_g and λ_c .

Equipment required:

Gunn oscillator, isolator, PIN modulator, frequency meter, variable attenuator, matched termination, Gunn power supply, VSWR meter, slotted waveguide section, detector mount, cables and accessories.

Theory:

The following relationships are important for rectangular waveguides.

$$C = f\lambda$$

$$\frac{1}{\lambda_o^2} = \frac{1}{\lambda_g^2} + \frac{1}{\lambda_c^2}$$

$$\lambda_g = \frac{\lambda_o}{\sqrt{1-(\lambda_o/\lambda_c)^2}}$$

$$\lambda_c = \frac{2}{\sqrt{(m/a)^2 + (n/b)^2}}$$

C = velocity of light

f = frequency

λ_o =wavelength in free space

Observations

λ_g = wavelength in waveguide

λ_c = cut off wavelength in waveguide

a = broader dimension in the cross-section of waveguide

b = smaller dimension in the cross-section of waveguide

For TE_{10} mode, by substituting the values of m and n

$$\lambda_c = \frac{2}{\sqrt{(1/a)^2 + (0/b)^2}} = 2a$$

$$\lambda_g = \frac{\lambda_o}{\sqrt{1-(1/2a)^2}}$$

$$\lambda_o = \frac{1}{\sqrt{(1/\lambda_g)^2 + (1/2a)^2}}$$

$$f = C/\lambda_o = C\sqrt{(1/\lambda_g)^2 + (1/2a)^2}$$

The guide wavelength can be measured as twice the distance between two successive maxima or minima in the standing wave pattern.

1. Set up the components and equipment as shown in Figure.
2. Set the variable attenuator at maximum position.
3. Set the Gunn power supply at 5 V.
4. Keep the control knobs of VSWR meter as follows:
   (a) Gain (coarse and fine)-Mid position.
   (b) Range (dB) - 50 dB position.
   (c) Meter switch - Normal position.
5. Tune the probe for maximum deflection in VSWR meter.
6. Tune the frequency meter knob to get a dip on the VSWR scale and note down the frequency f_o. Calculate $1/\lambda_o^2$ and enter it in tabular form.

7. Replace the termination with a movable short and detune the frequency meter.

8. Move probe along with slotted line, the deflection in VSWR meter will vary.

9. Move the probe to get minimum deflection position.

10. Record the probe position from the slotted line (d_1).

11. Move the probe to next minimum position and record the probe position against (d_2).

12. Calculate guide wavelength $\lambda_g = 2(d_2 - d_1)$ and enter it in Table.

13. Measure the waveguide inner broad dimension a and calculate λ_c, $= 2a$.

14. Calculate the frequency f_o, as given in the following equation and enter it in Table.

15. Compare this $$f_o = \frac{c}{\lambda_o} = c\sqrt{\frac{1}{\lambda_c^2} + \frac{1}{\lambda_c^2}}$$ with the frequency that is obtained by directly reading from the VSWR meter

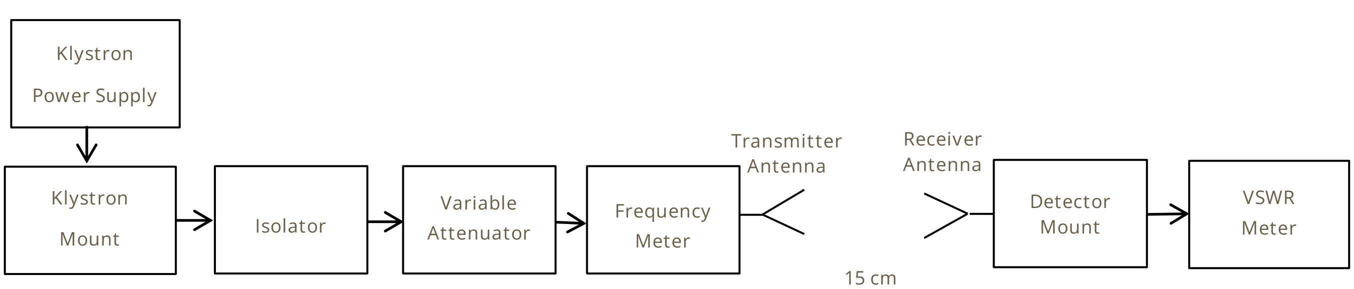
<u>Result:</u>

Experimentally measured the frequency and wavelength of microwave signal in a waveguide.

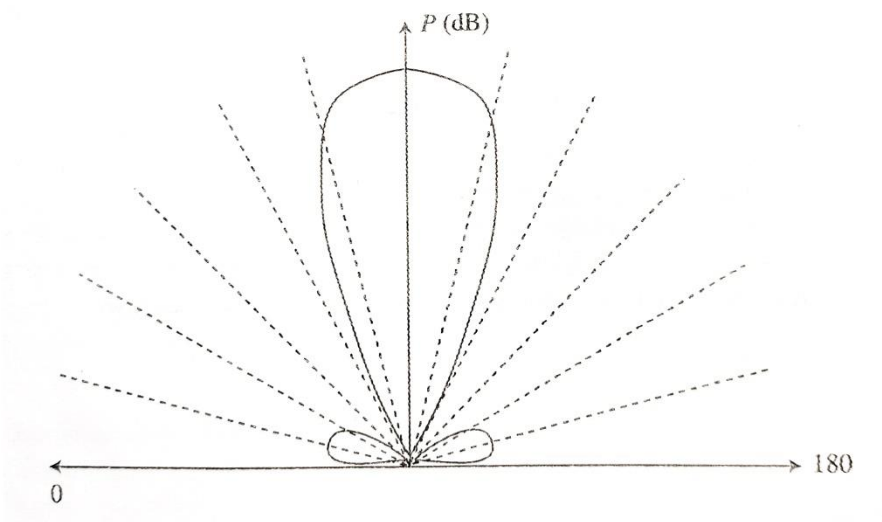
1. Mean Frequency
2. Calculated Frequency

.

<u>Experimental Set up</u>



Radiation Pattern



PART A **EXP. No. 4**	**Antenna Measurements**
DATE:	

Aim:

To measure and plot the radiation polar pattern and to measure the gain of the antenna and beam width.

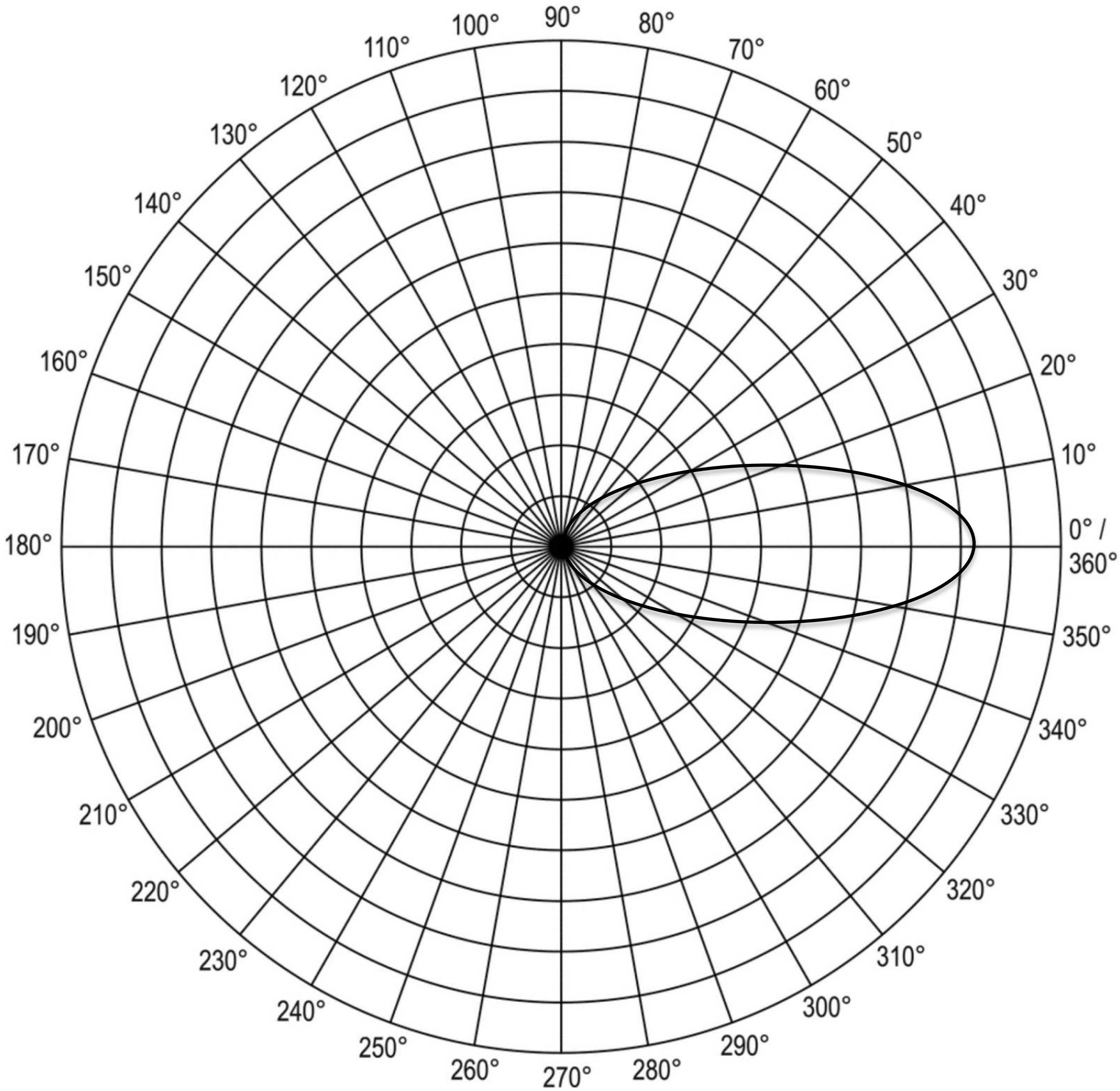
Equipment required:

Test tone generator, RF generator, PIN modulator, directional coupler, detector, horn antennas, function generator and accessories.

Theory:

Though an open ended waveguide is capable of radiating like an antenna, into open space, it suffers from many deficiencies such as reflected waves existing due to poor matching of impedance and non-directional radiation pattern. These are overcome if the walls of the waveguide at the mouth are flared so that it takes the shape of a horn. Many horn configurations are possible by flaring out the walls in E-plane or H-plane or in both the planes.

The radiation pattern is the graph of the field strength versus aspect angle at a constant distance from the radiating antenna. Though the antenna radiation pattern is three-dimensional, it is presented in two-dimension on a graph practically. An antenna pattern consists of major lobes and minor lobes. Gain of the antenna is defined as the ratio of power intensity at the maximum of the major lobe to the power intensity achieved from an imaginary omnidirectional antenna at that point. Beam width of the main lobe is the angle between two points on a main lobe where the power intensity is half the maximum intensity. In order to get the far field radiation pattern, transmitting and receiving antennas must be kept at minimum distance of $R = 2D^2/\lambda_o$, where D is the broader dimension of the horn.



Observations

To measure the required pattern, the receiving antenna must be kept at a minimum distance of *2D* where *D* is the dimension of the broader wall of the horn aperture.

The received power $Pr = \frac{Pt\ \lambda o\ G1G2}{(4\pi\ S)^2}$

Where P_t = Transmitted power

λ_o = Free space wavelength

G_1 and G_2 = Gains of transmitting and receiving antennas

S = Distance between two antennas

Then $Pr\ = \frac{Pt\ \lambda o\ G^2}{(4\pi\ S)^2}$

From this, $G = \frac{4\pi S\sqrt{Pr}}{\sqrt{Pt\lambda o}}$

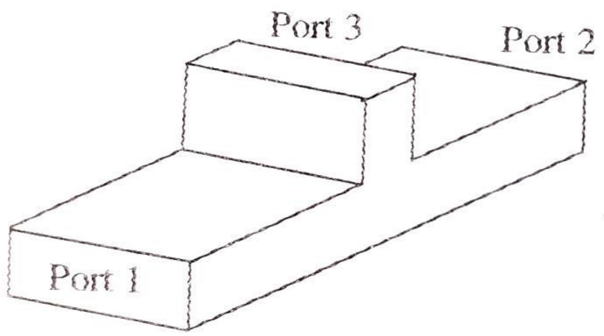
It can be seen from the above expression that values of P, and P, are not necessary, but the ratio only is required which can be measured using VSWR meter.

Procedure:

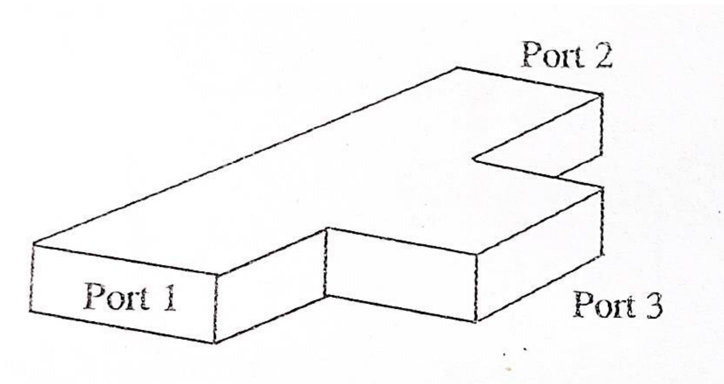
1. Set up the components and equipment as shown in Figure.
2. Use same type of transmitting and receiving antennas (horn antenna), keeping the axis of both the antennas in same axial line and maintain 15 cm distance between antennas at the beginning.
3. The variable attenuator is set accordingly for maximum deflection in VSWR meter.
4. The amplifier is set for maximum sensitivity.
5. Align the antennas at 0° direction.
6. Attenuator is adjusted for maximum deflection.
7. Obtain the received power from the VSWR meter.
8. Turn the receiving antenna till 90° both directions in steps of 10° and take corresponding
VSWR meter reading.
9. Draw the radiation pattern and measure 3 dB beam width..

Result:

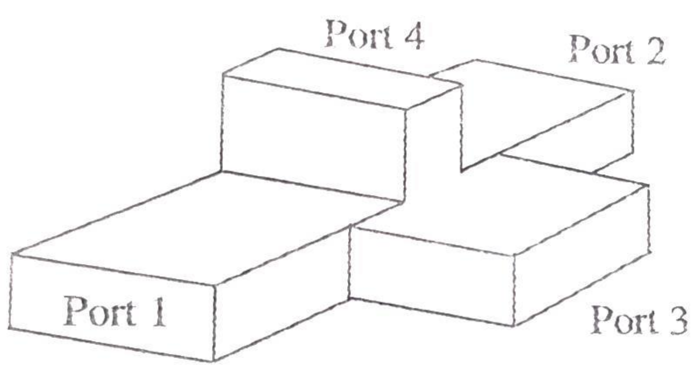
Plotted the radiation pattern of horn antenna.



E Plane Tee



H Plane Tee



Magic Tee

PART A EXP. No. 5	**Measurement of Isolation of E, H Plane and Magic Tee**
DATE:	

Aim:

To measure the isolation of E, H Plane and Magic Tee.
Compute 1. Isolation Coefficient 2. Coupling Coefficient.

Equipment required:

Microwave Source, Gunn Power Supply, PIN Modulator, VSWR Meter, E Plane, H Plane Tee and Magic Tee.

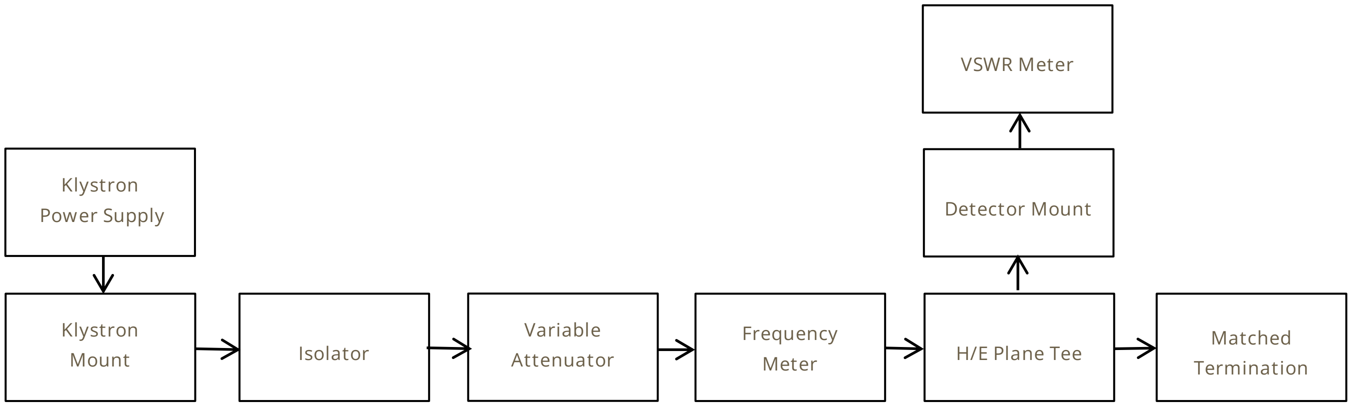
Theory:

E Plane Tee fix a linearly polarized antenna is the plane continuing the electrical vectors and the direction of maximum radiation. The electric field or E plane determine the polarization or orientation of the radio wave. For vertically polarized antenna, the E plane usually coincides with the vertical plane, For a horizontally polarized antenna, the E plane usually coincide with the horizontal plane. E plane and H Plane should be 90^0 apart.

H plane tee for a linearly polarized antenna is the plane containing the magnetic field vector and the direction of maximum radiation. For vertically polarized antenna, the H plane usually coincides with the horizontal plane.

Magic Tee is a combination of E planes Tee and H plane Tee. The arm 3 is H arm and arm 4 is E arm. If the power is fed from arm 4, it divides equally among the arm 1 and arm 2 but out of phase with no power to arm 3. Further if power is fed into arm 1 and 2 simultaneously, it is added in arm 3 and subtracted in arm 4.
The basic parameter to be measured for magic tee is defined below.

Experimental Set up



Observations

1. Input VSWR – It is the value of VSWR corresponding to each part as the load to the line while other parts are terminated in matched load.

2. Isolation – The isolation between E and H arm is defined as the ratio of the power supplied by the generator connected to the arm E to the power
3. deflected at parallel arm when side arm 1 and 2 are terminated with matched load.

$$\text{Isolation } (dB) = 10 \log_{10} (P4/P3)$$

Similarly isolation between other parts may be also defined.

4. Coupling Coefficient – It is defined as $C_{ij} = 10^{\alpha\text{-}/10}$

Where α = Attenuation (dB)

i = i/p arm

j = o/p arm

$\alpha = 10 \log_{10} |Pi/Pj|$

Where Pi = Power derived to arm i

Pj = Power derived to arm j

Procedure:

1. Connect the unit as shown in figure.
2. Energize the microwave source for particular frequency of operatiuon and adjust its detector for maximum output.
3. Set any power level and measure it without changing the settings.
4. Now place the H tee without changing the settings.
5. Place matched load at port 3 and find P*i*. Then place the matched load at Port 2 and find P*i.*
6. Repeat the above steps for E plane, H plane and Magic Tee.

Result:

Measured the isolation of E plane, H plane and Magic Tee.

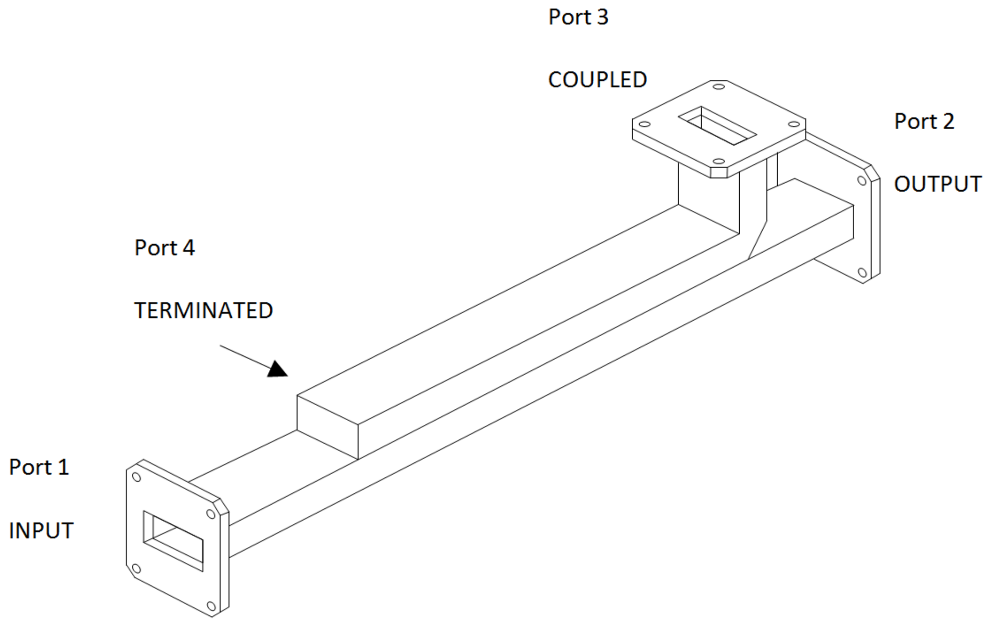
Coupling coefficient

E plane Tee =

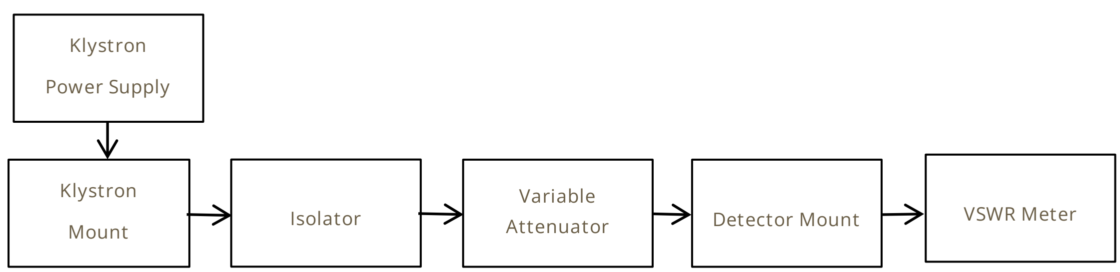
H plane Tee =

Magic Tee =

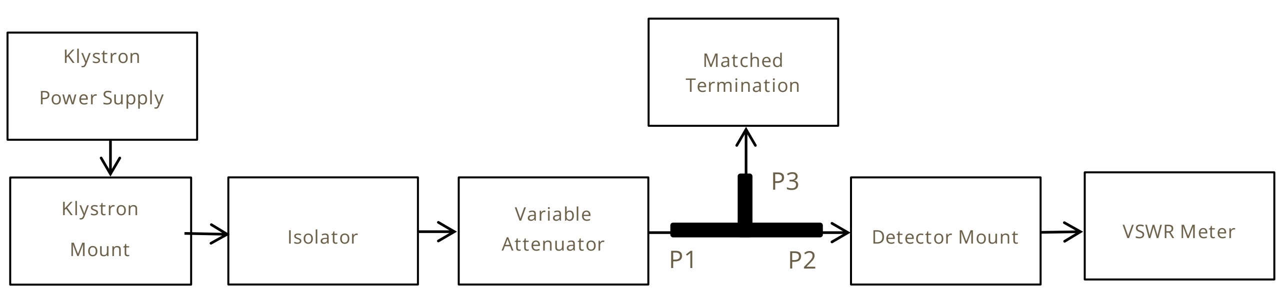
Isolation =



Directional Coupler with ports marked



Set up without connecting directional coupler to measure input power



Set up with directional coupler to measure insertion loss

PART A EXP. No. 6	**Measurement of Directional Coupler**
DATE:	

Aim:

Set up an arrangement for to measure the 1. Directivity, 2. Coupling Coefficient, 3. Isolation Coefficient of a given Directional Coupler.

Equipment required:

Microwave Source, Gunn Power Supply, PIN Modulator, VSWR Meter, E Plane, H Plane Tee and Magic Tee.

Theory:

A directional coupler is a device with which it is possible to measure the incident and reflected waves separately. It consists of two transmission lines, the main arm and auxiliary arm are electromagnetically coupled to each other as shown in Figure.

Power entering through Port 1 gets divided between Port 2 (through port) and Port 3 (coupled port) and almost no power comes out in Port 4 (isolated port) (Figure 4.30). Power entering Port 2 is divided between Port 1 and Port 4.

Following quantities are used to characterize a directional coupler.

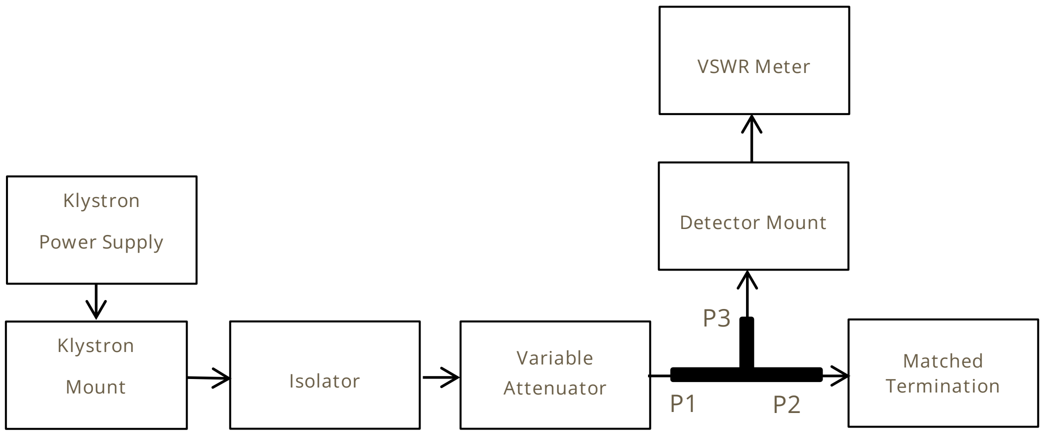
Coupling factor C = $10 \log_{10} P1/P3$ (dB)

Directivity D = $10 \log_{10} P3/P4$ (dB)

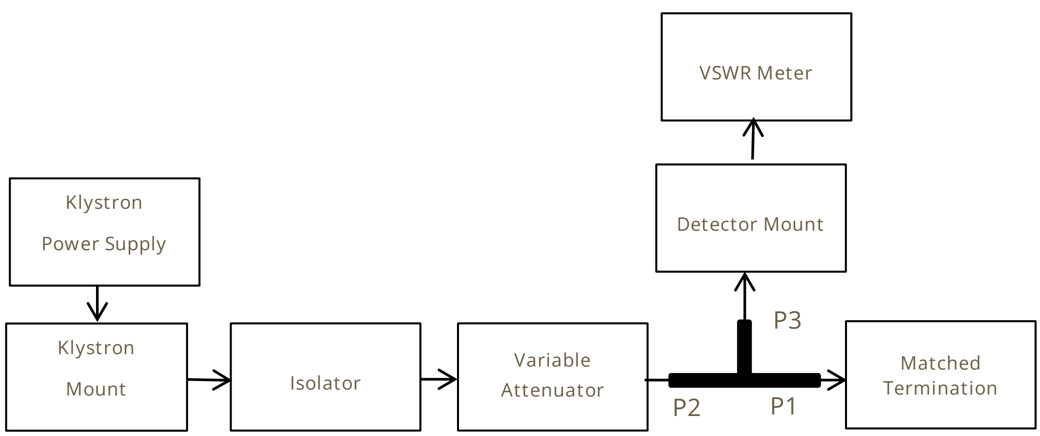
Isolation = $10 \log_{10} P1/P4$(dB)

Insertion loss = $10 \log_{10} P1/P2$

Coupling factor indicates the fraction of the input power that is coupled to the output port. Directivity is the measure of isolation between forward and backward waves. In this experiment isolation factor is not measured since the Port 4 of the directional coupler is permanently terminated with a matched load. Insertion loss is the measure of loss in the power while inserting the directional coupler.



Set up to measure coupling factor



Set up to measure directivity

Observations

Procedure:

Measurement of insertion loss:

1. Set up the microwave test bench without connecting the directional coupler as shown in Figure.
2. Measure input power using the power meter. Let it be P_1 (dB).
3. Without changing the Gunn bias, connect the directional coupler.
4. Connect the matched load to auxiliary arm P_3, as shown in Figure.
5. Measure the line output power P_2 (dB).
6. Insertion loss $L = P_1 - P_2$ *(dB).*

Measurement of coupling factor:

1. Measure *P1* as before.
2. Without changing the Gunn bias, connect the directional coupler as shown in Figure. Now matched load is connected to Port *P2* and power meter to Port *P3*.
3. Measure the auxiliary line output power *P3 (dB).*
4. Calculate coupling factor using the expression

$$C = 10 \log_{10} P1/P2 (dB)$$

Measurement of directivity:

1. Set up the test bench as shown in Figure.
2. Apply input to Port 1 and measure the output at Port 3. Measure the power output as *P13*. Reverse Port 1 and Port 2 of the directional coupler as shown in Figure.
3. Apply input at Port 2 and measure power at Port 3. Measure the power output as *P23*
4. Calculate directivity using the expression

$$D = 10 \log_{10} P13/P23 (dB)$$

Result:

Studied the characteristics of directional coupler.

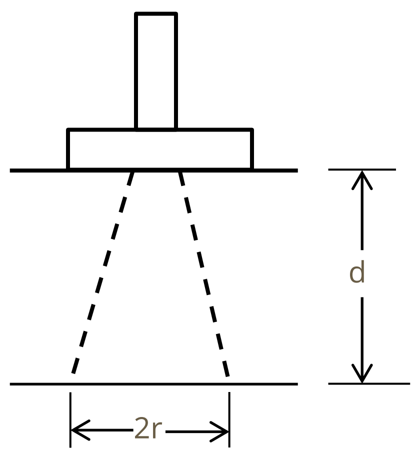
Coupling factor C =

Directivity D =

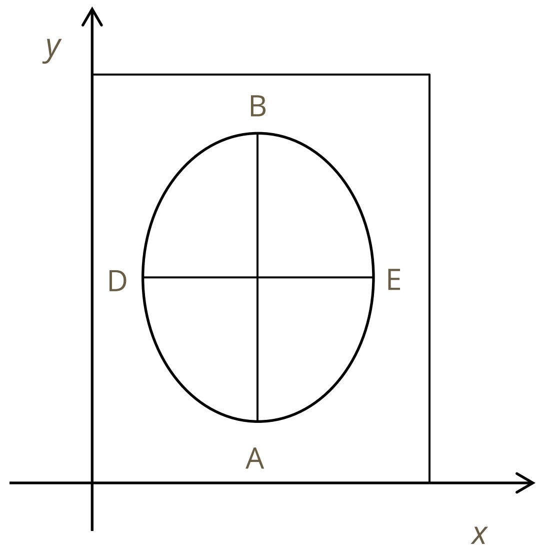
Isolation =

Insertion loss =

Experimental Set up:



Set up to measure nuemerical aperture



Pattern disply on graph

PART B EXP. No. 1	**Measurement of Numerical Aperture**
DATE:	

Aim:

To measure the numerical aperture and acceptance angle of a given optical fiber cable.

Components required:

Source, optical fiber, measuring stand, steel ruler and power supply.

Theory:

Numerical Aperture (NA) implies how much light is collected (gathered) by an optical fiber when it is coupled to a light source. The light rays entering the fiber within a certain angle will be accepted and propagated. The maximum angle within which light enters the fiber so that it will be propagated by total internal reflection is called acceptance angle, θa.

Sine of acceptance angle is called numerical aperture.

$$NA = \sin \theta a$$

Numerical aperture is measured from the far field pattern by trigonometric means. This is a less precise technique. Light is launched into the fiber under test and the far field pattern from the fiber is displayed on a screen which is positioned at a known distance d from the fiber output end face. The radius of the pattern r is measured. Numerical aperture can be obtained from the expression

$$\text{Numerical aperture } \sin \theta a = \frac{r}{\sqrt{r^2 - d^2}}$$

Procedure:

1. Connect one end of the fiber to the optical source Figure.
2. Insert other end of the fiber in the measuring stand. Energize the optical source.
3. Keep a minimum distance of about 10 mm between fiber tip and the graph plane.

Tabular Column

r (mm)	*DE (mm)*	*BC (mm)*	*d (mm)*	$\boldsymbol{NA = \frac{r}{\sqrt{r^2 - d^2}}}$	θ

Calculations

Average NA :
θ :

4. Now a circular red color spot is observed on the graph. Measure its radius. If the spot is elliptical in shape, instead of circle, measure its diameter horizontally and vertically and find out mean radius of the spot as $r = \frac{DE+BC}{4}$

5. Find the value of numerical aperture $\sin \theta a = \frac{\boldsymbol{r}}{\sqrt{\boldsymbol{r}^2 - \boldsymbol{d}^2}}$

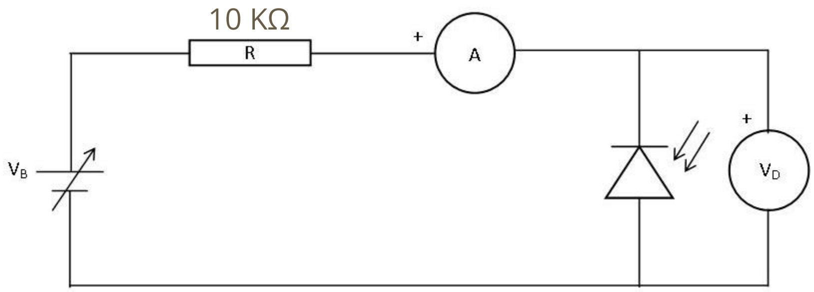
6. Repeat the experiment three or four times and take the average value of NA.

Result:

Numerical aperture of a fiber cable is measured.

1. Numerical aperture of the given optical fiber =
2. Acceptance angle =

Experimental Set up:



Tabular Column

Applied Voltage	Normal Light		Bright Light		Dark	
	V (Volts)	I (mA)	V (Volts)	I (mA)	V (Volts)	I (mA)

PART B EXP. No. 2	V-I Characteristics of Photo Diode
DATE:	

Aim:

To plot the V-I Characteristics of photo diode.

Components required:

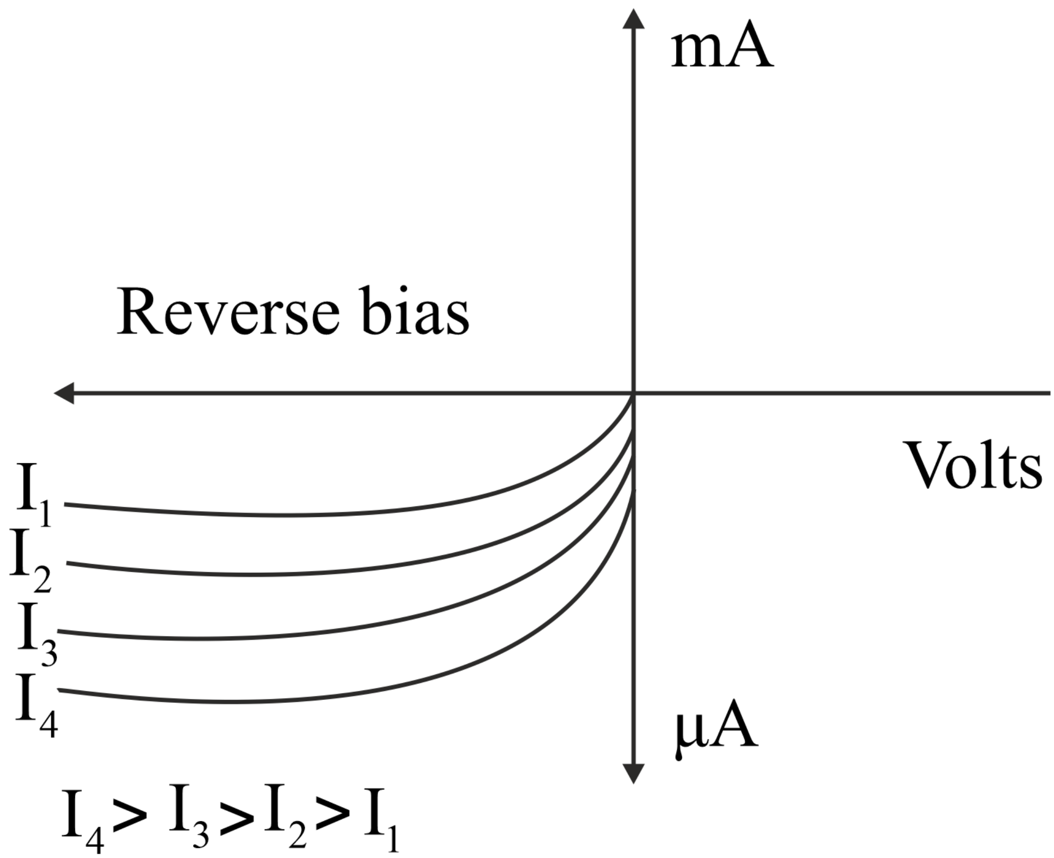
Photo Diode, DC Power supply, resistor, voltmeter, ammeter.

Theory:

If a photon having adequate energy [should be greater than the band gap] is absorbed by a p-n junction, an electron will be transferred to the conduction band, thereby forming a hole in the valence band. As a result, an open circuit voltage is created and a current will flow, provided the circuit is closed through a load resistor. In case of reverse bias p-n junction, the transit time can be made small and it will produce current linearly proportional to the incident photon energy. The frequency response can be improved if the p-n junction is separated by an intrinsic region. The introduction of the intrinsic region decreases the junction capacitance. This is called 'Positive Intrinsic Negative'[PIN] photo diode. For high frequency operation, the PIN diode can be made as small as practical, to match the size of the spot of the optical beam.

Procedure:

1. Set the experimental set up as shown in Figure.
2. Plug in the LED source.
3. Connect the photodiode to optical power source and connect the bias supply.
4. Increase the bias voltage Vg in steps of 0.5 V. Measure voltage across


mA
Reverse bias
Volts
I_1
I_2
I_3
I_4
μA
$I_4 > I_3 > I_2 > I_1$

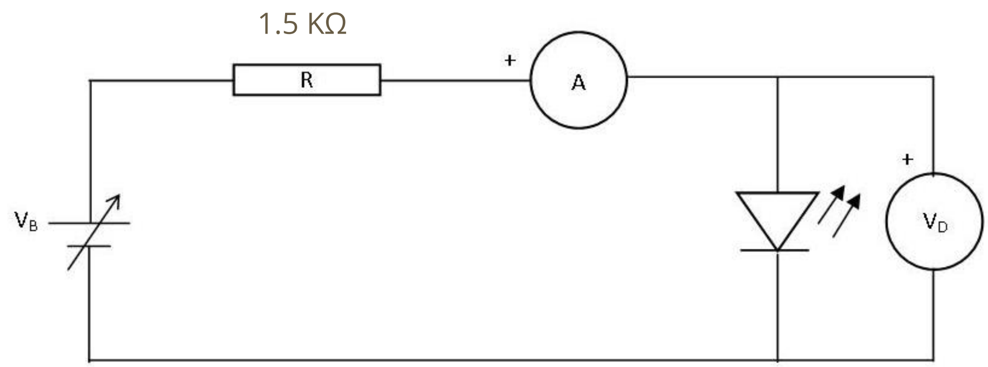
photodiode V_D and current I.

5. Repeat the above steps for different intensities of input light power.
6. Plot the V-I characteristics with V_D along x-axis and current I along y-axis.

Result:

Studied the V-I Characteristics of a Photo diode.

Experimental Set up:



Tabular Column

Applied Voltage	Voltage across Diode VD	Current A

PART B EXP. No. 3	**V-I Characteristics of LED**
DATE:	

Aim:

To plot the V-I Characteristics of LED and find the Cut in voltage.

Components required:

LED, DC Power supply, resistor, voltmeter, ammeter.

Theory:

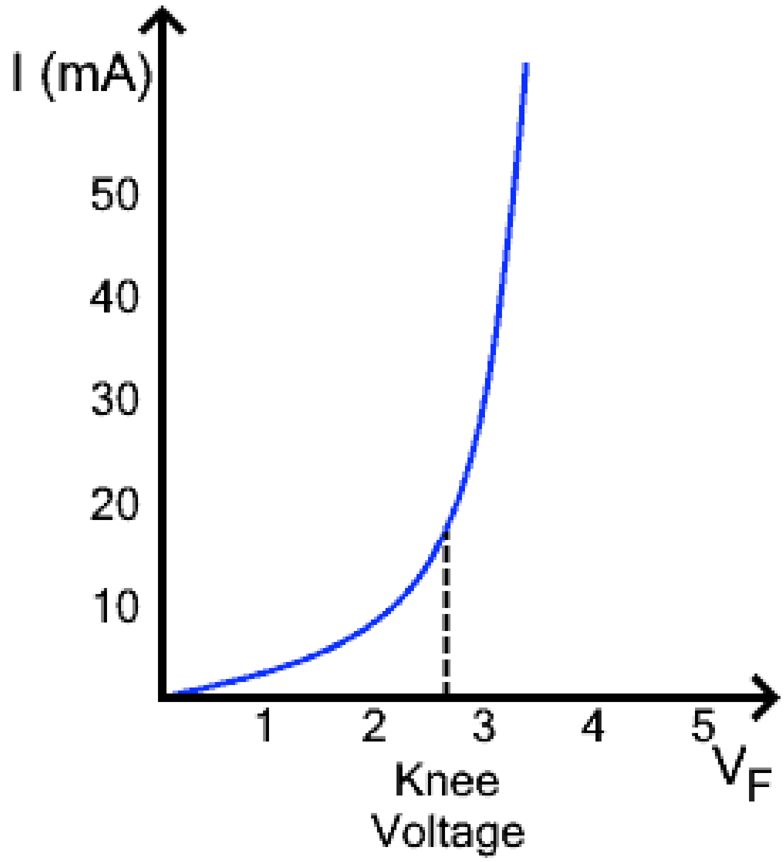
Light emitting diode is a PN junction diode which emits light when forward biased. The amount of light emitted depends on the forward current. When a light emitting diode is forward biased, the barrier potential is lowered. The electrons and holes move towards the junction and recombination takes place. After recombination, the electrons lying in the conduction band of N-region fall into the valence band of P-region. The difference of energy between the conduction band and valence band is radiated in the form of light.

For an LED, the colour of the emitted light depends on the type of semicon used. Gallium arsenide LED emits infrared radiations, gallium arsenide phosphide either red or yellow light, gallium phosphide emits red or green light and galli produces blue light.

LEDs operate at low voltages (from 1.5 V to 2.5 V). They are fast in in size, consume little power and have long life.

Procedure:

1. Set the experimental set up as shown in Figure.
2. Plug in the LED source.
3. Connect the photodiode to optical power source and connect the bias supply.
4. Increase the bias voltage Vg in steps of 0.5 V. Measure voltage across photodiode V_D and current I.



VI Characteristics of LED

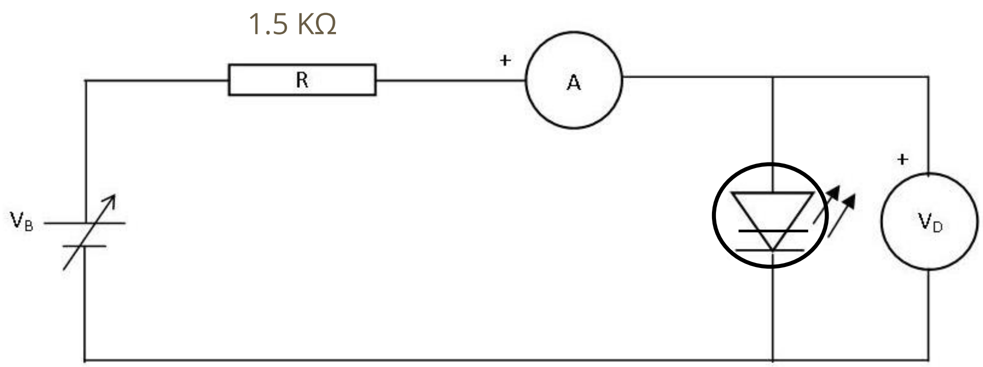
5. Plot the V-I characteristics with V_D along x-axis and current I along y-axis.

Result:

Studied the V-I Characteristics of a LED.

Cut in voltage =

Experimental Set up:



Tabular Column

Applied Voltage	Voltage across Diode VD	Current A

PART B EXP. No. 4	V-I Characteristics of Laser Diode
DATE:	

Aim:

To plot the V-I Characteristics of Laser Diode find the Cut in voltage.

Components required:

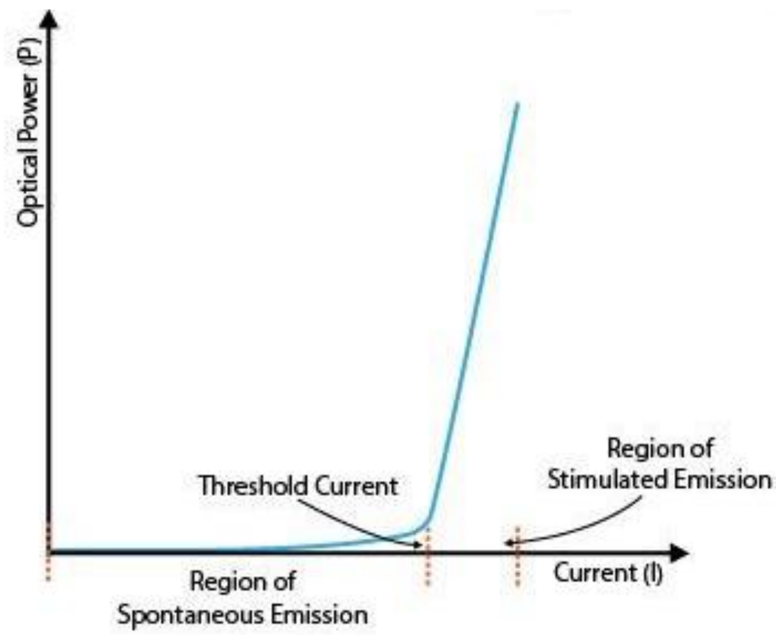
Laser Diode, DC Power supply, resistor, voltmeter, ammeter.

Theory:

The Laser Diode (LD) is the most common type of laser produced with a wide range of applications that include fiber optic communications, barcode readers, laser pointers, CD/ DVD/Blu-ray disc reading and recording, laser printing, laser scanning and increasingly directional lighting sources.

A laser diode is an optoelectronic device, which converts electrical energy into light energy to produce high-intensity coherent light. The working of the laser diode is almost similar to the Light Emitting Diode (LED). The major difference between the LED and laser diode is that the LED emits incoherent light whereas the laser diode emits coherent light.

The laser diode is made of two doped gallium arsenide (GaAs) layers. One doped GaAs layer will produce an N-type semiconductor whereas another doped GaAs layer will produce a P-type semiconductor. When this structure is forward biased, holes from the P-region are injected into the N-region, where electrons are the majority carriers. Similarly, electrons from the N-region are injected into the P-region, where holes are the majority carriers. When an electron and a hole are present in the same region, they may recombine by spontaneous emission. That is, the electron may reoccupy the energy state of the hole, emitting a photon with energy equal to the difference between the electron and hole states involved. These injected electrons and holes represent the injection current of the diode.



LASER DIODE P-I GRAPH

Procedure:

1. Set the experimental set up as shown in Figure.
2. Plug in the Laser Diode source.
3. Connect the photodiode to optical power source and connect the bias supply.
4. Increase the bias voltage Vg in steps of 0.5 V. Measure voltage across photodiode V_D and current I.
5. Plot the V-I characteristics with V_D along x-axis and current I along y-axis.

Result:

Studied the V-I Characteristics of a Laser Diode.

Cut in voltage =