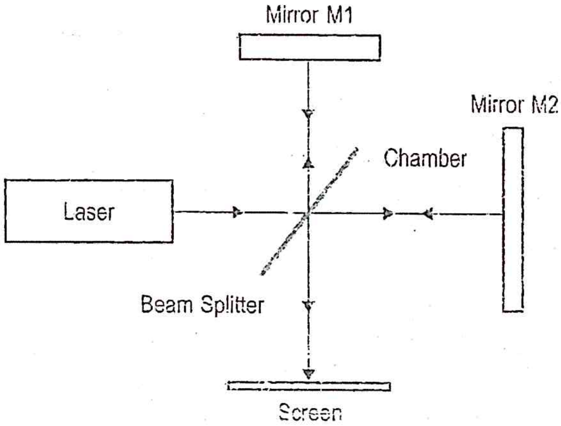
MICHELSON INTERFEROMETER

Model No: HO-ED-INT-06

AIM: -

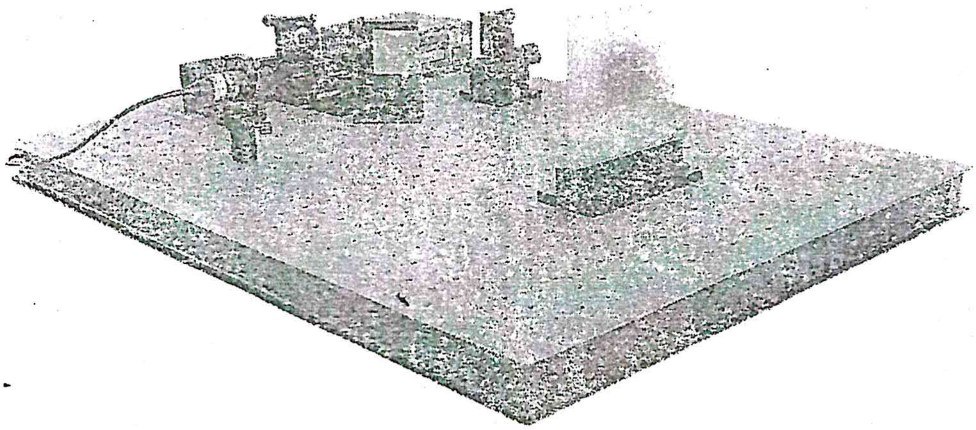
1. Determination of wavelength of laser beam.
2. To find the refractive index of the glass plate.
3. To find the refractive index of air.



Components and Equipments: -

- Bread board
- Diode Laser with power supply
- Laser mount
- Beam splitter with mount
- Mirrors with mount (2no.)
- Rotation stage with glass slide
- Pressure cell
- Screen
- Thump screws, etc.

Wave Length of Laser Beam



Theory: -

M1 and M2 are two plane mirrors silvered on the front surfaces. They are mounted vertically on two translation stages placed at the sides of an optical platform. Screws are provided at the back of the holders. Adjusting of which allows M1 and M2 to be tilted. M1 can also be moved horizontally by a micrometer attached to the M1 holder. The beam splitter, a planar glass plate partially silvered (50% - 50%) on one side. It is mounted vertically at an angle 45 degree to the incident light. When light from laser is allowed to fall on the beam splitter, one portion is transmitted through beam splitter to M1 and the other is reflected by beam splitter to M2. The reflected beams from M1 and M2 are superimposes at the beam splitter and interference pattern can observe on the screen.

The wavelength of laser is calculated by:

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

Where 'd' is the change in position that occurs 'N' fringes to pass and Δ is the calibration constant of the micrometer.

Calibrating the micrometer

For even more accurate measurements of the mirror movement, you can use a laser to calibrate the micrometer. To do this, set up the interferometer in the Michelson mode. Turn the micrometer knob as you count off at least 20 fringes. Carefully note the change in the micrometer reading and record this value as d'. The actual mirror movement $d = N\lambda/2$, where λ is the known wave length of the laser and N is the number of fringes that were counted. $\Delta = d/d'$ is the calibration constant for the micrometer.

Procedure

1. Attach the diode laser with mount, adjustable mirror and movable mirror as in the illustration, but do not install the beam splitter yet. Attach the viewing screen as in figure.

2. Align the laser so that the beam is parallel with the top of the base. The beam should strike the center of the movable mirror and should be reflected directly back into the laser aperture.

3. Position the beam splitter so that the beam is reflected to the fixed mirror. Adjust the angle of the beam splitter as needed so that the reflected beam hits the fixed mirror near its center.

4. There should now be two sets of bright dots on the viewing screen; one set comes from the fixed mirror and the other from the movable mirror. Each set of dots should include a bright dot with two or more dots with of lesser brightness (Due to multiple reflections in the thin film of the beam splitter). Adjust the angle of the beam splitter again until the two sets of dots are as close together as possible, and then tighten the screws securing the beam splitter and mirror mounts.

5. Using the lead screws on the back of the adjustable mirror, adjust the mirror's tilt until the two sets of dots on the viewing screen coincide.

6. Expand the laser beam slowly by rotating the collimating lens on front the diode laser.

7 As a rule a streaky interference pattern, resulting from a non-parallel alignment of the two mirrors is now already to be seen. Carry out a sensitive re-adjustment with the adjusting screws to bring the interference pattern to the wanted concentric form.

8 After aligning the laser with the interferometer and making certain that the fringes you are looking at move when the micrometer screws is turned, fix a position on the observing screen and note the micrometer reading.

9 Count the fringes that move past the fixed point (either outward or inward) as the screw is turned. Count at least 20 fringes as they pass the fixed point on the viewing region. Begin the counting with a hand on the micrometer and try to exert a steady pressure.

10. Begin the counting with a hand on the micrometer and note the initial reading on the micrometer. After 20 fringes pass, note the reading on the micrometer scale and compute the distance the mirror moved.

11. In the movable mirror mount, it is mounted in a translation stage. The micrometer shaft actuates a lever arm which pushes the translation stage carrying the mirror.

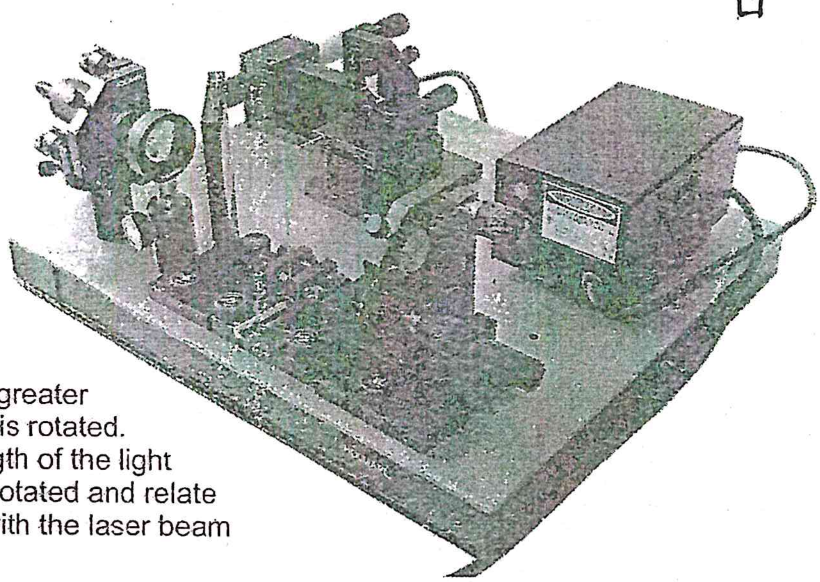
12. Repeat the procedure 3 or 4 times. Average the readings.

13. Substitute the readings in the equation to obtain results.

Result:-

The wavelength of laser beam λ = ...

Refractive Index of Glass Slide



Theory: -

The light passes through a greater length of glass as the plate is rotated. The change in the path length of the light beam as the glass plate is rotated and relate the change in path length with the laser beam through air.

The refractive index of glass slide , n = $\dfrac{(2t - N\lambda)(1 - \cos\theta)}{2t(1 - \cos\theta) - N\lambda}$

Where, t = the thickness of the glass slide
N = number of fringes counted,
θ = angle of rotation
λ = wavelength of laser beam

Procedure: -

1) Align the laser and interferometer in the Michelson mode.

2) Place the rotation stage between the beam splitter and movable mirror, perpendicular to the optical path.

3) Mount the glass plate on the rotation stage.

4) Position the stage & glass such that glass slide is perpendicular to the optical path.

5) When glass plate is introduced in the optical path of Michelson interferometer, the fringe will be shifted & will become blur. To make the fringe sharpen again, move mirror mount to & fro till the clear set of fringes is achieved on the viewing screen.

6) Slowly rotate the rotation stage. Count the number of fringe translations that occur as you rotate the table to an angle θ (at least 10 degrees.)

Before taking the readings, observe the fringe movement.

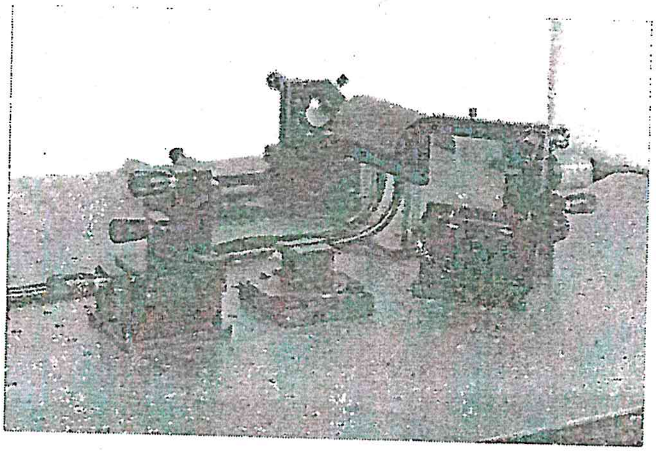
Result:-

Refractive index of Glass Slide n = ...

Refractive Index of Air

Theory: -

When a piece of material of thickness d is placed in one arm of the Michelson Interferometer, the change in optical path length is given by 2d Δn where Δn is the difference in refractive index between the sample and the material it replaced (usually air). In other words, 2d $(n_m - n_{air}) / \lambda$ extra wavelengths are introduced if air is replaced by a sample of refractive index n_m.



Let λ be the wavelength of light, n the refractive index of air at atmospheric pressure, d the length of the air cell, P_{atm} the current atmospheric pressure and ΔP the pressure change.

The relationship between the pressure change ΔP and the number of fringe shift $m_{\Delta P}$ is given by

$$m_{\Delta P} = (2d\,(n-1) / \lambda)\,(\Delta P / P_{atm})$$

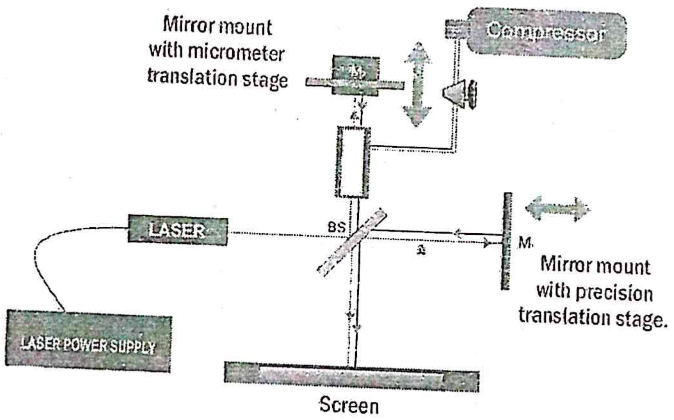
Procedure: -

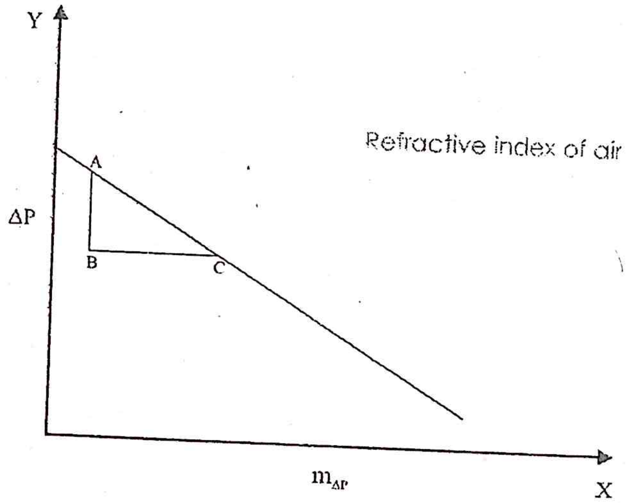
Arrange the Michelson Interferometer experimental set up. Introduce the pressure cell in any one of the arms of the interferometer. Tune the micrometer in order to get the interference pattern in a good manner. Now pressurize the cell up to 300mmHg. Slowly release the air and count the number of fringes. Reading of pressure gauge may be tabulated up to the total release of air from the cell.

Plot a graph between number of fringes and the corresponding pressure. The slope of the graph will give the value $m_{\Delta P} / \Delta P$. Put this value in the equation given below.

$$m_{\Delta P} / \Delta P = (2d\,(n-1) / \lambda)\,(1 / P_{atm})$$

From the above equation, we can calculate the value of refractive index of air 'n'.





Observations:-

Number of fringes counted	Pressure in the cell ΔP (in mmHg)

We have,

$(m_{\Delta P} / \Delta P)$	=	$(2d(n-1)/\lambda)(1/P_{atm})$
Length of the pressure cell d	=	
Wavelength of light λ	=	
$(m_{\Delta P} / \Delta P)$ from graph	=	
$(1/P_{atm})$	=	

Substituting the datas in the above equation, we can find the refractive index of air 'n'

Result:-

Refractive index of air n = ...

EXPERIMENT 4

MICHELSON'S INTERFEROMETER

AIM : a) To set up a Michelson's Interferometer and standardize it using a laser beam of known wavelength. b) To determine the unknown wavelength of a given laser beam. c) To determine the refractive index of a glass plate using the Michelson interferometer method.

APPARATUS : Diode laser (Red, 650 nm), Diode laser of unknown wavelength with associated power supplies, Laser and Mirror holders equipped with tilt stages and *XY-translators*, high-precision linear translational stage, Front Silvered Mirrors, Beam Splitter, Optic table, Allen screws, Allen keys, Screen, Collimating lens, scale/optical rails, optical posts and sleeves, rotation stage, glass slide.

PRINCIPLE : Interferometers are basic optic tools used for *precise* measurement of wavelength, distance, refractive index, temporal coherence of optical beams, vibration transmission etc. Figure 1, shows a schematic of the basic Michelson's interferometer. Light from a coherent source (typically laser) ***S***, is made to fall on a 50% beam splitter (***BS***) at an incident angle of *45°*. The reflected beam falls *normally* on mirror ***M1*** and the transmitted beam falls *normally* on mirror ***M2***. The reflected beam starting from ***M2*** is reflected by the beam splitter towards the screen while the beam reflected from ***M1*** gets transmitted through ***BS*** and then proceeds towards the screen. These two beams interfere with each other resulting in a fringe pattern. The path difference between the two beams is a function of the distance of the mirrors from the beam splitter. If either of the mirrors ***M1*** *or* ***M2*** are moved the path difference changes and the interference pattern appears to move. If N is the number of fringes that move across a fixed point on the screen when the mirror ***M1*** (or ***M2***) is translated through a distance d, then the wavelength of coherent source is given by

$$\lambda = \left(\frac{2d}{N}\right)\Delta \qquad (1.1)$$

Where Δ is the calibration constant of the micrometer screw attached to the translation stage of the mirror ***M1***.

Suppose the Michelson's fringe pattern is obtained on the screen with a glass plate introduced normally in the path of mirror ***M1***. If the glass plate is now rotated such that the reflected beam from ***M1*** makes an angle of incidence θ with the glass plate, the path difference between the two rays that cause the interference fringes changes continuously during the rotation and hence the fringe pattern appears to move. If t is the thickness of the glass slide and N is the number of fringes crossing a point on screen for a rotation θ of the glass slide, then the refractive index of the glass slide is given by

$$n = \frac{(2t - N\lambda)(1 - cos\theta)}{2t\,(1 - cos\theta) - N\lambda} \qquad (1.2)$$

PROCEDURE :

(a) Setting up the Interferometer

Mount the diode laser of known wavelength ($\lambda = 650\ nm$), Mirrors ***M1***, ***M2***, and the beam splitter (***BS***) to their respective mounts and associated tilt and translation stages.

components except the beam splitter as per the configuration shown in *Fig. 1*. Switch on the laser beam and align it by using the steering micrometers such that the beam is exactly parallel to the optic table surface. Adjust the tilt stage of mirror ***M2*** and its translator stage such that the laser beam falls at the center of the mirror ***M2*** normally. The reflected beam from ***M2*** should also be parallel to the optic table surface. Introduce the beam splitter such that the incident laser beam makes an angle of *45°* with it and a reflected beam is produced in the direction of the mirror ***M1*** (*Fig. 1,*). The tilt stage of ***M1*** is adjusted so that the reflected beam from the beam splitter falls normally on it and is centered over it. Careful adjustments are made to the tilt screws to ensure that the incident, transmitted and reflected beams in all directions are parallel to the optic table. Now, two bright laser spots would be visible on the screen corresponding to the two reflected rays coming from the front ends of mirrors ***M1*** **and** ***M2***. In addition a few laser spots of lower brightness should also be visible (due to multiple reflections in the thin film of the beam splitter). Adjust the angle of the beam splitter or the tilt stages of mirror ***M1***, ***M2*** such that the two bright spots coincide with each other. Now, introduce the collimating lens in between the laser diode and the beam-splitter. Adjust the micrometers of the tilt stages of ***M1*** / ***M2*** or both such that an interference pattern of concentric fringes of equal fringe width is observed on the screen. The fringes should appear to move when the micrometers attached to ***M1*** , ***M2*** or both is operated.

(b) Calibration of Micrometer

To calibrate the micrometer attached to the high-precision translation stage of mirror ***M1***, mark a fixed point on the screen with a sketch pen. Note the initial position of the micrometer screw. Now operate the micrometer screw and count the number of fringes that pass across the fixed mark (either outward or inward) simultaneously. Count at least *20* fringes. Note that final position of the micrometer, find the total distance moved by the micrometer as *d*. Repeat the above at least 4 times. Find the calibration constant of the micrometer using the equation

$$\Delta = \lambda\left(\frac{N}{2d}\right)$$

in each case.

(c) Finding an unknown wave length (λ')

To find out an unknown wavelength, replace the diode laser of known wavelength with another diode laser or unknown wavelength. Obtain the interference fringes exactly as described in (a) above, determine distance moved by the micrometer screw of ***M1*** in order for N' (say 25 fringes) to move across a fixed point on the screen. Let this distance be d', then the unknown wavelength is given by :

$$\lambda' = \Delta\left(\frac{2d'}{N'}\right)$$

(d) Refractive index of glass.

To find the refractive index of the given glass slide introduce the glass side normally in between the mirror ***M1*** and the beam splitter ***BS***. Now rotate the glass side about an axis perpendicular to the optic table. Notice that the interference fringe pattern moves as the glass slide is rotated. Count the number of fringes moving across a fixed point on the screen. If N_2 is the number of fringes crossing the fixed point for an angle of rotation of θ degrees, then the refractive index of the glass slide is given by *Eqn. 1.2*. The thickness of the glass slab is found out using a screw guage.

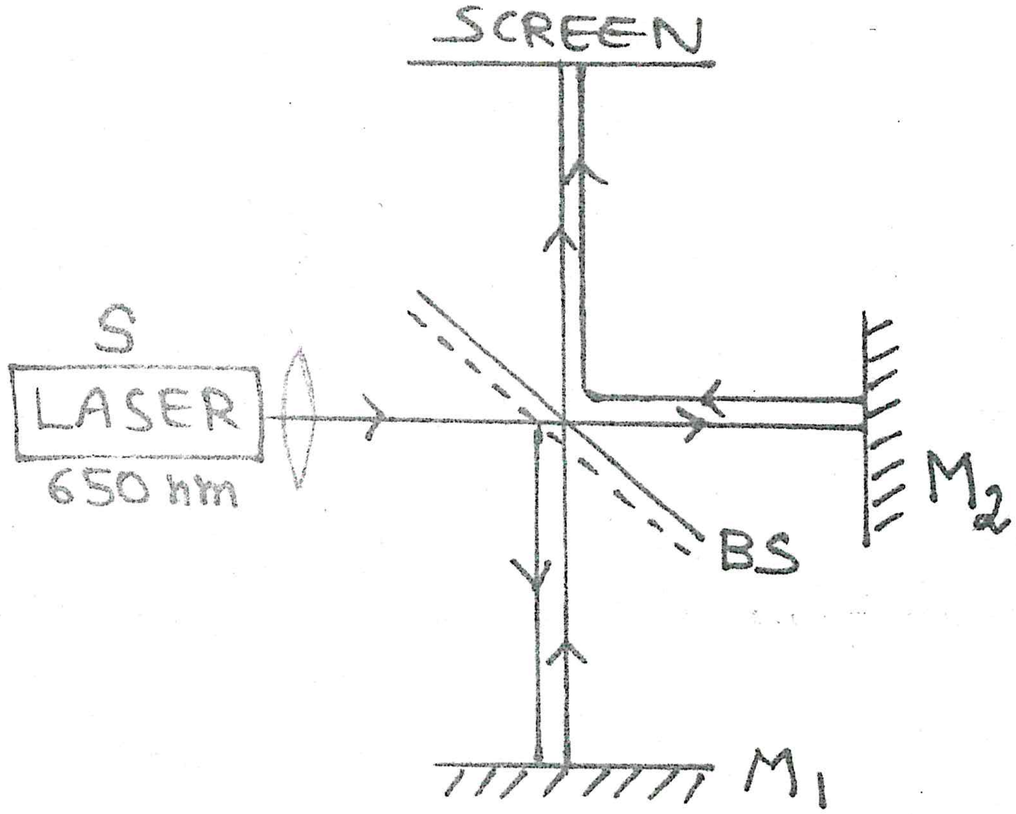


Fig. 1

l = length of the crystal (2.5cm ~~mm~~)

λ = wave length (632nm)

Solve the equation for several values of V and plot it as a function of voltage.

Calculations

Half wave voltage from the graph =

Extinction ratio = detector out put at half wave voltage / detector output at zero voltage.

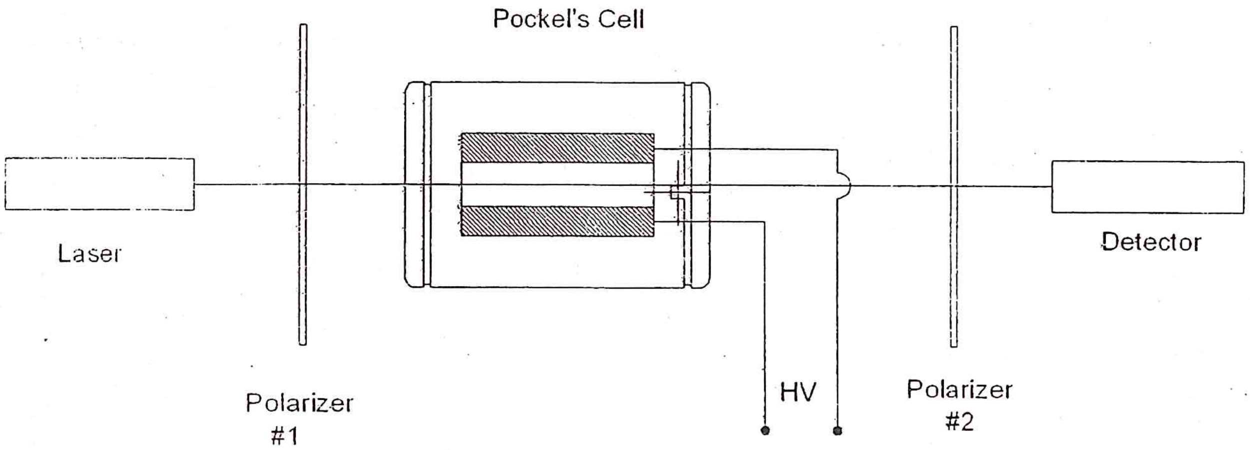
Result:

1. The intensity variation is plotted as a function of applied voltage.
2. Half wave voltage =

   Extinction ratio =

3. Birefringence Vs applied voltage graph is plotted.

Half wave voltage depends upon the nature of the material and increases with wavelength



Procedure:

1. Arrange the electro optic set up shown in the figure.
2. Carefully align the crystal along with so that light beam passes accurately along the axis of the crystal.
3. Rotate and position the first polarizer so that light beam passes through it with maximum intensity. This is to make sure that the light entering the crystal is polarized.
4. Rotate and position the second polarizer (analyzer) so that the light transmitted through it is minimum.
5. Connect the high voltage DC supply to the electrodes kept closely on both sides of the crystal parallel to the light beam.
6. Turn on the supply and gradually increase applied voltage from 0V to 2000V in steps of 100V, measuring the light reaching the detector at every 100V interval.
7. Record the voltage and output current reading at each 100V interval. The output current increases up to a point of input voltage and after that the output current decreases with the increase in voltage.
8. Plot the meter reading as a function of applied voltage.
9. Determine the value of $V_{\frac{1}{2}}$. Determine the extinction ratio, which is the ratio of the meter reading at $V_{\frac{1}{2}}$ to meter reading at V= 0.
10. Use the following equations for further calculation.

$P(V_{\frac{1}{2}}) = P(V) \sin^2 (\Pi D_n L / \lambda)$

$D_n = \lambda / \Pi L \sin^{-1} \sqrt{P(V) / P(V_{\frac{1}{2}})}$

$$\frac{P(V_{1/2})}{P(V)} = \sin^2\left(\frac{\pi D_n L}{\lambda}\right)$$

Were P (V) is the meter reading at voltage V

$P(V_{\frac{1}{2}})$ is the half wave voltage

$$\frac{\pi D_n L}{\lambda} = \sin^{-1}\sqrt{\frac{P(V_{1/2})}{P(V)}}$$

$\sin^{-1}$ $\pi/6$ $\pi/2$

Observations

Sl. No.	Input voltage (kV)	Output current (mA) $P(V)$	$\Gamma_n = \frac{\lambda}{\pi L}\sin^{-1}\left(\sqrt{\frac{P(V)}{P(V_{1/2})}}\right)$
1	0		
2	0.1		
3	0.2		
4	0.3		
5	0.4		
6	0.5		
7	0.6		
8	0.7		
9	0.8		
10	0.9		
11	1.0		
12	1.1		
13	1.2		
14	1.3		
15	1.4		
16	1.5		
17	1.6		
18	1.7		
19	1.8		
20	1.9		
21	2.0		

7

ELECTRO-OPTIC EFFECT

Aim: To plot the graph and study the birefringence with respect to applied voltage in an electro optic crystal (Lithium niobite ($LiNo_3$)).

Components and Equipments:-

$\mathcal{E} = -L \frac{dI}{dt}$

He-Ne laser with mount

$\mathcal{E} = -L$

Polarizer and analyzer

$\mathcal{E} = L$

Electro optic crystal (Lithium niobite ($LiNo_3$)) with mount

V H

$T = T_0$

Detector with mount

Output measurement unit

$\sin^2(\pi D_n L/\lambda) = 1$

2KV DC power supply.

$\frac{\pi D_n L}{\lambda} = \pi/2$

Theory:

$D_n = \frac{1}{2}\frac{\lambda}{L}$

As all of us know, many crystals exhibit birefringence naturally. There are certain crystals which are not birefringent naturally but become birefringent by application of an electric field. The phenomenon generally is called electro optic effect.

Transmission of the laser light through the crystal exhibiting birefringence is given by

$T = T_0 \sin^2 (\Pi D_n L / \lambda)$ 1

150
8

Where T is the transmission, T_0 is the intrinsic transmission of the assembly taking into account all the losses; D_n is the birefringence (ie the difference in the refractive index of two polarizations), L = length of crystal, λ = wave length of the laser.

The birefringence is increasing function of the applied voltage, so that the transmission will be an oscillatory function of the applied voltage.

$\lambda = 632$ nm

The maximum transmission occurs when;

$\frac{\lambda}{4} = 158$ nm

$D_n = ½ \lambda/\cancel{2}$ rad $D_n = \frac{1}{2}\frac{\lambda}{L}$ 2

$= 158 \times 10^{-9}$

This occurs at voltage called half voltage denoted as $V_{\frac{1}{2}}$.

$V_{\frac{1}{2}} = \lambda\, d / 2 r_{22}\, n_0^3\, l$

$= 0.0158 \times 10^{-5}$ m

where l is gap between two electrodes, r_{22} is the electro optic coefficient, n_0 is the ordinary refractive index and λ is the wavelength of light.

$\frac{1}{2} \times \frac{632 \times 10^{-9}}{2.5 \times 10^{-3}} = \frac{632 \times 10^{-6}}{5}$ 3 $\pi D_n \frac{L}{\lambda}$ rad $= \pi/2$ rad

$= \frac{63.2 \times 10^{-5}}{5}$

$= 12.64 \times 10^{-5}$

5

MANUAL

MEASUREMENT OF MAGNETORESISTANCE OF SEMICONDUCTORS

A Product of:

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MEASUREMENT OF MAGNETORESISTANCE OF SEMICONDUCTORS

It is noticed that the resistance of the sample changes when the magnetic field is turned on. The phenomenon, called Magnetoresistance, is due to the fact that the drift velocity of all carriers is not same. With the magnetic field on; the Hall voltage

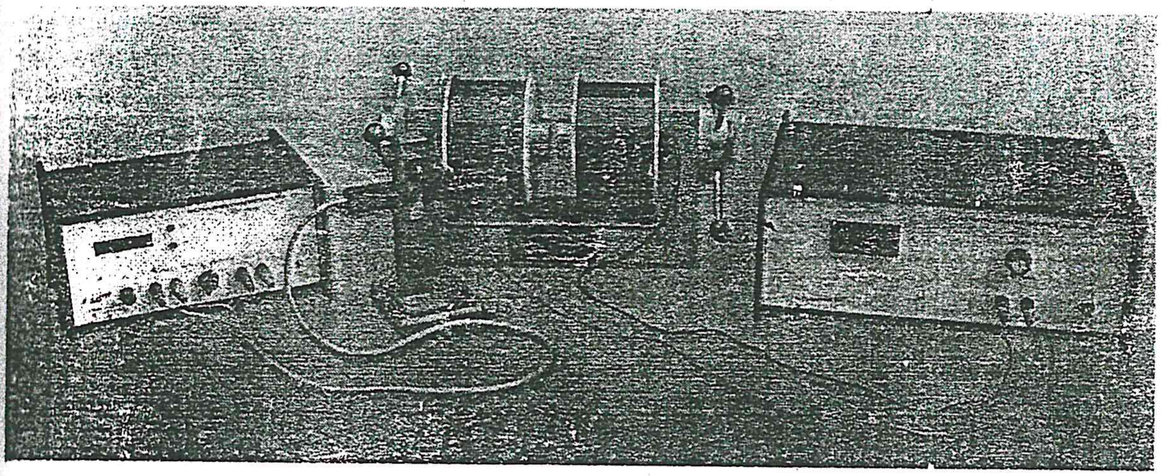
$V = E_y t = |vxH|$ compensates exactly the Lortentz force for carriers with the average velocity; slower carriers will be over compensates and faster one under compensated , resulting in trajectories that are not along the applied field. This results in an effective decrease of the mean free path and hence an increase in resistivity.

Here the above referred symbols are defines as v = drift velocity; E = applied electric field; t = thickness of the crystal; H= magnetic field

Experimental Set-Up For Magnetoresistance

The complete set-up consists of the following

(a) Four probe arrangement
(b) Sample: Ge crystal p-type
(c) Magnetoresistance set-up, Model DMR-01
(d) Electromagnet EM-07
(e) Constant current source Model CS-07
(f) Digital Gaussmeter Model DGM-20



COMPLETE MAGNETORESISTANCE SET-UP

(a) Four probe arrangement:

It consists of 4 collinear, equally spaced (2mm) and individually spring loaded probes mounted on PCB strip. The two outer probes for supplying the constant current to the sample and two inner probes for measuring the voltage developed across these probes. This eliminates the error due to contact resistance, which is particularly serious in semiconductors. A spring loaded plate from is also provided for placing the sample and mounting the four probes on it. The whole system is made on non-magnetic Aluminum strip.

(b) Sample

Highly doped Ge Crystal (p-type) dimension 10x10x0.5 mm

(c) **Magnetoresistance set-up Model DMR-01**

This unit consists of a digital millivoltmeter and constant current power supply. The voltage and probe current can be read on the same 3½-digit 7-segment digital panel meter through a selector switch provided on the front panel.

(i) Digital Millivoltmeter

Intersil 3 ½ digit single IC, ICL7107 has been used. Since the use of internal reference causes the degradation in performance due to internal heating an external reference have been used. Digital voltmeter is much more convenient to use, because the input voltage if either polarity can be measured.

Specification

Range	: 200 mV with 100 uV resolution
Resolution	: 100 uV minimum
Accuracy	: ± 0.2% of the reading + 1 digit
Display	: 3 ½ digit 7 segment LED, auto polarity & decimal Indication

(ii) Constant current Power supply

This power supply, specially designed for Hall Probe, provides 100% protection against crystal burn-out due to excessive current. The supply is a highly regulated and practically ripple free dc source.

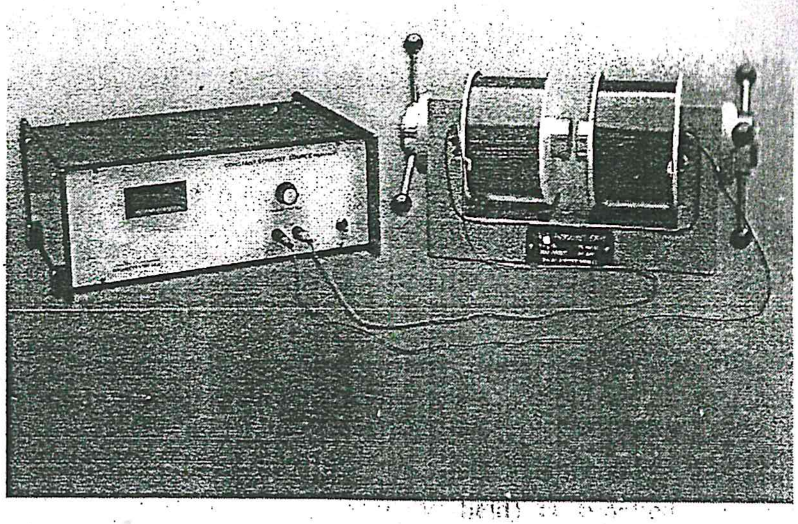
Specifications.

Current	: 0 - 20 mA
Resolution	: 10 μA
Accuracy	: ± 0.2% of the reading ± 1 digit
Open circuit voltage	: 18 volt
Load regulation	: 0.02% for no to full
Line Regulation	: ± 0.05% for 10% in main's voltage

The details of other sub unit can be had from their respective manuals provided

ELECTROMAGNET Model EM-07

These electromagnets have the most widely used 'U' shaped soft iron yoke. **The soft iron of a special quality,** structurally uniform, well machined and finished to meet the rigid standards.



The pole pieces are made from dead annealed soft iron blocks of best quality available. They are well shaped, machined and finished. Normally flat pole pieces are supplied for uniform filed in large area.

The coils are wound on non-magnetic Aluminum formers with uniform layers of R.C.C. copper wire. **The new and modern design of the coils provides good thermal conductivity characteristics and eliminates trouble some hot spots even at high magnetic field.**

SPECIFICATIONS:

Field Intensity	7.0 Kgauss at 10 mm air gap. The air-gap is continuously variable upto 50 mm with two way knobbed wheel screw adjusting system.
Pole Pieces	50 mm diameter flat for uniform field in large area. Normally flat pole pieces are supplied with the magnet.
Energizing Coils	Two, each coil is wound on non-magnetic formers and has a resistance of about …… Ohm.
Yoke Material	'U' shaped soft iron.
Power Requirement	0-35 V @ 4.0 Amp., if the coils are connected in series.

CONSTANT CURRENT SOURCE Model CS-07

Constant Current Source Model CS-07 is an inexpensive and high performance constant current source suitable for small and medium electromagnet. Although the equipment was designed for the electromagnet, Model EM-07 and EM-10, it can be used satisfactorily with any other electromagnet provided the coils resistance does not exceed 6 Ohm.

The current regulation circuit is IC controlled and hence results in the highest quality of performance. Matched power transistors are used to share the load current. The supply is protected against transient caused by the inductive load of the magnet.

APPLICATION

Power source of electromagnets having coil resistance upto 6 Ohm per coil. Reduces current for higher resistance coil.

Suitable for other loads in the range of 6-8 Ohm only.

SPECIFICATIONS:

Current Range	: 0-4 Amp. or as desired
Load regulation	: 0.1% for load resistance variation from zero to maximum
Line Regulation	: 0.1% for $\pm$ 10% mains variations
Protected	: Electronically protected against overload or short circuit.
Display	: 3 ½ digit, 7 segment LED DPM
Power	: 220V $\pm$ 10%, 50Hz

A calibration chart for one fixed air-gap (Current Vs. magnetic field) is supplied. which eliminates the need of a Gaussmeter when supplied with EM-10.

UNPACKING

1. Keeping the case in upright position and remove all the nails from the top lid.
2. Remove the side panels also and unscrew the clamp holding the base of the magnet with the bottom of packing case.
3. Put the magnet on a table. The magnet is in a assembled state, including the coils connections. Fix the handles provided in a small box with the magnet.

OPERATING INSTRUCTIONS

1. Connect the two coils in series i.e. the direction of current in both the coils should be same. Otherwise little or no magnetic field would results even as full current.
2. Connect the leads to the power supply and switch on the power supply. The electromagnet is now ready to use.

PRECAUTIONS

1. Power supply should be connected to a 3-pin main's socket having good earth connection.
2. Always increase or decrease the current gradually, switch .ON. or OFF the power supply at zero current position.
3. Keep the pole pieces covered with small amount of grease to avoid rusting and the magnet as a whole may be covered with dust cover provided, when not in use.