MEASURMENTS WITH MACH-ZEHNDER INTERFEROMETER

Aim: 1. Set-up a Mach-Zehnder interferometer
2. To determine the refractive index of air as a function of pressure.
3. To find the refractive index of the glass in the form of a plate.
4. Determination of wavelength of light / Calibration of micrometer movement

Components and Equipments :

Bread board to assemble optical components, Diode Laser with power supply, Laser mount, Beam splitters with mount, Mirrors with mounts, Rotation stage with glass slide mount, Pressure cell, Screen.

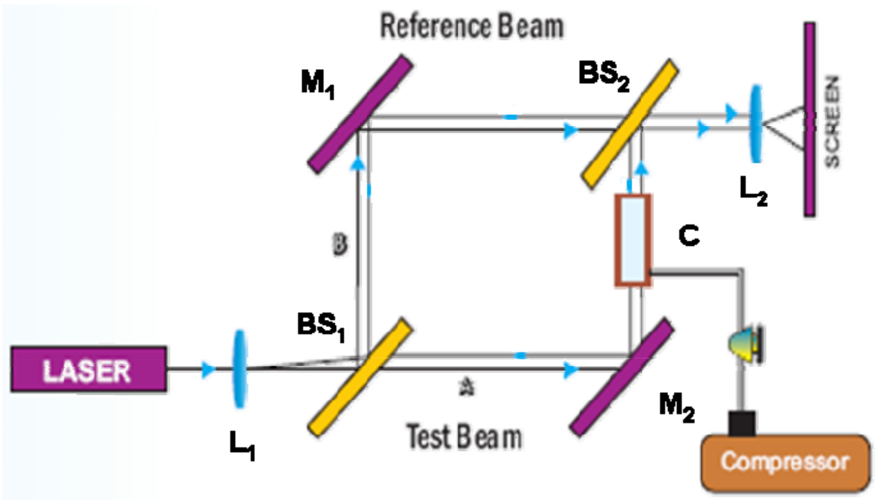

Fig. 1 (Note that in the actual experimental setup the reference and test beams are interchanged)

Warning : The interferometer beam splitters and mirrors have very sensitive surfaces. Please do not touch them. Check with your instructor before making any adjustments that require you to touch any of the glass surfaces.

Procedure :

You need to setup/examine the setup of the interferometer on the bread board as shown in Fig.1. Following components are fixed on the base plate:
A diode laser on an adjustable mount, mirror (M_1) whose tilt is adjustable and can be translated with a screw, mirror (M_2), beam splitters (BS_1 and BS_2) on tilt adjustable mounts. The Mirror M_2 is fitted with a micrometer screw for precise

translation of the mirror via a lever. The lenses L_1 and L_2 and measurement cell C are removed at first.

1. Align the laser so that the beam is parallel with the top of the base. The beam should strike the centers of the mirrors.
2. Adjust the angle of the beam splitter BS_1 as needed so that the reflected beam hits the fixed mirror M_1 near its center. Now the mirror M_1 is adjusted so that the reflected beam hits BS_2 at the center.
3. There should now be two sets of bright dots on the screen; one set comes from the mirror M_1 and the other from the mirror M_2. Adjust the angle of the beam splitter BS_2 and the mirror M_2 such that the two sets of spots overlap on BS_2 and the beams run parallel to each other as they move away from BS_2. This can be checked by moving the screen on the base plate.
4. Expand the laser beam by placing the lens on front the diode laser and look for fringes. It may require some skillful observations and adjustments to get fringes. This written procedure is only a guide line
5. The screws on the back of the mirror M_2 is used to vary the path difference between the two beams.

1. Variation of Refractive index of air with pressure:

To carry out this experiment an air cell C (Fig.1.) is introduced in the test beams. The pressure inside the cell can be changed by a compressor. If the optical path length of one beam changes by one wavelength, the interference pattern is shifted by one fringe. The optical path length is equal to nL, where n is the refractive index and L is the physical path length. The optical path length can be changed by changing either n or L. In our experiment one of the beams passes through the cell of length L. The air will be compressed in this cell, changing the refractive index n. The other beam passes through the same length of air, but with no cell in that beam, the pressure will remain constant. If the refractive index changes by Δn, the path length changes by ΔnL. As the air is compressed, the pattern will shift by one fringe at each time the refraction index changes by an amount $\Delta n=\lambda/L$. A shift of m fringes will occur when the refractive index changes by an amount $\Delta n=m\,\lambda/L$.

The refractive index for most gases is close to 1. For air and other ideal gases, the difference between the refractive index and 1 is proportional to the pressure of the gas. Thus we define the refractive index of air as **n =1+kp**, where p is the air pressure and k is an unknown constant. When the pressure is changed, the change in the refractive index is $\Delta n=k\,\Delta p$. We can therefore relate the number of fringes shifted , m, to change in pressure $\Delta p= \Delta n/k=m\,\lambda/Lk$.

Therefore the unknown constant,k, is given by $k = m\lambda/L\Delta p$. If we determine m for different settings of Δp, a plot of m Vs Δp will be a straight line. The slope of this line will give $k = (\lambda/L)(1/slope)$. We can calculate the refractive index of air at room temperature and the atmospheric pressure P using

$$n = 1 + \frac{\lambda}{L}\frac{P}{slope} \qquad (1)$$

Observations **:**

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

Result **:** Determine the refractive index of air from Eq.(1)

2. Refractive Index of a Glass Plate

A glass plate mounted on a rotary table is introduced in one of the beams. 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 results in shift of the fringes. The refractive index of the glass plate is given by

$$n = \{(N\lambda)^2 + 2t(1 - \cos\boldsymbol{\theta})(t - N\lambda)\} / 2t\{t(1 - \cos\boldsymbol{\theta}) - N\lambda\} \qquad (2)$$

where t = the thickness of the glass plate, N = number of fringes counted, θ = angle of rotation, λ = wavelength of laser light

Procedure :

1) Place the rotation stage between M_2 and the beam splitter BS_2.
2) Mount the glass plate on the rotation stage.

3) Position the stage and glass plate such that the glass slide is perpendicular to the optical path.
4) When glass plate is introduced in the optical path of Mach-Zehnder interferometer, the fringe may loose contrast. To make the fringe sharpen again, move (not tilt!) the mirror M_2 by translation screw till the clear set of fringes is achieved on the viewing screen. If the fringe centre shifts to a side, it can be brought back by tilts of the mirror $M_{2.}$
5) Slowly rotate the rotation stage. Count the number of fringe translations that occur as you rotate the table through $\pm 20^o$.

Result **:** Calculate the refractive index of the glass plate using Eq.(2).

Assignment:
1. Determine the 'extra path difference' introduced in the beam in which the glass plate of thickness t is introduced normal to the beam, compared to the other beam.
2. When the glass plate is rotated through an angle θ, the 'extra path difference' changes, which is observed in terms of the fringe count N. Determine this change, and hence obtain Eq.(2).
3. Why will fringe pattern loose contrast, when glass plate is introduced.
4. Is there any change in the movement of the fringes while increasing and decreasing the pressure in the cell.
5. Estimate the change in the vacuum wavelength, when the light is used at the atmospheric pressure.

3. Wavelength of Laser beam / Calibration of the micrometer serew

The wavelength of laser light source can be determined if the mirror M_1 is moved in a controlled manner by the micrometer screw and the number of fringes moved counted. The micrometer screw shifts the mirror $M_{1,}$ in the direction of the normal to its surface, through a lever mechanism, which de-magnifies the micrometer movement. The fringe count is given by $\mathbf{L = N\lambda = 2d\Delta}$**,** where L is the path difference that occurs when 'N' fringes pass as the micrometer is moved through a distance of 'd' and **Δ** is the calibration constant that depends on the angle between the light beam and the mirror as well as the demagnification factor M of the lever. Alternatively the calibration constant of the mirror movement, can be determined if λ is known.
Procedure: Determine the micrometer reading every time the fringe count changes by 5 and plot 2d vs N. The slope of this graph can be used to determine **Δ.**
Assignment : Prove that $\mathbf{\Delta = (\cos\theta)}/M$