Experiment No. 2

Object: To study the Magnetostriction in metallic rod with the help of Michelson interferometer arrangement.

Apparatus Used: He-Ne Laser with adjustable stand, Magnetostriction set-up with mechanical and optical components to construct Michelson Arrangement, Magnetostriction coil, Constant current source, Screen, Post mount stand.

Formula Used:

Magnetostriction effect in ferromagnetic rods is characterized by the change in its length as magnetization increases from zero to its saturation value. The change in length (Δl) is measured with Michelson arrangement by using the following formula:

$$\Delta l = \frac{n\lambda}{2}$$

where,

n = Change in the no. of fringes (i.e. no. of fringes appeared or disappeared)

λ = Wavelength of the light source used in Michelson arrangement (i.e. He-Ne laser 6328 x 10^{-8} cm)

Theory:

Basic methodology involved:

In the Michelson interferometer (M.I.) arrangement, an interference pattern is obtained with the help of two mirrors. A rod of ferromagnetic material is attached with one of the mirrors and this rod is surrounded by a solenoid. The magnetic field is produced in the solenoid when current flows through the solenoid. Due to the change in current flowing in the solenoid, the intensity of produced magnetic field changes which in turn changes the length of the ferromagnetic rod attached with one of the mirrors. So the mirror attached with ferromagnetic rod moves forward or backward as length of rod changes due to magnetostricitive effect. This change in length of rod is very small which cannot be measured by ordinary scale. M.I. is used to measure this small change in length as the wavelength of source used is of the order of μm in this experiment. So any change in length of the order of wavelength can be measured by this experiment. Due to the shift in position of one of the mirrors, the interference pattern of M.I. changes and fringes appear or disappear at the centre of the fringe pattern.

Michelson interferometer:

In a Michelson interferometer, the light beam from a laser source splits into two beams (amplitude splitting) by a half-silvered glass plate (beam splitter), each of these beams is reflected by a mirror, and brought to interfere on a screen placed behind the beam splitter as shown in Fig.1.

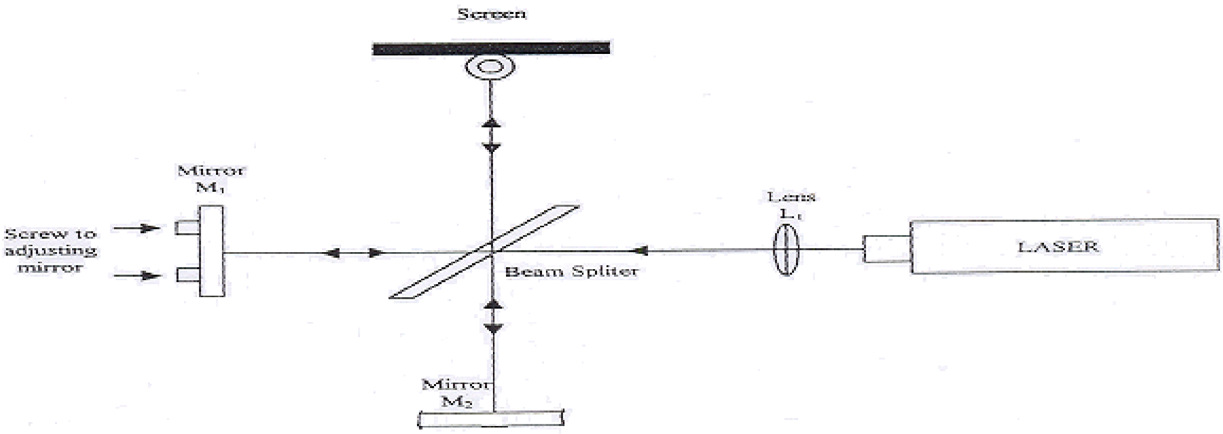

Fig. 1: Michelson interferometer

The lens $\mathbf{L_1}$ is used to expand the light beam between laser and the glass plate and this will produce the circular interference fringes. In order to see circular interference fringes, the light beam is expanded between the laser and the glass plate by a lens $\mathbf{L_1}$.

The light beam travels an extra distance (say **d**) towards the mirror $\mathbf{M_1}$ w.r.t mirror $\mathbf{M_2}$. In order to understand the formation of fringes, if the real mirror $\mathbf{M_2}$ is replaced with its virtual image $\mathbf{M_2'}$,which is formed by reflection by the glass plate, a point **P** of the real light source appears as the points **P'** and **P''** of the virtual light sources **L1** and **L2** as shown in Fig. 2.

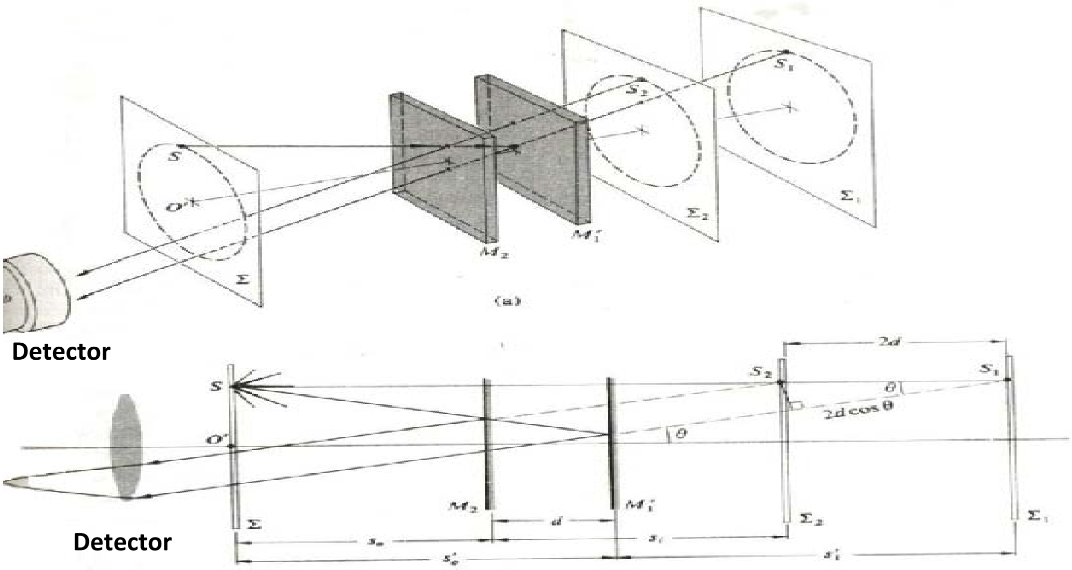

Fig. 2: A conceptual arrangement of Michelson interferometer showing the formation of circular interference fringes.

As a consequence of the different path lengths traversed by light from mirror $\mathbf{M_1}$ and $\mathbf{M_2}'$, the phase difference between virtual light sources is given by:

$$\delta = \frac{2\pi}{\lambda} 2d \operatorname{Cos} \theta$$

Where, λ is the wavelength of the laser light used.

Alignment of these two virtual light sources with the help of screws attached to mirror $\mathbf{M_1}$ as shown in figure 1, produces an interference pattern on the screen, where maxima occurs when δ is equal to an integer multiple of 2π or we can say that when path difference is governed by the following relation:

$$2d \operatorname{Cos} \theta = m\lambda \; ; m = 1,2,3 \ldots \ldots \ldots \ldots$$

The value of *m* is maximum for central ring and decreases when we progressively move away from the centre towards the boundary .i.e. for fixed values of *m* and *d*, *Θ* remains constant over a conical surface and, hence circular fringes are produced on the screen.

<u>Magnetostriction and its measurement using Michelson interferometer arrangement:</u>

Magnetostriction and piezo-magnetism are defined as the change in dimension (induced strain) of the ferromagnetic sample when magnetic field is applied or production of magnetisation in the sample with applied stress.

The interaction between the magnetic moments of the atoms that produces alignment of the moments acts as a force between the atoms. In the presence of large external magnetic field magnetic moments are forced to become oriented in field directions and this will influence the interaction force between the atoms and hence the interatomic distances. The material now (usually) responds by some changes in its dimension, this effect is called **Magnetostriction**.

The measurement of Magnetostriction or alteration in the length of a rod **(Δl)** due to an applied magnetic field is measured by appearance or disappearance of fringes due to shifting of mirror $\mathbf{M_2}$ as shown in Fig 3:

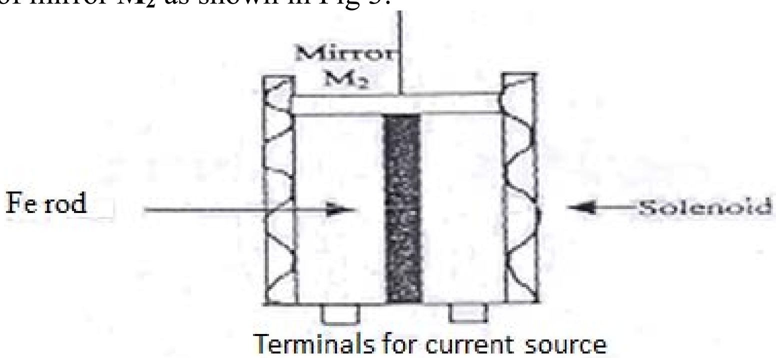

Fig 3: A solenoid with sample rod inside it attached to mirror M_2 of Michelson interferometer. Terminals are used to provide current to solenoid.

In the presence of solenoid magnetic field distortion of rod shifts the position of mirror $\mathbf{M_2}$ and this cause the appearance/disappearance of fringes on the screen. Hence the distortion in the length of rod is written as:

$$\Delta l = \frac{n\lambda}{2}$$

Where

n = Change in the no. of fringes

λ = Wavelength of the laser source

Experimental set-up:

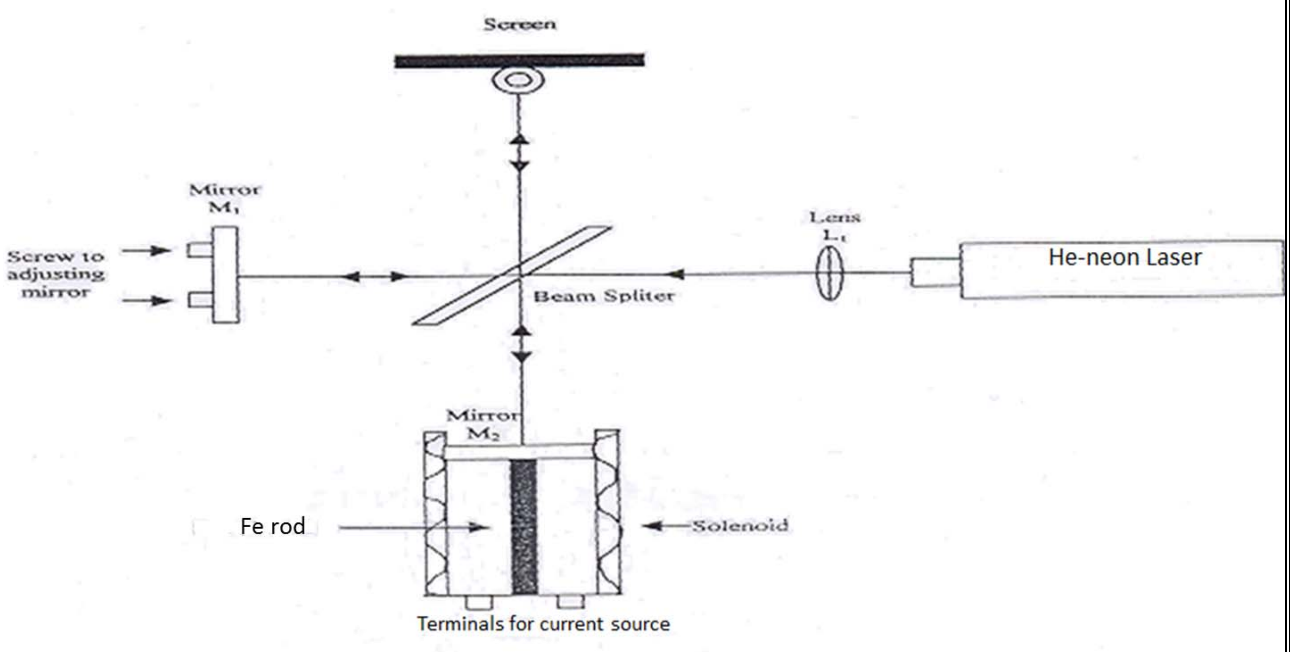

Fig 4: Michelson arrangement

Procedure:

1. Put the He-Ne Laser on stand at the fixed end side of the mini optical bench i.e. on right hand side of the set-up. Switch 'ON' the laser. Align the laser such that the laser beam falls in the middle of lens L_1 which spread out the beam.

2. Align the laser beam, beam splitter and mirror M_2 such that the laser beam from lens L_1 falls on the beam splitter.

3. Adjust the beam splitter such that it reflect the 50% of the incident light to the mirror M_2 which again reflected and relayed to the projection screen through beam splitter, while the other 50% part of the incident beam is transmitted through beam splitter and

fall on mirror M_1 which again reflected it and also proceed through beam splitter on the screen. Thus we get two luminous spot on the screen. Make them closer by adjusting Magnetostriction coil. Coincide these spots by adjusting the mirror M_2 (by very slightly adjusting the screws provided at the back side of mirror M_2) until as slight flickering of the luminous spot can be seen on the screen.

4. Get the clear interference pattern on the screen by adjusting mirror M_1 and Magnetostriction coil with mirror M_2.

NOTE: The mirror M_2 should be in the middle of the Magnetostriction coil.

5. Connect the Magnetostriction coil with the constant current source and apply some current say 200 mA. The rings in the interference pattern will start appearing. Note the total number of rings appearing for a definite time (say 5 minutes) corresponds to the coil current. Make table as shown below and record these readings in table.

6. Switch 'OFF' the current source, the interference ring will start disappearing. Note the total number of rings disappear for the definite time (same as it was in the case of counting rings appearing, say 5 minutes). Record these readings also in table.

7. Repeat the experiment for different values of coil current say 300 mA, 400 mA, 500 mA etc.

8. Calculate the change in length corresponding to different coil currents.

Observations:

(a) Table for observation of shift in fringes:

S. No.	Current I (mA)	No. of rings appears in 5 mins (n_1)	No. of rings disappears in 5 mins (n_2)	Mean $n = (n_1 + n_2)/2$
1.	200			
2.	300			
3.	400			
4.	500			

(b) Table for relative change in length:

S. No.	Magnetostriction Coil Current I (mA)	Relative change in length $\Delta l/l$ (l= 11.9 cm)
1.		
2.		
3.		
4.		
.		
.		

<u>Calculations:</u>

(i) For Magnetostriction coil current, I = 300 mA

The mean of no. of rings, $n =$

Wavelength of laser light, $\lambda = 6328 \times 10^{-8}$ cm

Therefore, the change in length, $\Delta l = n\,\lambda / 2$

(ii) Similarly we can calculate Δl for other value of coil current.

(iii) Plot a graph for fractional change in length ($\Delta l / l$) vs applied current (I).

<u>Results:</u> The fractional change in the length for different coil currents due to positive Magnetostriction effect in Fe rod is shown by the curve between ($\Delta l / l$) and I.

<u>Maximum Probable Error:</u>

$$\Delta l = \frac{n\lambda}{2}$$

Taking log of both sides and differentiates, we get:

$$\frac{\Delta(\Delta l)}{\Delta l} = \frac{\Delta n}{n} \#$$

\#

Where

$\Delta(\Delta\lambda)$ =Least count of the instrument which is used to measure the initial length of the rod.

Δn = Least no of fringes appearing or disappearing (i.e. 1).

Sources of error and precautions:

(i) Alignment of set up should not be disturbed during this experiment.

(ii) Don’t see the laser source directly.

(iii) He-Ne laser should fall normal on lens L_1.

(iv) Count the no. of rings appearing and disappearing accurately.

Viva-Voice:

Q1. What are the necessary conditions to get interference pattern?

Q2. Explain the division of amplitude method for interference.

Q3. Why circular fringes are observed in Michelson arrangement?

Q4. In the Michelson interferometer arrangement, what changes are observed in interference pattern, when the distance between beam splitter and one of the mirror is increased/decreased?

Q5. Give some applications of Michelson interferometer.

Q6. Define the term ferromagnetic materials and discuss the same in terms of magnetic domain.

Q7. What is Magnetostriction?

Q8. What is Piezo-magnetism and how it’s different from Magnetostriciton?

Q9. What is the Magnetostrictive energy and also describe the Magnetostriction phenomena in the term of this energy?

Q10.Describe any useful application in which Magnetostriction phenomena is involved

References:

1. Optics by Ajoy Ghatak (TMH): *From this reference you can learn about Interference, Division of amplitude and Michelson Interferometer.*
2. Elementary Solid State Physics by Omar Ali (Pearson): *From this reference you can learn about Ferromagnetic material, Magnetic domains, Magnetostrictive energy and Magnetostriction.*
3. Advanced Practical Physics by B. L. Worshnop and H.T. Flint (KPH).
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5. Advanced Practical Physics Vol. I & II by Chauhan & Singh (Pragati Prakashan).