FABRY-PEROT INTERFEROMETER

Objectives:

I. **Alignment of Fabry-Perot Interferometer to observe concentric circular fringes**

II. **Measurement of the wavelength of a diode Laser**

Introduction

The Fabry-Perot interferometer uses the phenomenon of multiple beam interference that arises when light shines through a cavity bounded by two reflective parallel surfaces. Each time the light encounters one of the surfaces, a portion of it is transmitted out, and the remaining part is reflected back. The net effect is to break a single beam into multiple beams which interfere with each other. If the additional optical path length of the reflected beam (due to multiple reflections) is an integral multiple of the light's wavelength, then the reflected beams will interfere constructively. More is the number of reflection inside the cavity, sharper is the interference maximum. Using Fabry-Perot (FP) interferometer as a spectroscopic tool, concepts of finesse and free spectral range can be understood.

Principle of Working

The basic principle of working of the Fabry-Perot interferometer is schematically explained in the adjacent figure.
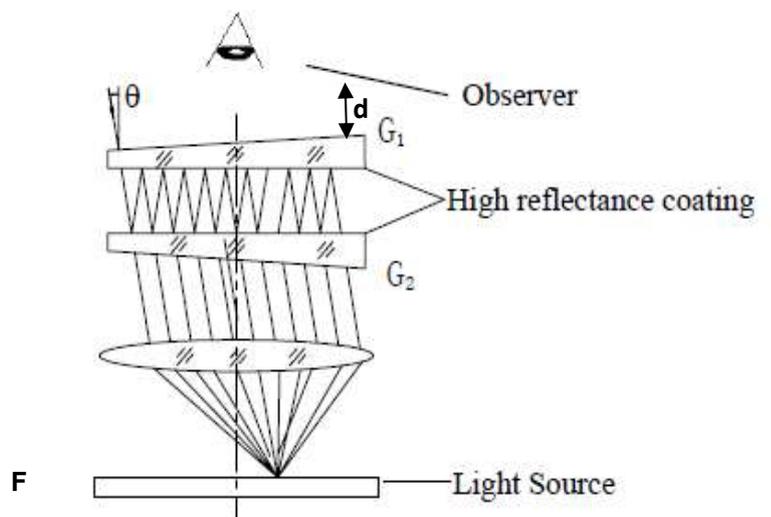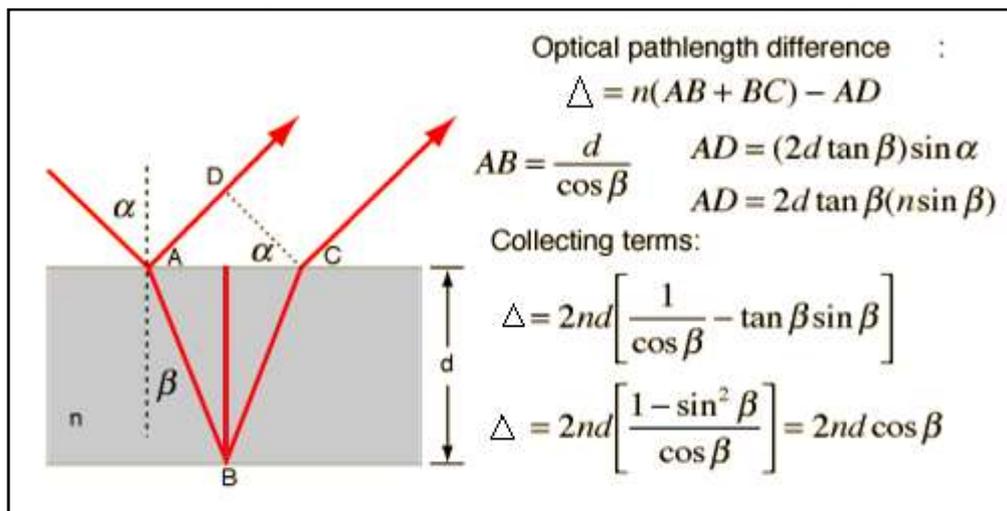

Fig 1: Schematics of a Fabry-Perot Interferometer

Two partial mirrors **G1** and **G2** are aligned parallel to one another at a distance d, forming a reflective cavity. When irradiated by a monochromatic light (a laser here) of wavelength λ at an angle of incidence θ, multiple reflections takes place inside the cavity. Part of the light is transmitted each time the light reaches the second reflecting surface. All such transmitted light rays interfere with each other to give rise to a maxima or minima depending on the path difference between them. Let n be the refractive index of the medium in the cavity (in this case it is air). Then the optical path difference between two neighbouring rays is:

$$\Delta = 2nd\cos\theta \quad \ldots \quad \ldots \qquad (1)$$

Then the phase difference is given by $\delta = \left(\frac{2\pi}{\lambda}\right)\Delta \ldots \quad \ldots \qquad (2)$

In the figure below calculation of path difference is shown for a general cavity is shown where α and β are the angles of incidence and refraction, respectively.

Optical pathlength difference :
$$\triangle = n(AB + BC) - AD$$
$$AB = \frac{d}{\cos\beta} \qquad AD = (2d\tan\beta)\sin\alpha$$
$$AD = 2d\tan\beta(n\sin\beta)$$

Collecting terms:
$$\triangle = 2nd\left[\frac{1}{\cos\beta} - \tan\beta\sin\beta\right]$$
$$\triangle = 2nd\left[\frac{1 - \sin^2\beta}{\cos\beta}\right] = 2nd\cos\beta$$

Fig 2. Calculation of path difference

Thus, the resultant transmitted light intensity I_T is:

$$I_T = I_0 \frac{1}{1 + \frac{4R}{(1-R)^2}sin^2\frac{\delta}{2}} \qquad \ldots \qquad \ldots \qquad (3)$$

where, I_0 is the incident intensity, R is the reflectivity of the mirrors. It can be noticed that I_T varies with δ.

I_T is maximum when $\quad$ Δ = mλ (m = 0, 1, 2…) or δ = 2mπ… $\quad$ … $\qquad$ (4)

and minimum when $\quad\quad\quad \Delta = (2m +1)\lambda/2$ ($m =0, 1, 2…$) or $\delta = (2m+1)\pi$ ... (5)

The complete interference pattern appears as a set of concentric rings. The sharpness of the rings depends on a parameter called coefficient of finesse, F, defined as $F = \dfrac{4R}{(1-R)^2}$.

Determination of wavelength λ : Using the relations 1 and 4 (or 5) wavelength of the incident light can be determined accurately. Let the initial separation between the mirrors is d_1. If one counts the number of fringes (say maxima) appearing or disappearing at the centre ($\theta \approx 0$) by varying the distance between the mirrors to d_2, then λ can be determined as follows:

$2d_1 = m_1 \lambda,\quad\quad\quad 2d_2 = m_2 \lambda,\quad\quad\quad m_2 - m_1$ = Number of maxima counted

$$\lambda = \frac{2(d_2 - d_1)}{m_2 - m_1}\quad\quad\quad ...\quad\quad ...\quad\quad\quad (6)$$

Apparatus:

1. Optical Rail (1 meter)

2. Fabry-Perot setup (Fixed Mirror mount with Two Etalon)

3 Movable Mirror with Kinematic and fine linear Micrometer (0-10 mm)

4 Diode Laser mount with Kinematic (5 V) Power Supply

5 Achromatic Lens mount

6 Frosted Glass viewing Screen and mount with Micrometer
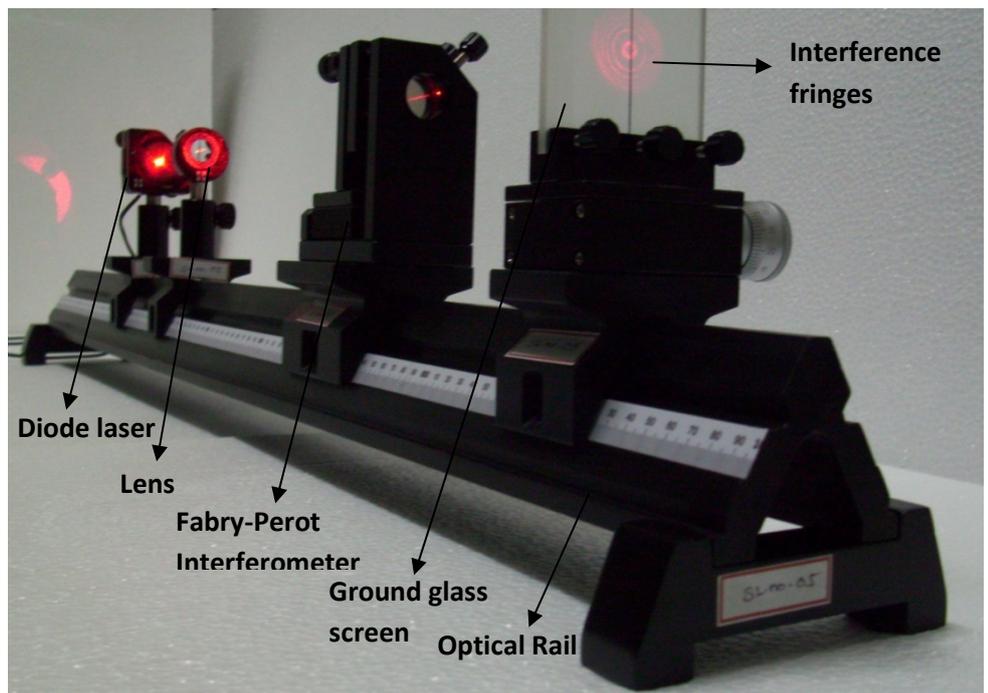
Fig 3. The Fabry-Perot set up

Procedure

I. Alignment of Fabry-Perot Interferometer to observe concentric circular fringes

1) Mount and lock the diode laser on the optical rail towards one end.

2) Mount the Fabry-Perot interferometer towards the middle of the optical rail (about 40 cm from laser). It has one fixed and one movable mirror as shown in Fig. 4.

3) Adjust the three screws behind the movable mirror to make sure that the two mirrors are visibly parallel to each other approximately and the distance between them is about 2mm.

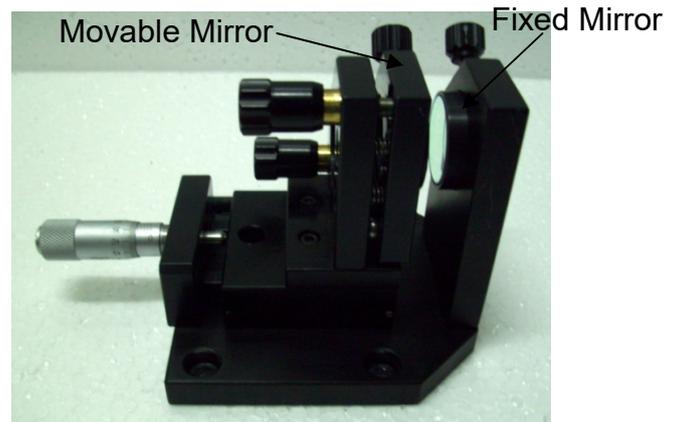**MAKE SURE THAT THE TWO MIRRORS NEVER TOUCH EACH OTHER'S SURFACES**.

Fig.4: Fabry-Perot interferometer

4) Mount the ground glass screen at the other extreme end.

5) Switch on the diode laser and adjust it such that the beam passes through the centre of the two mirrors. Adjust the two black screws (for movement in x and y directions) behind the movable mirror to let the multiple reflected beams coincide on the screen. It means both the mirrors are now nearly parallel.

6) Place a lens (f= 100mm) in front of the laser to expand the beam to create a broad source. Adjust the position of the lens so that the entire reflection cavity is illuminated. With all the components perfectly set, the observer can find a series of very intense, concentric circular interference rings on the ground glass screen.

II. Measurement of the Wavelength of a diode Laser

1) Setup the F-P interferometer as described above to observe clear circular fringes at the centre of the ground glass screen.

2) Determine the least count of the micrometer screw attached to the movable mirror. Record the reading d_1 of the fine micrometer.

3) Turn the micrometer slowly and count the number of fringes that appear (or disappear) at the centre of the ground glass screen. Keep on recording the micrometer reading d_2 after every count 50 fringes.

CAUTION: The micrometer screw is extremely sensitive. So move it very slowly to avoid collapse of many fringes while counting, which will lead to error.

4) Acquire enough data and fill up the observation table. Plot a suitable graph to get a straight line. Find slope of the graph and use Eq. 6 to determine λ.

Obervation Table: Least count of micrometer = ...

Initial position of micrometer, d_1 = ...

Sl. No.	No. of fringes appaeared/disappeared m_2-m_1	No. of divisions rotated on micrometer	$d_2 - d_1$ (cm)
1	50		
2	100		
3	150		
..	..		
..	..		
..	..		

Graph: From graph, using least square fit, find Slope = ...

Calculations: λ = ...

Estimation of error:

Precautions:

1. Do not touch or contact in any way either the front or back surfaces of the mirror pieces. Doing so will permanently damage the mirror coatings.
2. Avoid eye exposure to the direct laser beam.
3. Move the micrometer screw very slowly.

Reference: Max Born, Emil Wolf. Principles of Optics. Pergamon Press, Oxford.