5. Theory

When a ray of light passes through a plane-parallel plate with two reflecting surfaces, it is reflected many times between the two surfaces and hence multiple-beam interference occurs. The higher the surface reflectance is, the sharper the interference fringes are. That is the basic principle of a Fabry-Perot interferometer. As shown in Figure 2, two partially reflecting mirrors $\mathbf{G_1}$ and $\mathbf{G_2}$ are aligned parallel to each other, forming a reflective cavity. When monochromatic light is incident on the reflective cavity with an angle θ, many parallel rays pass through the cavity to get transmitted. The optical path difference between two neighboring rays is given by δ:

$$\delta = 2nd\cos\theta$$

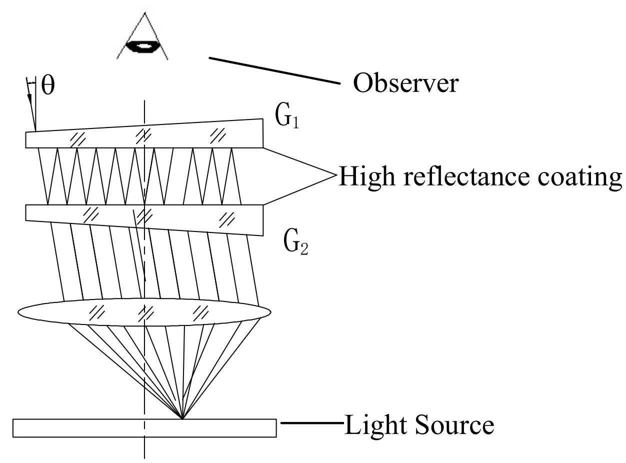

Figure 2 Schematic of Fabry-Perot interferometer

Thus, the transmitted light intensity is:

$$I' = I_0 \frac{1}{1 + \frac{4R}{(1-R)^2}\sin^2\frac{\pi\delta}{\lambda}}$$

where I_0 is the incident light intensity, R is the mirror reflectivity, n is the refractive index of the medium in the cavity, d is the cavity length or mirror spacing, and λ is the wavelength of the monochromatic light in vacuum.

Thus, I' varies with δ. When

$$\delta = m\lambda \qquad (m = 0, 1, 2\ldots)$$

I' becomes maximum so that constructive interference of the transmitted light occurs; when

$$\delta = (2m'+1)\lambda/2 \qquad (m' = 0, 1, 2\ldots)$$

I' becomes minimum and destructive interference of the transmitted light is observed.

6. Experimental Examples

6.1 Observation of Multi-Beam Interference

1) Place the main unit on a stable table free from vibrations.
2) Adjust the preset micrometer till the spacing between the two mirrors G1 and G2 is approximately 1~2 mm. **Warning:** mirrors move closer when turning the preset micrometer in counter clockwise direction. Keep an eye on mirror gap while turning the preset micrometer to avoid mirror collision.
3) Place the pinhole plate on the open window of the Sodium lamp, observe these pinhole images generated by multiple reflections of the two mirrors behind the F-P cavity, and adjust the two kinematic screws of G_2 to make the comet-like images shrink to minimum in all directions. This means the two mirrors are approximately parallel. **Warning:** keep an eye on mirror gap while adjusting the kinematic screws to avoid mirror collision.
4) Replace the pinhole plate with the ground glass (G) to create an extension light source, and sharp multi-beam interference rings can be observed behind G_2 with a naked eye as shown in Figure. 3.

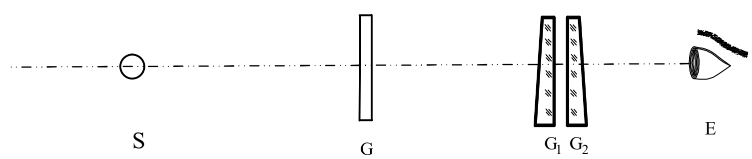

Figure 3 Observing patterns of multi-beam interference

5) Move your eye up and down to see whether the diameter of the central ring changes, finely adjust the left-upper kinematic screw of G_2 mirror till no diameter changes are observed. Similarly, move your eye left and right, and adjust the right-lower screw. Finally, the two mirrors will be almost perfect parallel when no diameter changes observed anywhere. Note: the mirrors were pre-aligned at factory, so only minor adjustments of the kinematic screws may be needed. **Warning:** keep an eye on mirror spacing while adjusting the kinematic screws to avoid mirror collision.

   Note: it is suggested that this and the following experiments be conducted under dim or dark environment on an optical table free from vibrations.

6.2 Measurement of the Wavelength Difference of Sodium D-lines

The yellow Sodium doublet consists of two spectral lines (D-lines) with a small wavelength difference. When a Sodium lamp is used as the light source, the combined interference fringes of the two spectral lines will alternatively appear as clear and blur as the movable mirror is moved continuously. The wavelength difference of the yellow sodium doublet lines is given by

$$\Delta\lambda = \frac{\bar{\lambda}^2}{2\Delta d}$$

Where $\bar{\lambda}$ is the averaged wavelength of the two lines that is set as 589.3 nm, Δd is the distance between two adjacent locations of the movable mirror that creates blur interference patterns.

The experimental procedures are as follows:

1) From the previous experiment, the two mirrors of the F-P cavity are almost adjusted to be perfect parallel. Move the movable mirror close to the fixed mirror with a separation of approximately 1~2 mm (**Warning:** keep an eye on mirror spacing to avoid mirror collision), and obtain a clear, wide-spaced interference pattern of Sodium doublet;
2) Slowly turn the fine micrometer to increase mirror spacing, fringes become blur gradually, till all the fringes disappear. Record the reading d_1 of the fine micrometer;
3) Continue to turn the fine micrometer in the same direction and new interference pattern appears. Record the reading d_2 where the interference pattern vanishes again;
4) Repeat this process in different places near zero path difference point to get an average value of $\Delta d = |d_1 - d_2|$.
5) Calculate the wavelength difference of the yellow Sodium doublet.

Note: this experiment can be conducted by just observing behind the F-P cavity with naked eyes, but it would be better to use the provided convex lens and the mini microscope as shown in Figure 1. Figure 4 shows a photo of the interference fringes of Sodium D-lines taken through the mini microscope, illustrating Sodium D-lines of 589.0 nm and 589.6 nm well resolved by the Fabry-Perot interferometer.

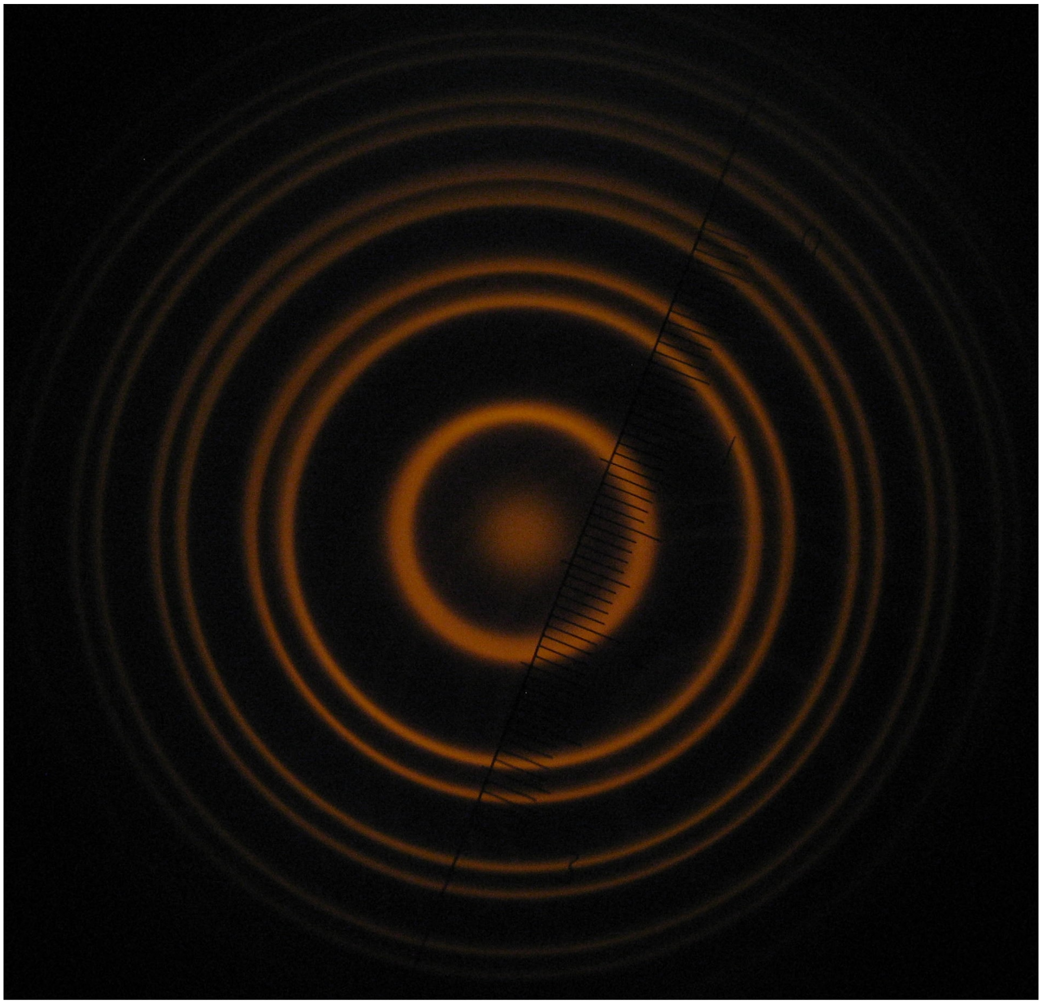

Figure 4 Interference patterns of Sodium D-lines