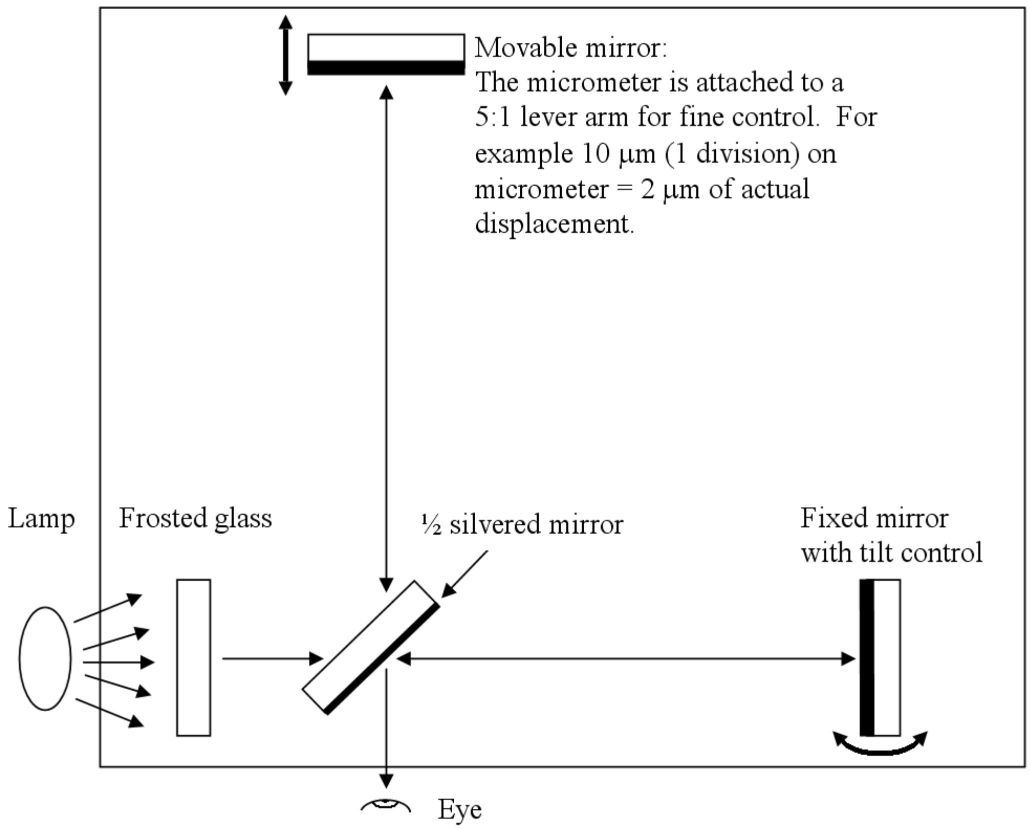
Experiment 7: Michelson Interferometer PHY 431

During the last lab, fringes could be seen when two glass surfaces were pressed against each other, with waves interfering when reflected off two different, but nearly parallel, glass surfaces. In a Michelson interferometer again a pattern is observed, when waves subject to two different fates interfere. Specifically, in that interferometer a single beam of light is split into two beams by a half-silvered mirror. Each beam travels to a different mirror, which directs the reflection again back to the half-silvered mirror, see the figure. The resulting light, that reaches the observer, is a superposition of the two beam portions which interfere yielding a fringe pattern.



For a narrow beam of light, if the two arms of the interferometer have exactly the same length, the optical path difference (OPD) between the two rays will be zero. Hence, if no phase difference is introduced by the reflection process, the two arriving rays will be in-phase and a bright fringe will appear straight on. If you have an extended light source, though, you will see a radial pattern of light and dark fringes, as path length differences develop for rays traveling from different points at slightly different angles relative to the optical axis. If the movable mirror changes position, OPD changes and the fringe pattern evolves. However, when the light has a well-defined wavelength, each time the mirror position is shifted by $\lambda/2$, the OPD increases or decreases by one wavelength. In this situation, the fringe pattern returns approximately to its original form. If the mirror images seen by the observer are perfectly parallel to each other, the fringe pattern is circular. If there is some misalignment an elliptical pattern emerges and possibly just a portion thereof in the form of nearly parallel lines is seen.

In section D, involving sodium lamps, you will investigate a beat pattern. This phenomenon is very familiar to those you who have tuned a stringed musical instrument. For two strings tuned to a slightly different frequency, the ear does not hear the pure tone of either string. Instead you hear a tone equal to the average frequency, but the amplitude is pulsing.

Procedure:

A. Using a Hg lamp as source (λ=546.1 nm—green line) play with the controls of the interferometer and observe straight and circular fringe patterns. As the OPD is varied, circular fringes may appear from or disappear toward the center. If they are appearing, moving outward from the center, then the OPD is increasing. If the fringes are disappearing, moving toward the center, with the center becoming fringe sink, then the OPD is decreasing. Try to get the OPD close to zero for central rays. Near zero, the fringes will be very thick and it will be difficult to tell whether they are moving inward or outward when OPD is varied.

B. Now switch to a white light source and carefully search for fringes. You will likely find that you can only see fringes if the OPD is less than 3λ. If you lose the pattern, you may need to go back temporarily to the monochromatic source. **Q1.** Why does the OPD have to be nearly zero to see the pattern for the white light? For the most pronounced pattern, the fringe in the center corresponds to the angle where the OPD is exactly zero. **Q2.** Does the center fringe appear to be dark or bright? How can you explain this? Record the position of the micrometer at zero OPD for your interferometer.

C. Return to the Hg lamp to measure the wavelength for the green line. It is recommended that you adjust the appearance of the fringes to minimize eye strain. While slowly moving the mirror, count at least 50 fringes appearing. From the distance by which the mirror moved, you can find the wavelength. **Q3.** What is the wavelength (in nm) and its uncertainty?

D. Now switch to the yellow Na lamp. The yellow line of the Na lamps actually represents two very closely spaced lines at 589.0 and 589.6 nm. Near zero OPD you will observe clear fringes. As the OPD increases, the fringe pattern contrast decreases and becomes difficult to see. But the contrast eventually will increase again at larger OPD. You can go through several maxima and minima in this way. What you are seeing is the beat pattern between the two sodium lines. By measuring the wavelength and the separation of minima, calculate $\Delta\lambda$ using the formula

$$\frac{\Delta\lambda}{\lambda} = \frac{1}{n}$$

Here, *n* is the number of fringes in one period (minima to minima) - OPD then changes by $n\lambda$. This exercise requires going over more than 100 fringes. To maintain your sanity and eyesight, you may estimate the number of fringes, instead of counting every one. **Q4.** What is the wavelength difference of the two Na emission lines? What is the uncertainty in $\Delta\lambda$?