OBJECTIVES

To observe the fine structure lines of mercury and the Zeeman splitting of one or more of these lines as a function of magnetic field.

To compare the observed splitting with theoretical splitting.

REFERENCES

Melissinos, sections on Mercury in Chap. 2 and Chap. 7.
Tipler, section on Zeeman effect.
Vaughn, "The Fabry Perot Interferometer".
Born and Wolf, "Principles of Optics".
Hernandez, "Fabry-Perot Interferometers"
(The last three may be checked out in the stockroom)

ZEEMAN EFFECT

The observation of spectral line splitting when an atom is placed in an external magnetic field --known as the Zeeman effect--was first explored by Faraday. However, because of the low resolution of his instrument, he was unable to detect any spectral line splitting. It was later successfully observed by Zeeman, for whom the effect was named.

This advanced laboratory employs a Fabry-Perot interferometer, a high-resolution spectroscopic instrument. It produces a fringe pattern when a light beam hits and transmits through and/or reflects off its mirrors causing interference. Use the reference texts listed above to understand interferometer basics. It can be seen that when a discharge lamp is placed in a magnetic field, each interference fringe is split into several fringes. One can analyze such an effect in light of quantum mechanics as well as classical mechanics.

GENERAL ARRANGEMENT

The apparatus, as shown in Fig. 1, consists of six main parts: (1) a laser and a beam steering mirror for rough adjustments, (2) a discharge lamp placed in an electrically powered magnet, (3) a condensing lens assembly, (4) a collimating lens assembly, (5) a linear polarizer, (6) a Fabry-Perot interferometer, and (7) a photomultiplier (PMT) detector unit. Students are expected to be able to set up the apparatus by following the procedures below and by experimenting with other arrangements.
ALIGNMENT OBJECTIVES - GENERAL

1. Insure that angle of incidence of light is completely normal to the front surfaces of the interferometer mirrors,

2. incident light is perfectly collimated (parallel), and

3. interferometer mirrors are perfectly parallel.

The procedures outlined below are suggested methods to help you achieve these objectives. You will probably discover better ways.

Laser Alignment

The laser is used in this experiment simply as an alignment tool to aid in the adjustment of your optical components. First, adjust the height of the laser so that the beam is at the same height as the center of the interferometer mirrors (it should also pass directly through the center of the magnet pole pieces). Place the laser straight to the beam steering mirror, which faces the laser at 450 in order to project the laser beam along the length of the table. Adjust the two knobs of the mirror so that the laser beam is parallel to the table top (height adjustment) and aligned with a line of screw holes (side adjustment) all the way along the top of the table. Use the glass rulers to measure the horizontal and vertical displacement of the laser path. One knob of the mirror controls the deflection horizontally and the other vertically. Concentrate at first on making the beam parallel to one of the rows of screw holes, because once it is straightened horizontally, the whole path can be shifted laterally by adjusting the translator stand of the mirror (not the angle of the mirror).

About Lenses

Referring to the figure, there are two lenses, 1 and 2, in the condensing unit and one, lens 3, in the collimating unit. Light rays from the light source are divergent. When Lens 1 is focused on the light source, it generates nearly parallel light for better focusing by lens 2. Besides making light nearly parallel, lens 1 can provide fine adjustments of the light path along the x- and y- directions. Assumptions here are (1), that light between lens 1 and lens 2 does not have to be parallel for the rays emerging out of lens 3 to be parallel and (2), that the x- and y-adjustments of lens 1 do not prevent the final rays from being parallel. What is meant by x- and y-adjustments is that as you move lens 1 around using the two thumb screws on the condensor, the image of light projected on the pinhole aperture of the collimating unit also moves around. Next, focusing of light on the aperture is done by lens 2. The aperture acts as a point source. Lens 3 is focussed on the light rays from the point source and is adjustable along the z-axis to make them parallel.

Positioning Elements

Place all the elements (condenser, collimator, etc.) one at a time, so that their optical axis is at the same height as the interferometer. Start with the condensing lens. The focal length of lens 1 in the condensing unit is 12.5cm, so the discharge lamp should be positioned so that it is 12.5cm from the condensing lens. Remove the filter from the condensing unit, and make sure the shutter is open. Adjust the position of the holder and the lens so that beam is directed along the optical axis (parallel to the table top, and directly above the holes).

Now put the collimating lens assembly unit in place, and adjust its height and angle so that the laser beam passes through the pinhole aperture and emerges from the collimater lens without diverging from the optical axis (this can be tedious!).
Next, check the alignment of the Fabry-Perot interferometer. Set the separation between plates to .5 cm. To make sure the beam incident on the interferometer is perpendicular to its mirrors, insert a microscope slide into the light path between the collimating unit and the interferometer. Adjust the tilt and azimuth angle of the interferometer baseplate so that the incident and reflected beams coincide on the same spot. Look at the projection of the interferometer on the wall. If you see a series of red dots trailing off one way or another, use the micrometer adjustments on the interferometer to bring them into coincidence.

You should now be able to produce interference fringes. In order to see them more easily, put a piece of frosted glass in front of the interferometer, and project the output onto a piece of white paper. Carefully make fine micrometer adjustments to center the bullseye pattern. Try to get just a few broad fringes rather than many narrow fringes. The fewer you have, the more parallel the interferometer plates.

Parallelism will be observed by positioning the center of the fringe pattern bull's eye in the center of the field of view. Slowly move the micrometer adjustments, alternating from one to the other, causing the fringes to become farther apart until the bull's eye emerges. This will take time. To make sure it is the bull's eye, turn on the high voltage supply which is connected to the interferometer. The high voltage controls the length of the piezoelectric material on which one of the mirrors is mounted. This effectively adjusts the separation between the two mirrors on the order of wavelengths. You should be able to see the fringes move as you adjust the high voltage. CAUTION: Do not exceed 400V on the high voltage. When you are satisfied with your alignment, turn off the laser and place the mercury lamp between the poles of the magnet. In stall the large plano-convex lens at the output side of the interferometer, 125mm from the PMT translating stage assembly. (The curved side of the lens should face toward the interferometer.)

From now on you will use the discharge lamp as the light source. Use the clamp to position the light source between the poles of the magnet, and turn on the light. (It will take a few minutes before the light intensity reaches maximum.) Turn off the lights and you will see the image of the light on the pinhole aperture plate. Adjust the focus of lens 2 by moving the focus pin of the condensing unit back and forth until the image is sharpest. Project the light from the collisurface of the interferometer mirrors is identical. Instead of generating a pattern of concentric rings, the entire field of view is uniformly illuminated with either constructive or destructive interference. Each "fringe" is then easily discernable by the
Note: Do not turn on the P80ton counter.