Lab 4 The Michelson Interferometer

Introduction

There are, in general, a number of types of optical instruments that produce optical interference. These instruments are grouped under the generic name of interferometers. The Michelson interferometer causes interference by splitting a beam of light into two parts. Each part is made to travel a different path and brought back together where they interfere according to their path length difference. You will build a Michelson interferometer and use it to observe the interference of light from a diode laser.

Background - see Pedrotti^3, Sections 8-1 to 8-3, as well as Chapters 5 and 7.

The Michelson Interferometer

The Michelson interferometer is a device that produces interference between two beams of light. A diagram of the apparatus is shown in Fig.1. The basic operation of the interferometer is as follows. Light from a light source is split into two parts. One part of the light travels a different path length than the other. After traversing these different path lengths, the two parts of the light are brought together to interfere with each other. The interference pattern can be seen on a screen. Light from the source strikes the beam splitter (designated by S). The beam splitter allows 50 % of the radiation to be transmitted to the translatable mirror M_1. The other 50 % of the radiation is reflected to the fixed mirror M_2. After returning from M_1, 50 % of the light is reflected toward the screen. Likewise, 50 % of the light returning from M_2 is transmitted to the screen. At the screen, the two beams are superposed and one can observe the interference between them.

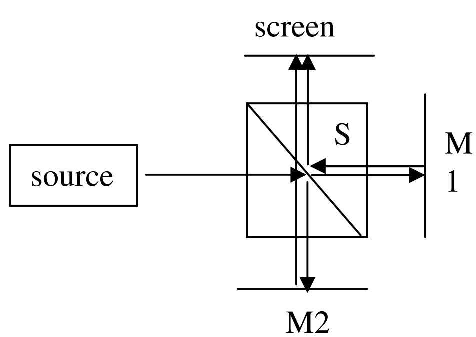

Figure 1. Schematic of the Michelson interferometer.

Experiment

You will build the Michelson interferometer step by step and operate it by hand in the first week. In the second week you will automate the motion of the mirror and measure the interference pattern with MatLab, and then analyze the data.

Begin by setting up the laser and beam splitter, and obtain retro-reflection off the front glass surface. Note the arrows on the top of the beam splitter and arrange your setup so that the two mirrors will be in the directions of the arrows. Now add the translatable mirror on the straight-through direction as shown in Fig. 2 below. Keep the mirror close to the beam splitter to minimize the effects of vibrations when the mirror is translated by the motor. Center the beam in the mirror and obtain retro-reflection to the source. Make sure to securely bolt all components into place.

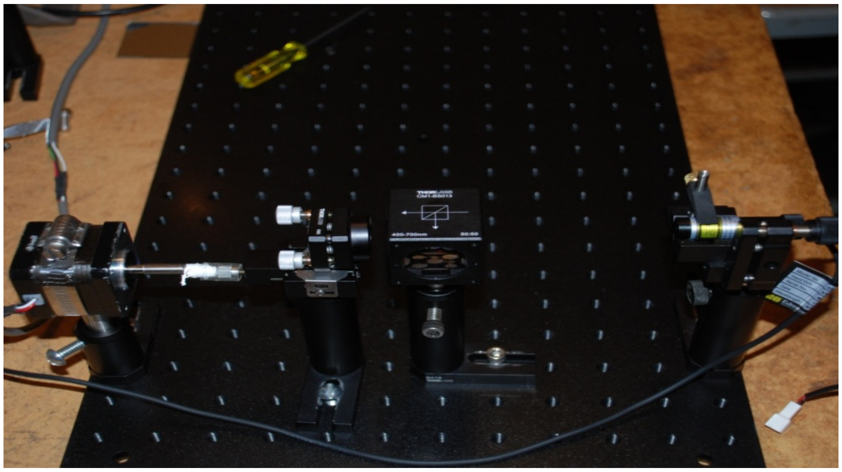

Figure 2. First step in construction of the Michelson interferometer. Components include (from right to left) the diode laser, the beam splitter, the translating mirror, and the stepper motor. Note the arrows on the beam splitter.

Now add the second (stationary) mirror, on the side of the beam splitter in the direction of the arrow. Make sure that this mirror is the same distance from the beam splitter as the first, to within 1 mm (see Fig. 3). Center the beam in this mirror as well. Now project the two output beams from the beam splitter onto a screen. Use the alignment screws on the second mirror to super-impose the bright spots from the first and second mirrors on the screen.

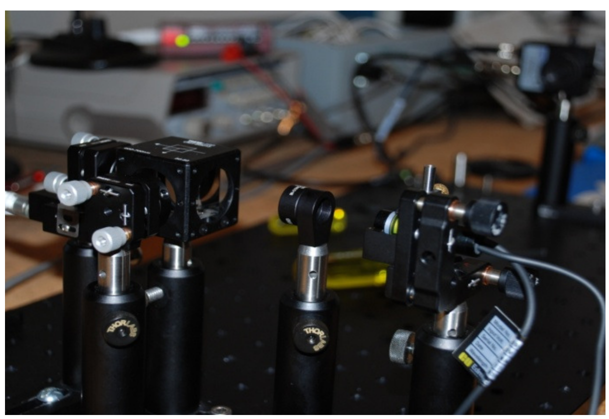

Figure 3. The completed Michelson interferometer. Additional components include (from right to left) the photo-detector (in background), a diverging lens and the stationary mirror.

Now add a diverging lens to the input beam to increase the size of the projected spots on the screen (see Fig. 3). By very carefully adjusting the alignment of the second mirror you should see interference fringes develop as the two spots are superimposed. One should now carefully adjust mirror 2 to bring the “bull’s eye” of the interference pattern to the screen. The result should look something like Fig. 4. What happens when you block the light path in either of the arms of the interferometer?

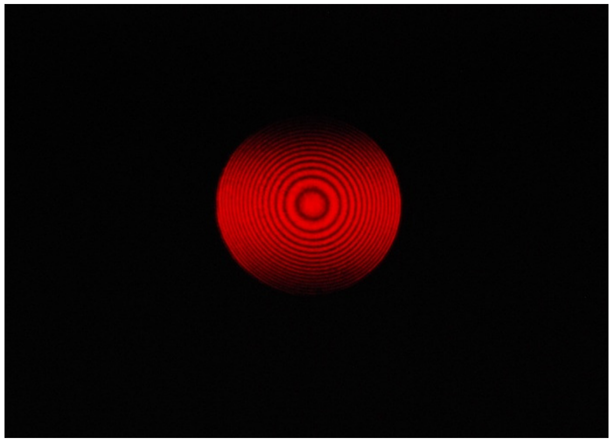

Figure 4. The “bull’s eye” interference pattern produced by the Michelson interferometer.

In the first week your task is to construct the interferometer and move the translatable mirror by hand to observe the appearance and disappearance of the fringes. Why does the contrast between light and dark fringes change? Compare to theory. Note the sensitivity of the interferometer to vibrations of the optical table and to air currents. Press down lightly somewhere on the optical table and observe the effect on the bullseye. Why is it so sensitive? Set up the photo-detector as shown in Fig. 3 to record the variations in intensity at the center of the “bull’s eye” as you move the mirror by hand. Approximately what distance translation causes the center to go from bright to dark? Compare to theory.

In the second week use the translating motor (at 10,000 steps/rev.) to carefully move the translatable mirror and record the fringe variations. It will be necessary to stop the motor after each move to allow the vibrations to die down before taking data. Fourier analyze the data to determine the periodicities present in the data. Deduce the wavelengths of the two strongest spectral lines in the laser diode. The lines are the result of the discrete wavelength modes in the laser cavity. From this observation, determine the size of the laser cavity.