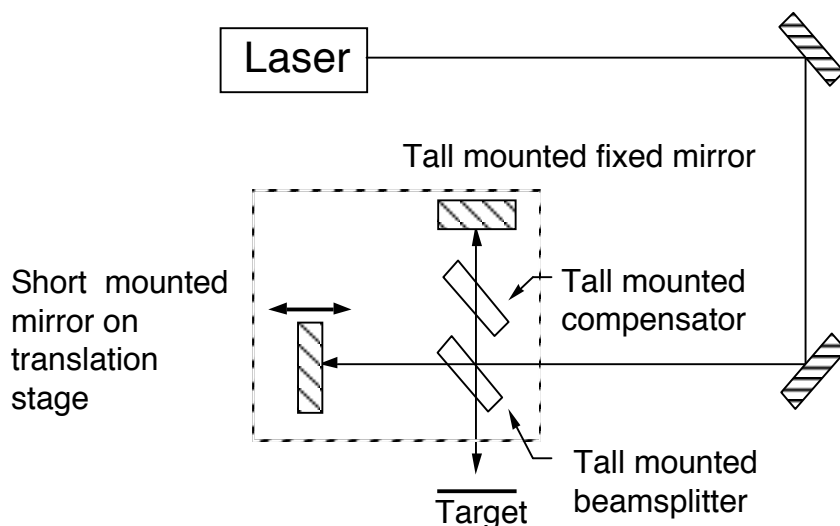


Laboratory #3Week of January 27

Read: pp. 407-410 of "Optics" by Hecht

Do:  
1. Experiment III.1: Michelson Interferometer: align and measure  $\lambda$  of HeNe  
2. Experiment III.2: White Light FringesExperiment III.1: Michelson Interferometer: align, calibrate, and measure  $\lambda$  of HeNe

The goal of this lab is to familiarize yourself with the Michelson Interferometer, to align it properly, and to calibrate the motion of the mirror. The figure shows a schematic of the Michelson Interferometer you will use. Set it up so that the output of the interferometer is directed off the table towards you. This is not great for the part of the experiment involving the Helium-Neon laser, but is very useful for the rest of the experiment. Be sure to use the target when using the Helium-Neon laser. **Do not under any circumstances look into the interferometer output when using the laser** (even though you will do this when using the lamp sources).

To align the interferometer, first use the alignment procedure so the laser beam is parallel to the table top, and ensure that the beam passes through the approximate center of the beamsplitter and movable mirror. Realign your beamsplitter and fixed mirror so that the beam reflected off the beamsplitter hits the center of the fixed mirror. Make sure that your mirrors are approximately equidistant from the front side of the beamsplitter! Block the fixed mirror and send the reflection of the movable mirror back to the laser. Repeat for the movable mirror.

There should now be two or more reflected beams on the target. Carefully adjust the movable and fixed mirrors so that the beams overlap on the target. At this point you may already notice some interference fringes. To make things more clear, convert the parallel laser input beam into a diverging beam (i.e., a point source) by inserting a diverging lens (-25 mm works well) in front of the interferometer. You should then see a set of concentric circles (a bull's eye pattern). These are the fringes formed by the interference of the two beams that have traveled

through the two arms of the interferometer. Careful adjustments of the interferometer mirrors will allow you to center this pattern.

If we let  $d$  be the difference in path lengths of the two arms of the interferometer, then the pattern of concentric circles is described by the equation

$$2d \cos \theta_m = m\lambda \quad \text{Eq. 1}$$

where  $m$  is an integer and  $\theta_m$  is the angle of the  $m$ th dark ring (due to constructive interference). As you change  $d$  by moving one of the mirrors, the size of the pattern will change. As  $d$  approaches zero, the pattern gets large, and in principle, the dark fringe at  $d=0$  will fill the screen. In practice, you will see a hyperbola form at the center that is hard to see due to astigmatism and imperfection in the optics as well as alignment. Demonstrate this behavior.

To measure wavelength, one merely has to move the mirror and count the fringes that “go by”. The center of the pattern at  $\theta=0$  will act as a source or sink of fringes. If we record the appearance or disappearance of  $N$  fringes during a displacement  $\Delta d$  of the mirror, then

$$\lambda = \frac{2\Delta d}{N} \quad \text{Eq. 2}$$

which is equivalent to saying that we will see one fringe every time that  $d$  changes by  $\lambda/2$ .

### *Counting Fringes*

One mirror of the interferometer is mounted on a translation stage. Be careful of sudden movements which will disturb the interferometer and the reliability of your measurements. The reaction force acted upon the base of the translation stage due to the motor may throw off measurements. It is best to have the motor turning before beginning to count fringes if you can set it to move slowly enough. It does not matter which way the stage moves, just be careful to avoid running to the end of the travel. You can adjust the max speed, step size, and acceleration to the max speed under “settings.” You should be able to use this method to get results close to the actual wavelength of the Helium-Neon laser at 633 nm. Count at least 20 fringes and the distance several times to reduce the uncertainty in your measurement of the wavelength.

### *Verifying the Translational Stage Velocity*

Now we will attempt to increase the accuracy of our measurement. To do this we need to ensure that the velocity of the translation stage which we set is correct. Place a photodiode at the center of the output of the interferometer so that the innermost circle fills the aperture. Use an iris or lens to ensure that no other fringes hit the detector. You can also use a toilet roll tube to remove room light noise from the photodetector. Now if you move the stage at constant speed there should be a sine wave on the oscilloscope. You can then freeze the image with the Run/Stop button. These images can be saved onto a flash drive. Now if you measure the frequency of the signal, you will have the number of fringes moving past the center of the oscilloscope per second. Use this value and the velocity of the stage to find a new form of Equation 2. Use this equation and the value you measured above for the wavelength to verify that the velocity is correct.

### *Precise Wavelength Measurement*

Now that we have used two separate methods to check the stage velocity, we can accurately find the wavelength using the velocity as a known value. Determine the wavelength of the HeNe laser using the oscilloscope with the translational stage moving at a constant velocity.

Before going to the next experiment use a polarizer in each arm of the Michelson Interferometer to verify the first Fresnel-Arago law (see p. 391-392 and p. 411 of Hecht), which says that orthogonal polarization states cannot interfere.

What happens if you stick a microscope slide into one of the arms? If you use a heat gun to carefully heat the microscope slide? Explain.

### **Experiment III.2: White Light**

Make sure that your interferometer is capable of moving through the point where a hyperbola appears to each end where a bullseye pattern begins to form again. You may need to adjust the mirror tilt to center this pattern. Now move the stage so that the hyperbola is as large as possible (this will be the “center”) and send it back a little ways (~1mm or less) from this point. Now set your stage so that the step size is very small, and you can see the pattern move clearly as you jog the stage. **Turn off your HeNe laser.**

You should now be able to observe interference from the room lights. These emit a strong green line which will interfere over a large distance. Place a white piece of paper at the input of the interferometer so it is illuminated by the room lights well and look with one eye into the output of the interferometer. You should be able to see faint green rings. Now slowly move the stage toward the “center”. If your step size is small enough and you watch carefully, the green rings should get more contrasted and eventually a full spectrum of light will appear! Discuss your findings.

Equipment needed:

Item	Qty	Source (part #)
Helium-Neon Laser	1	Melles Griot 05 LHP 121
Sodium vapor lamp	1	
Base plate	1	Thor Labs BP2
Translation stage	1	
Controller (with Power cable and USB cable)		
Photodiode	1	Thor Labs
Oscilloscope	1	Tektronix
Mirror mount	4	Thor Labs KM1
Al mirror	4	Newport 10D10ER.1
Beam splitter	1	Newport 10B10BS.1
Compensator	1	Newport 10B10
-25 mm lens	1	Newport KPX043
Iris (adjustable)	2	Thor Labs ID12
Mounting posts	10	Thor Labs P3
Polarizer	2	Edmund A38,396
Microscope slide	1	
Index note card	limitless	
Laser block	1	
Ruler	1	