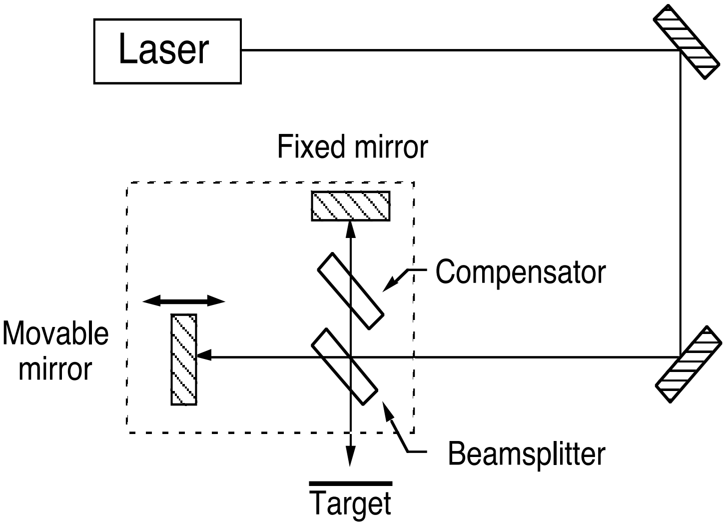
PH 481 **Physical Optics** **Winter 2013**

Laboratory #3 **Week of January 28**

Read: pp. 407-410 of "Optics" by Hecht
Do: 1. Experiment III.1: Michelson Interferometer: align, calibrate, and measure λ of HeNe
2. White light fringes

Experiment III.1: Michelson Interferometer: align, calibrate, and measure λ 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. It is set 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 (at an approximate height of 13.5 cm). This should place the laser beam approximately in the middle of the movable mirror. If the beamsplitter is already adjusted, another beam should hit the fixed mirror in is center. If your table has the laser coming from the left, the fixed and movable mirror will be swapped. Adjust the movable and fixed mirrors so that they return beams nearly directly back to the laser.

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. Slight 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

$$2d\cos\theta_m = m\lambda,$$

where *m* is an integer and θ_m is the angle of the *m*th dark ring (due to constructive interference). As you change *d* by moving one 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, that is hard to see due to astigmatism and imperfection in the optics.

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 Δd of the mirror, then

$$\lambda = \frac{2\Delta d}{N},$$

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

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. 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 under "settings." After the stage is moving at full speed (you can adjust the max speed under "settings") there should be a sine wave on the oscilloscope. You can then freeze the image with the Run/Stop button. From here you may export data from the oscilloscope onto a flash drive which may be viewed in Excel or some other data analysis program.

The Helium-Neon laser has a wavelength of 633 nm. We want to verify the wavelength of the laser using the equation above. In order to use the translation stage as a mechanism for constant velocity, we must first check its validity. To do this, solve for the wavelength of the HeNe laser by counting the fringes that pass by with your eye. You should count about 20 fringes several times to reduce uncertainty in your measurement. With the oscilloscope, use this value of the laser wavelength to verify the velocity of the translation stage. Next, run the stage at a velocity of your choice and use the oscilloscope to verify that it is traveling at constant velocity. Lastly, assuming the velocity function of the translation stage is both accurate and constant, determine the wavelength of the HeNe laser with the oscilloscope.

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 glass slide into one of the arms? If you use soldering iron to carefully heat one of the components? Explain.

Equipment needed:

Item	Qty	Source (part #)
Helium-Neon Laser	1	Melles Griot 05 LHP 121
Al mirror	2	Newport 10D10ER.1
Polarizer	2	Edmund A38,396
-25 mm lens	1	Newport KPX043
Sodium vapor lamp	1	
Translational Stage	1	Thor Labs
Controller		
Oscilloscope	1	Tektronix
Photodiode	1	Thor Labs
Michelson hardware		
Platform	1	Thor Labs (special)
Mounting posts	4	Thor Labs P3
Translation stage	1	
Mirror mount	2	Thor Labs KM1
Al mirror	2	Newport 10D10ER.1
Optics mount (face plate)	2	Thor Labs (special)
Riser block	3	Thor Labs RB2
Base plate	1	Newport BP2
Beam splitter	1	Newport 10B10BS.1
Compensator	1	Newport 10B10