PHY 252 Lab 2: Searching for the Æther Wind

Spring 2008

In this lab, you will use the same Michelson interferometer setup from last week, but look at its measurement characteristics in more depth and then seek to look for the "Æther wind" which, if it existed, might have been expected to alter the speed of light.

1 Determining random and systematic errors

Last week you noted a micrometer position in its dial units, which we will call d_1. You then moved the micrometer until m fringes had crossed your reference mark on a viewing screen, at which point you recorded a second micrometer position d_2. As we'll see later on in the course, we can predict from fundamental physics the emission wavelength corresponding to a particular atomic transition, so we will assume that the wavelength λ of light emitted from the laser is a known quantity. Therefore, we can determine a scaling factor k between micrometer dial position differences $(d_2 - d_1)$ and true physical distances x_{12} from

$$x_{12} = \frac{m}{2}\lambda = k(d_2 - d_1) \text{ or } k = \frac{m\lambda}{2(d_2 - d_1)}. \quad (1)$$

All said and done, right?

Well, maybe not. How reproducible is your measurement of k? Are there any systematic variations? Any random variations? We want to learn something about the accuracy of measurements in the process of answering these questions. Here's the procedure:

1. Set up the Michelson interferometer all over again, following the procedure you used in the last lab.

2. Starting from micrometer dial position d_1, move the micrometer until m_{12} fringes go by. Record the ending position d_2.

3. Now move from d_2 until another m_{23} fringes go by (chose $m_{23} = m_{12}$; that is, you might move by $m = 15$ fringes each time), and record d_3.

4. Keep doing this, recording $d_4, d_5, \ldots, d_{21}$ or so, with the same number m of fringes going by each time.

Now how should we look at the data? Let's ask if there is any possible variation in the micrometer scale factor k. That is, we want to calculate a scale factor for each individual move:

$$\begin{aligned} k_1 &= \frac{m\lambda}{2(d_2 - d_1)} \\ k_2 &= \frac{m\lambda}{2(d_3 - d_2)} \end{aligned}$$

and so on. Next, you can calculate the mean scale factor

$$\bar{k} = \frac{1}{N-1} \sum_{i=1}^{N} k_i$$

and the individual deviations from the mean

$$\Delta k_i = k_i - \bar{k}.$$

Plot these values of Δk_i versus the index i. If it were a perfect experiment with no random or systematic error, you would have the same value of k_i in each case, giving Δk_i for all values. But what do you see? Is there any systematic trend to your errors that you can see? What's a "typical" or representative error? You might try calculating a "typical" error according to

$$\sigma_k = \frac{\sqrt{\sum_{i=1}^{N} (k_i - \bar{k})^2}}{N-2}$$

and see if this gives a good characterization of the "typical" error.

Note that all of the above calculations are really easy to do in a spreadsheet program.

2 Hunting for the æther wind

Now that you understand the measurements you can get out of your Michelson interferometer, let's go looking for the æther wind. If one arm of the interferometer were flying into the wind, while the other was across the wind, you would expect to see differences in light propagation speeds and thus in the number of waves per distance in one arm versus another. Therefore you want to measure the micrometer dial distance required to produce, say, 30 fringes going by in one interferometer orientation, and then you should rotate the entire interferometer by 90° and repeat the measurement. Using $\bar{k}$ as determined above, what was the physical distance $x_{0^\circ} = k(d_2 - d_1)$ needed to have 30 fringes go by in one orientation ($\theta = 0^\circ$), versus the distance $x_{90^\circ} = k(d_2 - d_1)$ needed to have 30 fringes go by in the other orientation ($\theta = 90^\circ$)? Make your comparison in the context of the random error you found in micrometer scale factors σ_k above.