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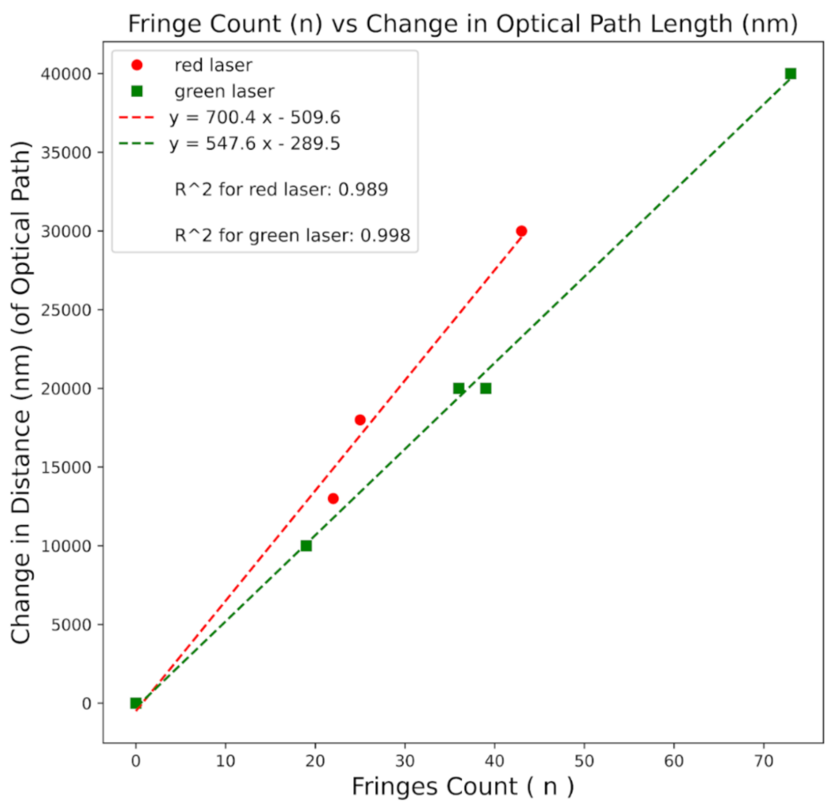
Interferometry Results Draft

So far for this experiment, we have completed two of the three tasks that we set out to do from the start of the lab. The tasks we have completed are finding the error of the micrometer of the interferometer and plotting the relationship between the wavelength and the fringe-count per change in the optical path.

Fringe-count Over Displacement as a Function of Wavelength

Figure 1:
(Plot made on python):



The Figure 1 above shows the results after measuring the fringe count (n) for two different lasers along a changing optical path (nm). The red circles indicate the data points of fringe count and change in optical path (nm) for the red laser that was tested and the green squares are the data points of fringe count and change in optical path (nm) for the green laser that was tested. A linear regression was fit to the data for each laser, and since the $\lambda = 2\Delta d/n$ the slope of this linear regression is equal to wavelength of each respective laser. The linear regression for the red laser data is y = 700.4 x - 509.6, and the linear regression for the green laser data is y = 547.6 x - 289.5. The measured wavelength from the slope of the linear regression for the red laser is 700.4 nm and the wavelength measured from the slope of the linear regression for the green laser is 547.6 nm. These results are close to the expected results, and this will be further discussed in the error discussion. It is also important to mention that both of these linear regressions indicate a strong linear relationship between fringe count and change in optical path since the R^2value for the red laser data is 0.989, which is close to 1, and the R^2value of the green laser data is 0.998, which is even closer to 1. Therefore the relationship between fringe count and optical path length change is linear.

The Index of Refraction of Air

Figure 2:
(Plot made in Python)

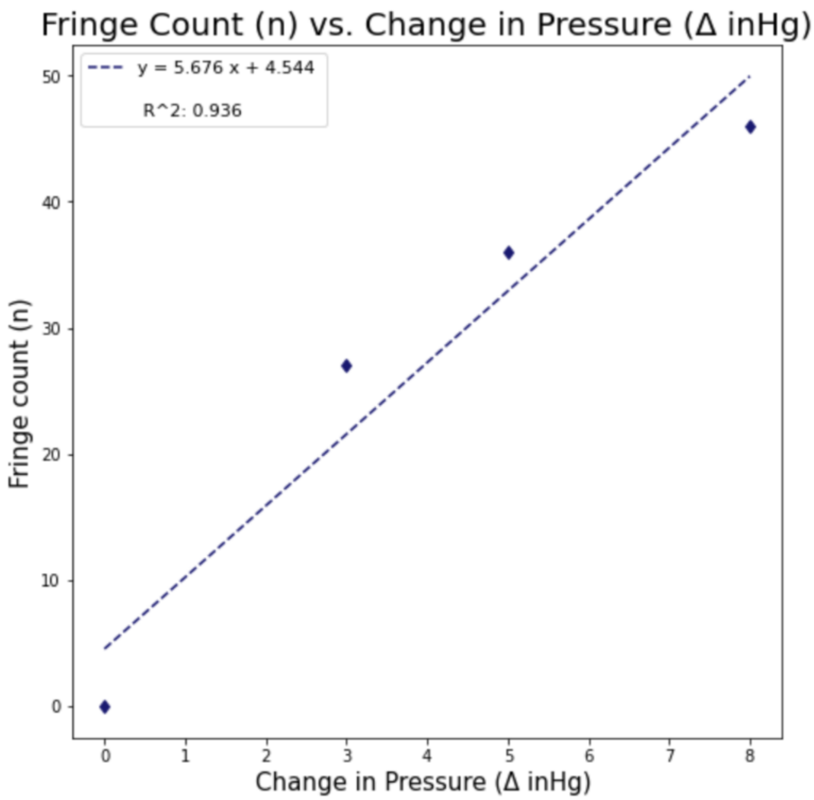


Figure 2 above shows the results after measuring the fringe count of a HeNe red, 633nm laser passing through a vacuum chamber with a length of 27.6 cm where the pressure was being changed. As you can see above the linear regression plotted for this data is y= 5.676 x + 4.544, and the data has an R^2value of .936 which indicates a strong linear relationship between change in pressure and fringe count. Using the equation, $m_{air} = (n * \lambda * p_{atm}) / (2L * \Delta p) + 1$, we were able to calculate the index of refraction of air. Where n (46) is number of fringes, λ (633 nm) is the wavelength of the laser, p_{atm}(1atm) is the pressure of the air, L $(27.6 * 10^7 nm)$ is the length of our vacuum chamber, and Δp $(8 * 0.0334\ atm)$ is our change in pressure. The index of refraction of air calculated is 1.00020, which is fairly close to the expected index of refraction of air.

Error Discussion

From the data, the percent error of the wavelengths for the red laser and green laser, and the index of refraction of air were calculated using a simple, custom python function that applies $\%\ error\ =\ ((observed\ -\ expected)\ /\ expected)\ *\ 100$. For the red laser the expected wavelength was 633 nm and we measured 700.4 nm. For the green laser the expected wavelength was 532 nm and we measured 547.6 nm. The percent error of the red laser's wavelength we calculated was 10.65% and the percent error of the green laser's wavelength we calculated was 2.93%. Our measured wavelengths were only slightly above the expected wavelengths of each laser, which is a result of our experimental uncertainty.

The measured value for the index of refraction of air is 1.00020 and the expected value of the index of refraction of air is 1.000293. The percent error for our value of the index of refraction of air is 0.009% under the expected value, which denotes our experimental uncertainty was low.

An important thing to mention is that the blue lasers that were available to us for this experiment were unable to function for this experiment because the blue lasers had too large of a spread. The blue lasers had such a large spread that they were unable to properly pass through the beam splitter. Had the blue lasers had a smaller spread like the red and green laser our data and Figure 1 plot would have benefited from having another set of data points since it would make the plot have a better representation for the relationship between the wavelength and the fringe count per change in the optical path.

It is also worth mentioning that time constraints resulted in minimal data points when measuring the data to calculate the index of refraction of air. If we could have had more trials testing different ranges of change in pressure and resulting fringe counts the data would better represent this relationship, and could have possibly led to an index of refraction of air value that was closer to the actual value.

The Error of the Interferometer's Micrometer

An additional potential source of error in our experiment may have been introduced from the mechanism we used to adjust the optical path length. The device itself is extremely accurate, using a vernier scale to get accurate measurement lengths within .005 mm of the true value. However, when we are varying this path length by a single 1/100 of a mm this could be considered a sizable error. There is also the issue of moving this device through these incredibly small changes in the distance at a steady rate in the dark. It is possible that this also introduced error into our experiment, as it is reasonable to move some in between the end of counting the fringes and observing the new optical path length. This could have resulted in us missing some fringes, therefore, giving us higher wavelengths than expected.

Future Improvements

This experiment can be improved by testing more lasers with different electromagnetic wavelengths in order to plot the relationship between the wavelength and the fringe-count per change in the optical path with more data points. Having more data points will aid in creating a plot that is far more representative of the relationship between the wavelength and the fringe-count per change in the optical path, therefore, communicating more accurate data. Another way that this experiment can be improved is by having the interferometer apparatus stand on some foam or float in some mercury in order to minimize the vibrational interference from the environment since the current table and optical breadboard setup is susceptible to being moved by footsteps, bumped into, and shaken by the vacuum chamber when the pump is sucking out air, which are all things that affect the fringes being counted on the wall. The experiment may also be improved if there was a way to calibrate the gauge and vacuum chamber apparatus in order to ensure the data will be useful whilst continuing the experiment. Other possible ways to improve this experiment include the use of an electronic fringe counter to get a precise number of fringes that pass on the wall. Similarly using some kind of electronic system to vary the optical path length of the beam could improve the data that was found in this experiment.