Lab 2 Michelson Interferometer Tasks

Key Plot with caption due Friday, September 18th at 10pm

Read Ch. 1, Secs. 1.1-7 in your Lyons text (pp 1-21)

A Michelson Interferometer is a device that splits coherent light into two beams, which are sent along paths of different lengths, L_1 and L_2, and then recombined. Depending on the relative phase the light picks up on each path, the beams can constructively or destructively interfere on recombining, with the time-averaged intensity of the recombined beam proportional to $\cos(kL_1 - kL_2)$, where $k = 2\pi/\lambda$ is the wavenumber and λ is the wavelength. Thus, adjusting the length of either path by one wavelength will cause the interference pattern to go through one full cycle of constructive and destructive interference.

Instead of changing the path length of one of the beams, the interference can also be affected by changing the wavelength along one of the paths. This can be accomplished by having one path go through a medium with a different index of refraction n. Since $\lambda = \lambda_o/n$, where λ_o is the wavelength of light in vacuum, an additional section with length L along the first path through a medium with index of refraction n results in the recombined beam's time-averaged intensity being proportional to $\cos(kL_1 + \frac{2\pi L \Delta n}{\lambda_o} - kL_2)$. A change in the index of refraction $\Delta n = \lambda_o/L$ results in the interference pattern going through one full cycle. Going through a change of ΔN cycles in the pattern thus corresponds to a change in the index $\Delta n = \frac{\Delta N \lambda_o}{L}$.

To change the index of refraction along a section of one path, we can pump out the air in this section. The index of refraction of air n_{air} is slightly higher than the vacuum $n = 1$. For purposes of this measurement we will assume the model that the index is proportional to the amount of air (number of molecules) in the section (whether this is a good assumption will be a matter for experiment to decide). Theoretically the amount of air in a fixed volume at fixed temperature is proportional to the pressure P, so changes in the pressure of the section will be proportional to changes in the index of refraction. The gauge measuring pressure reads 0 at one atmosphere and 76 cm Hg (corresponding to the change in height of a Mercury barometer) at vacuum. The constant of proportionality between n and P can be calculated by noting that the change from air to vacuum is $(n_{\text{air}} - 1)$ for n and $P_o = 76$ cm Hg for P, so that $\Delta n = \frac{(n_{\text{air}}-1)}{P_o}\Delta P$. Combining this with the equation relating index change to the change in interference pattern yields: $\Delta N = \frac{L(n_{\text{air}}-1)}{\lambda_o P_o}\Delta P$.

1. Setup the interferometer. See p2 for a diagram of all the parts.
2. Measure the wavelength of the laser light in air using the Michaelson interferometer by changing one of the path lengths and observing the interference changes. Make enough measurements to get your standard error of your wavelength measurement to less than 10 nm.
3. Pump out air from a section of one path and record the pressure and number of interference cycles gone through for at least 5 different pressures. Plot the results and address the question of whether the assumption of proportionality between pressure and index is justified. Justified or no, use this proportional assumption to find the index of refraction of air based on these measurements and the measurement in task 1. Give an uncertainty on this measurement based on calculated and estimated uncertainties for each of the measurements.
4. Deconstruct the interferrometer and store it in its case. See p2 for how to store all the parts.