Interferometry

Major Ideas

Michelson Interferometer Mechanisms & Uses

A Michelson interferometer relies on a beam splitter. This device will cause some of the of light of a certain wavelength or range of wavelengths to be reflected and allow the other portion to pass through; these can later be recombined to create interference. Once the beam has been split, both of the resulting beams are reflected off of normal mirrors so that they are directed toward one another. They are then reflected back toward each other and recombine; this is what causes the interference, which we can see as fringes in the combined beam. Splitting the beams allows us to alter one beam without altering the other so we can observe changes in interference. The Michelson interferometer setup has played a very important role in the history of physics; it was used in the Michelson-Morley experiment in an attempt to detect interference due to motion through the aether, which we now know does not exist, and was used to detect gravitational waves. This interferometer can also be used to perform precise measurements. Say we have monochromatic light and move one of our mirrors. We should see a number of fringes appear and disappear during this movement. Since wavelength and distance moved are directly proportional, if we know our wavelength, we can use this to precisely determine the distance moved; conversely, if we know the distance moved, we can determine the exact wavelength. We can also use the interferometer to determine the index of refraction of a gas. If we introduce a cell in which we can control the pressure over which the two split beams experience different pressures, we will be able to relate the length of the cell and the index of refraction of the gas to an equivalent distance. As we change the pressure, the index of refraction will change, so the equivalent path length will be changing. By comparing the change in pressure with the fringe count, we can determine the index of refraction at a given pressure.

Major Equipment

Beam Splitters: Dielectric and Metal Film

A beam splitter is an optical device that splits a beam of light by allowing part of it to reflect and part of it to pass through. The split beams are not necessarily of the same intensity. There are two primary types of coatings used to make beam splitters; dielectric and metal. A dielectric coating will generally maintain polarization for both beams and should split beams nearly evenly. It will also absorb very little light. However, they work best for specific wavelengths, so they don’t work well for experiments involving varied or unknown wavelengths. Dielectric coatings are formed from metal oxides, and their properties can be controlled by altering layers’ compositions, thickness, and number. These alterations take advantage of the way light reflects off multiple surfaces placed very near each other, as the index of refraction of each layer of the dielectric coating varies. Metal film coatings for beam splitters are generally far less efficient, causing a significant reduction in total intensity between the resulting beams. This is because they rely on an extremely thin layer of metal coating so that there is both significant reflectivity and transmittivity. Because of this, they’re generally less common. However, their ability to function for wide bandwidths makes them useful in experiments where intensity loss isn’t an issue.

Data Analysis

Fringe Count

We collected optical and pressure data in order to find the index of refraction of air. The number of fringes can be determined by examining the number of peaks or valleys in a portion of the optical data. For a number of appearing and disappearing fringes *N*, wavelength *λ*, and distance moved *d*, we have a relationship

$$d = \frac{N\lambda}{2}.$$

By introducing a cell of length *L* in which we can control the pressure, we have an length *nL* over which the two split beams experience different pressures, where *n* is the index of refraction. Index of refraction increases with pressure. So, as we change the pressure, *n* will change by an amount Δn, changing the path length by ΔnL. We can substitute this into the equation above for *d*, so

$$\mathrm{L}\Delta n = \frac{N\lambda}{2}.$$

If we define $n = 1 + kp$ for some unknown *k*, we have $\Delta n = k\Delta p$, giving us

$$\mathrm{Lk}\Delta p = \frac{N\lambda}{2}.$$

By measuring the pressure, we can solve for *k*:

$$k = \frac{\mathrm{N}\lambda}{2L\Delta p}$$

Substituting *k* will give us our index of refraction for a given pressure:

$$n = 1 + \frac{\mathrm{N}\lambda}{2L\Delta p}p.$$

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