A wavemeter is a device that measures the wavelength of an unknown laser. Our goal is to create a wavemeter precise to one part per million. Our design features a Michelson Interferometer that creates an interference pattern projected on to a photodiode. Moving a pair of mirrors across a 26-cm motorized track causes oscillations in light intensity that can be observed with a photodiode. These oscillations (fringes) are converted to a digital signal and counted with digital circuitry.

A reference laser with a well-known wavelength (Helium-Neon laser, λ₀ = 632.991 nm in vacuum) is used by comparing its interference pattern with that of the unknown laser. The wavelengths and number of counted interference fringes follow a simple ratio.

**INTRODUCTION**

The basic concept is derived from Fox et al. (2). This design features two banks of parallel counters. Two photodiodes convert the interference fringes to a digital signal which is then sent to the counters. The counters are incremented when the digital signal of their respective photodiode drops to zero. Counting is done until the unknown laser’s counter reaches a reference value. Once this value is reached, all counting stops and the data is retrieved using digital shift registers.

Our design includes many features that increase our sensitivity and functionality. The reference laser is temperature controlled so that the wavelength will not drift over time. The mirrors used to create the fringes are placed on a cart that is magnetically levitated over the track to minimize friction when the cart is pulled. An Arduino Microcontroller is used to automate the entire device by setting the motor direction, controlling the digital counters, performing all calculations and displaying the results on an interactive LCD display. The Arduino also allows us to use digital temperature, pressure and humidity sensors to correct for the index of refraction and dispersion of air, giving us the true vacuum wavelength of the unknown laser with part per million resolution.

**OPERATIONAL METHODS**

The design uses the relationship

\[
N = \frac{\lambda_2 - \lambda_1}{\lambda_2 - \lambda_0}
\]

Where \(\lambda_1\) and \(\lambda_2\) are the wavelengths of the unknown and reference laser, respectively, \(N_0\) is the number that will be counted by the unknown laser and \(N_0\) is the number that will be counted by the fringes of the reference laser. By setting \(N_0\) to the known wavelength of the reference laser in units of piconewtons, \(N_0\) will become the wavelength of the unknown laser (also in pm).

**OPTICAL DESIGN**

The optical design features a modified Michelson Interferometer with two counter-moving mirrors. The classic textbook interferometer design consists of one moving mirror and one stationary mirror. In our modified design, one path is redirected to the other side of the moving mirror and is reflected back around. This configuration effectivly makes two moving mirrors with only one moving piece, doubling the resolution.

This design provides several benefits for both sensitivity and practicality. Since there are two moving mirrors the fringe pattern now has twice the frequency. This allows for twice as many fringes in the same distance. Moving both mirrors with only one moving part simplifies the mechanical design by reducing the number of pulleys and other mechanical equipment.

**MECHANICAL DESIGN**

The mechanical design features a cart to hold the moving mirror pair. This cart is pulled down a 26-cm track by a 2-RPM reversible electric motor. Our design contains magnets glued to the cart and track to levitate the cart. The current design is somewhat unstable and is very difficult to balance. Currently, new geometries for the track are being tested to provide more stability.

Our Helium-Neon laser has at least two resonance modes because of the Doppler width of the Neons emission spectrum. As the internal temperature of the laser increases the vapor tube expands. This causes the intensity of each mode to change. The modes have a significant frequency difference (500 MHz), so as they change the frequency will drift. Since we need a very stable reference laser we must account for this fluctuation. Since the resonance modes have orthogonal polarizations, two orthogonal Brewster plates are used to view the intensity of the two modes and photodetectors monitor their change. A digital feedback loop connected to an internal heater placed inside the laser will force the polarization modes to the same intensity. Then once they are the same intensity we can discard one so that there is only one polarization mode.

**APPLICATION DESIGN**

The electronic design features a digital counting circuit, a motor driver circuit and optimized photodetectors.

In the actual design not both counters go up. The reference laser’s counters are actually counted from the reference point to zero. This greatly simplifies the electronic design because the counters have a built in trigger when they reach zero. The counters are tied together so that when the down counter reaches zero the other counter stops. The up counter then interfaces with a shift register to output its counts. The photodiode circuit is optimized for speed, operating up to one MHz. The motor driver circuit contains a simple digital switching chip to control the direction of the motor. The circuit also has detectors to prevent the cart from running off the end of the track.

**SOFTWARE DESIGN**

An Arduino Microcontroller is used as the brain of the wavemeter. It controls the direction of the motor and makes sure the cart does not go past the edges of the track. The Arduino reads digital data from the counters and performs statistical analysis. It controls an LCD display and buttons, so initial parameters can be changed easily.

We monitor the temperature, pressure, and humidity, because the index of refraction depends on the wavelength of the light as well as atmospheric conditions. This data is used by the Arduino to correct for the index of refraction and optical dispersion of air, giving us the true vacuum wavelength of the unknown laser.

**REFERENCES**


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