Wavelength Detection through Michelson Interferometry

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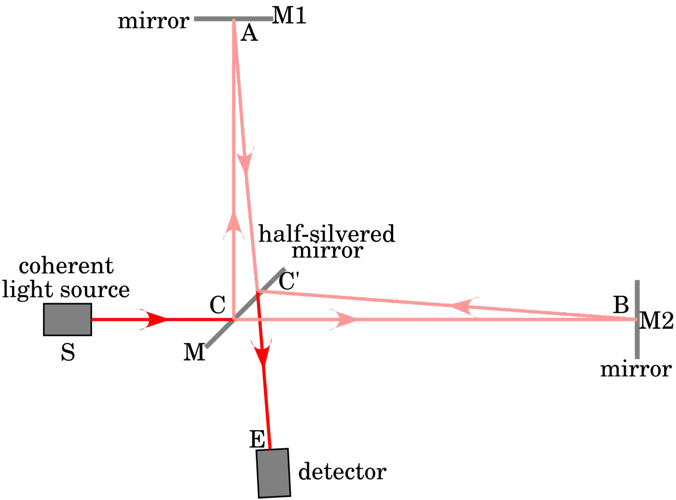
Outline

What is Michelson Interferometry?



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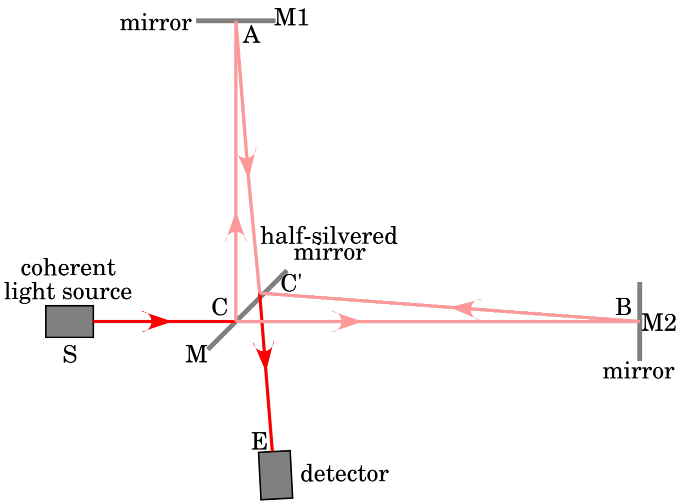
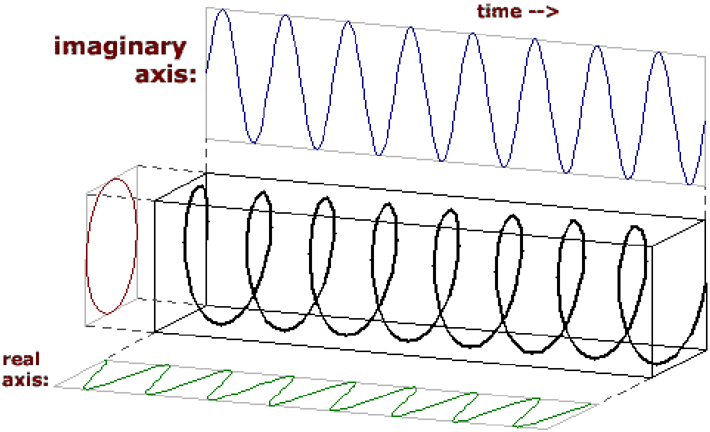


Use detector measurements to determine wavelength of light source.

Light travels as waves

$$E(t) = E_1 e^{i(\phi_1 - \omega t)}$$



Superposition of waves work as addition

$$E_T(t) = E_1 e^{i(\phi_1 - \omega t)} + E_2 e^{i(\phi_2 - \omega t)}$$

From complex waves to observables

- What photodetectors observe is the *intensity* of a wave.
- $I \propto \langle E_T^* E_T \rangle = E_1^2 + E_2^2 + 2E_1 E_2 \cos(\phi_1 - \phi_2)$
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  - $\phi_1 - \phi_2 = (2n + 1)\pi$ - destructive interference

Relative length traveled to relative phase

- One wave travels a length $2l_1$, and one wave travels a length $2l_2$. What is the relative phase offset of the two?

$$\phi_1 - \phi_2 = \frac{4\pi}{\lambda}\left(l_2 - l_1\right)$$

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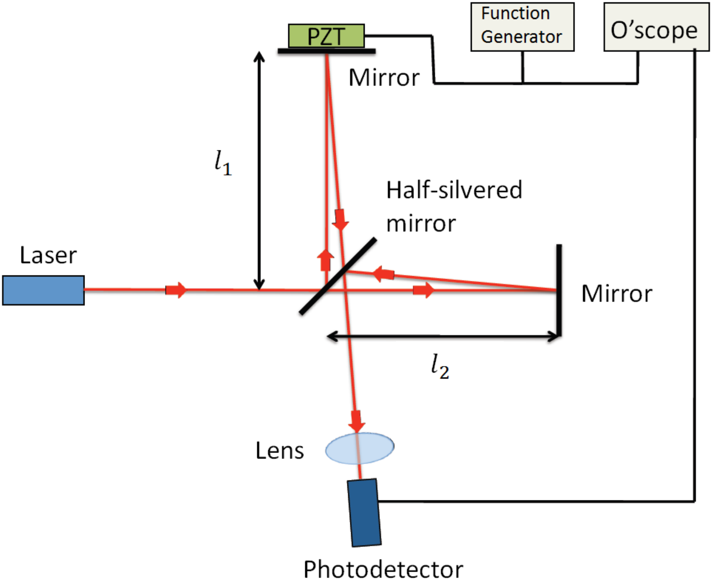
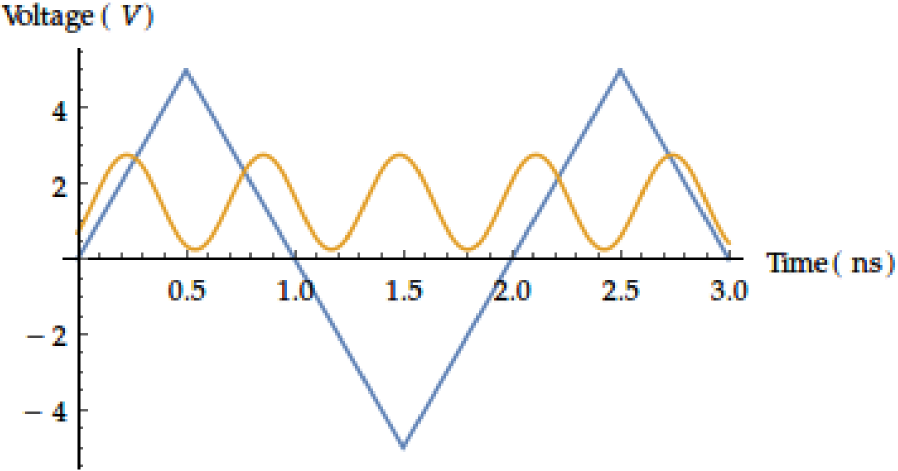
Overview of experimental setup



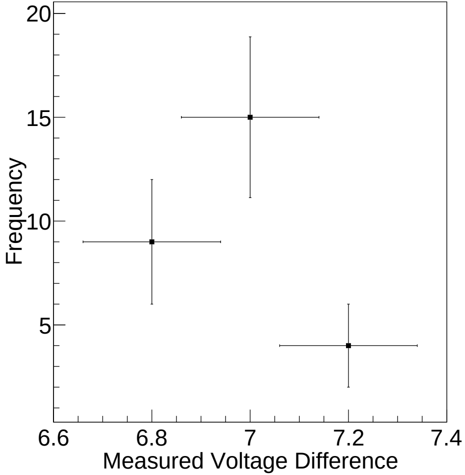
PZT converts voltage to displacement

- PZT changes relative length difference from $2(l_2 - l_1)$ to $2(l_2 - l_1 - \Delta V)$.
- Linear relative length difference causes a linear phase difference proportional to the wavelength.
- Linear phase difference causes periodic intensity differences.
- Measure voltage differences corresponding to a full period in intensity.

Oscilliscope display of interference patterns



Distribution of measured voltage differences



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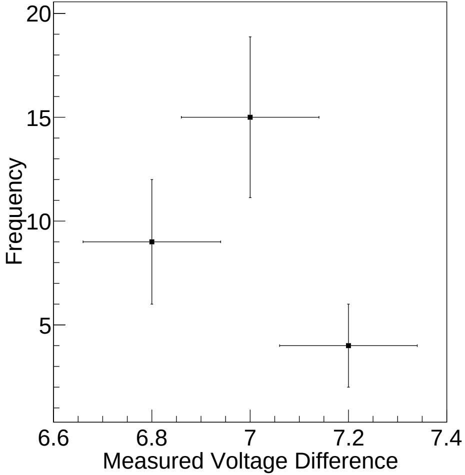

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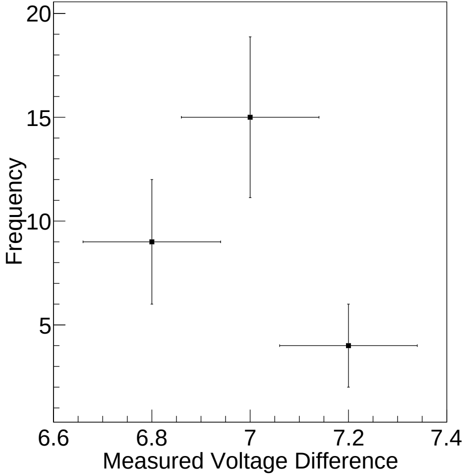

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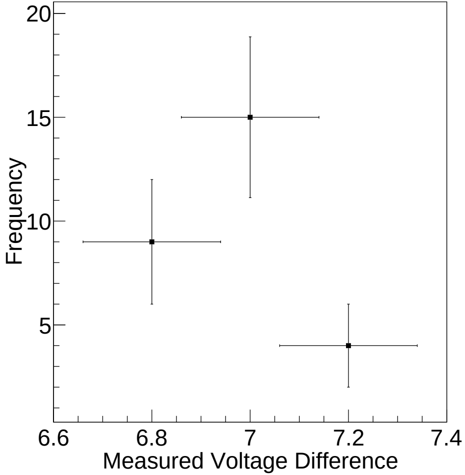

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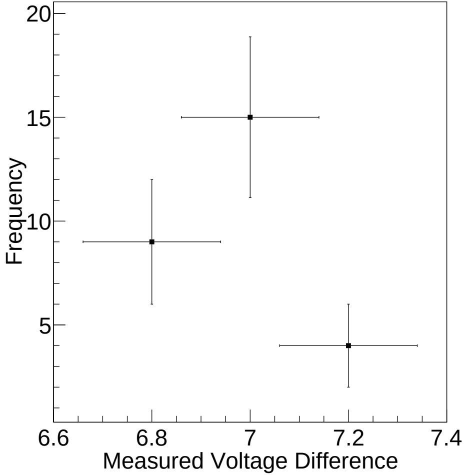

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- $\lambda = 620 \pm 38$ nm

Predicted wavelength agrees with independent calculations

- Wavelength reported on laser is 594.6 nm.
- Predicted wavelength of 620 ± 38 nm mostly falls within this range.
- Michelson interferometry can be used to accurately calculate wavelengths.

Wavelength calculation through Michelson interferometry

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- By controlling this length with a PZT, we can accurately determine the wavelength of the light source.
- Error propegation is largely controlled by the PZT.
- The aether probably doesn't exist.

Derivation of wavelength/voltage correpondance

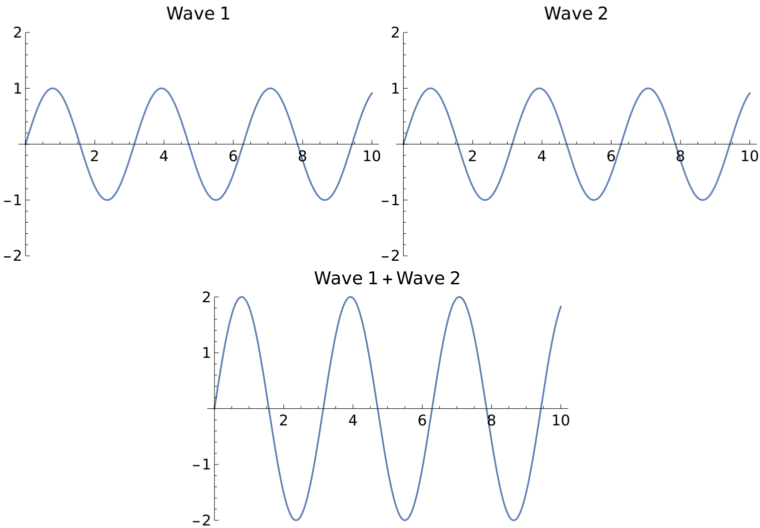
$$I \propto E^2 \left(1 + cos\left(\frac{4\pi}{\lambda}(l_2 - l_1 - \Delta V)\right)\right)$$

One period with respect to V given by

$$2\pi V = \frac{4\pi\Delta}{\lambda}$$

$$\lambda = \frac{2\Delta}{V}$$

Constructive interference in light waves



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