Wavelength Detection through Michelson Interferometry

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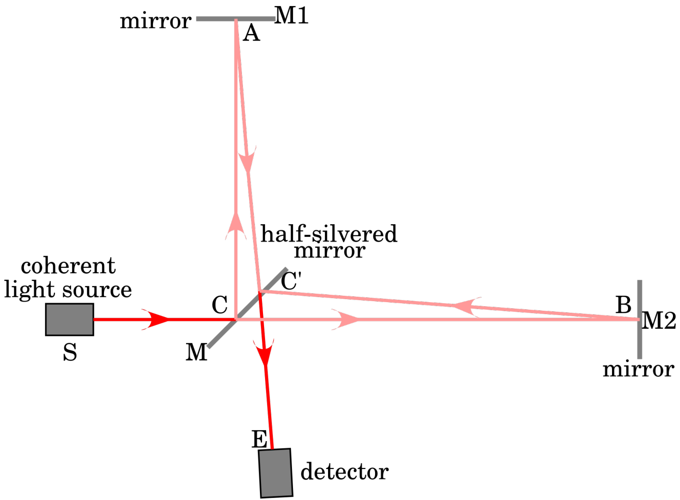
Outline

What is Michelson Interferometry?



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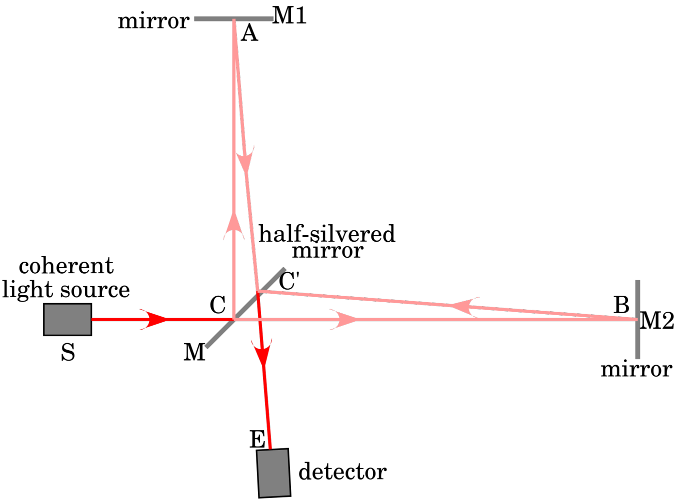
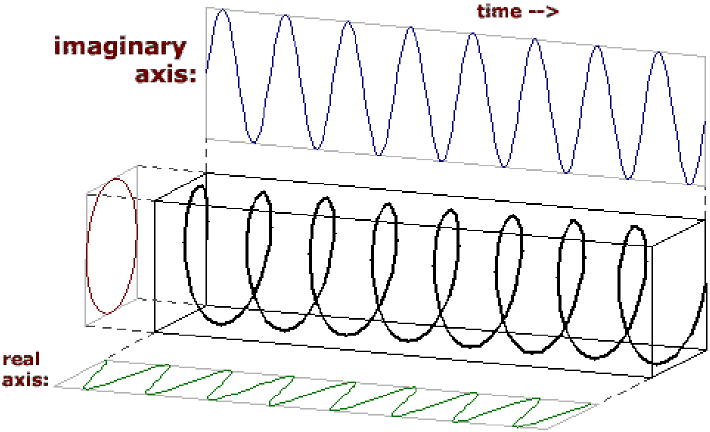


Use detector measurements to determine wavelength of light source.

Light travels as waves

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



Superposition of waves work as addition

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

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Form of the superposition dependent on relative phase, $\phi_1 - \phi_2$

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Constructive interference: $\phi_1 - \phi_2 = 2\pi n$, $n = 1, 2, 3, \ldots$

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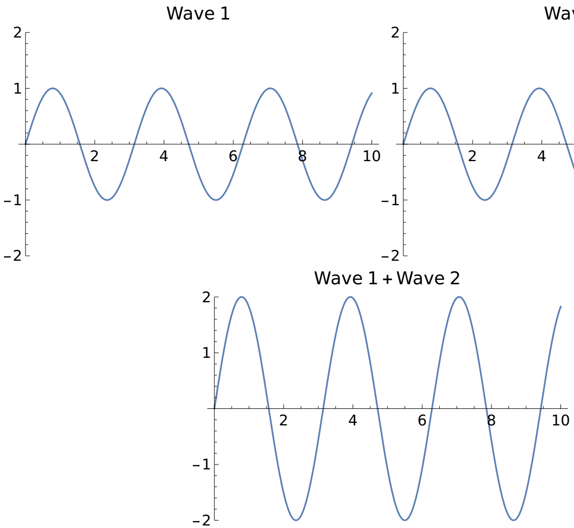
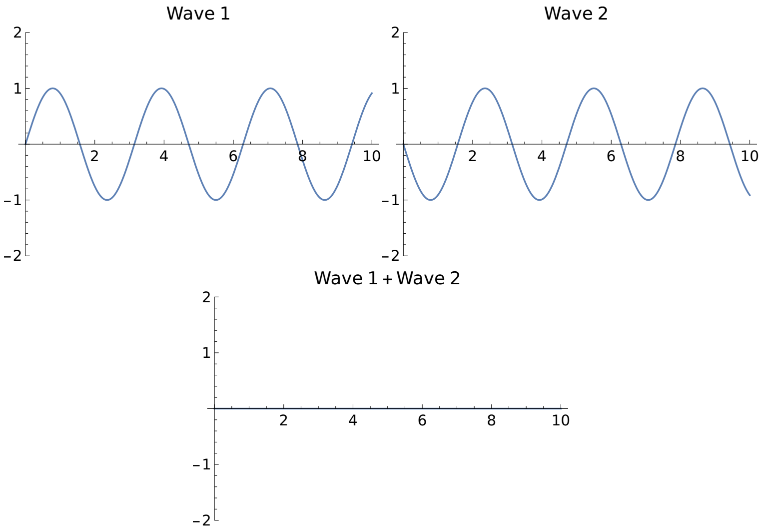
Constructive interference through relative phase difference



Destructive interference through relative phase difference



From complex waves to observables

- What photodetectors observe is the *intensity* of a wave.
- $I \propto \langle E_T^* E_T \rangle = E_1^2 + E_2^2 + 2E_1 E_2 \cos(\phi_1 - \phi_2)$
- Interference affects intensity too!

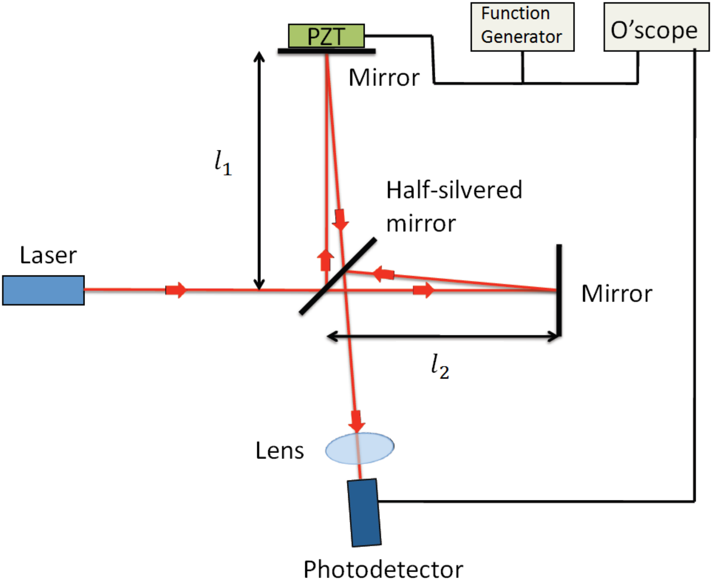
Relative length traveled to relative phase

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

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

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

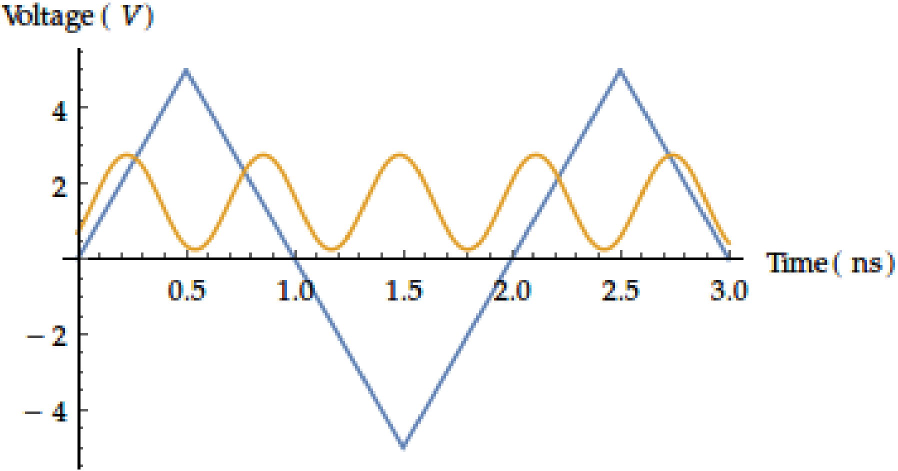
Overview of experimental setup



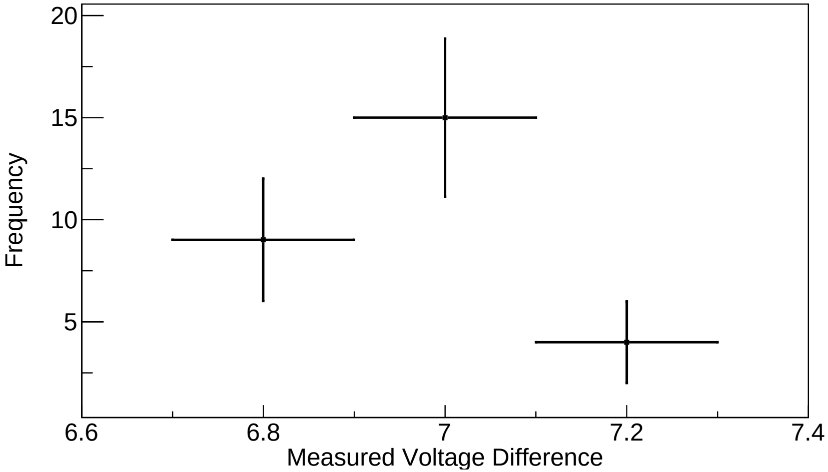
PZT converts voltage to displacement

- PZT changes relative length difference from $2(l_2 - l_1)$ to $2(l_2 - l_1 - \Delta V)$.
- Relative length difference causes a phase difference proportional to the wavelength.
- $I \propto E^2(1 + \cos(C(\lambda)V))$

Oscilliscope display of interference patterns



Distribution of measured voltage differences



Wavelength Calculation and Error Propegation

Sources of error:

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- PZT voltage to length conversion 44.6 ± 2.6 nm/V
- $\lambda = 620 \pm 38$ nm

Predicted wavelength agrees with independent calculations

- Standard wavelength of orange light: 590-620 nm.
- Predicted wavelength of 620 ± 38 nm mostly falls within this range.
- Michelson interferometry can be used to accurately calculate wavelengths.

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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.