Determining the wavelength of a coherent light source via Michelson interferometry

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Introduction

- Michelson interferometry commonly used in optical experiments
- Most well-known in 1887 Michelson-Morley experiment
- Applications in probing phenomena in fundamental physics e.g. gravitational waves
- Ranges in scale from tabletop setup to several kilometers

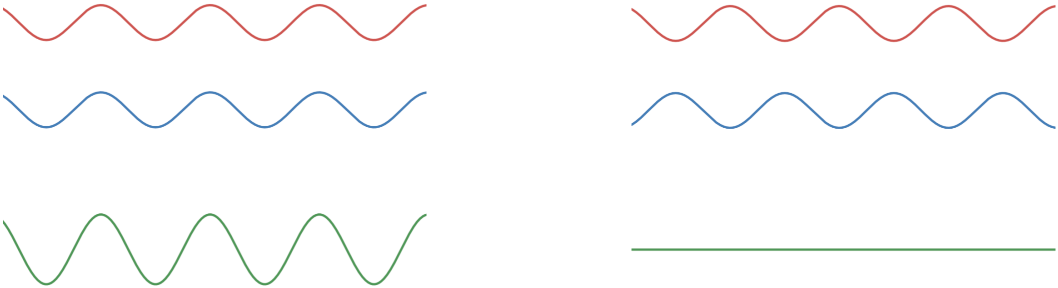
Motivation

- Measure wavelength of coherent light source using Michelson interferometry
- Use properties of interference to align optical setups

Interference

- Can be understood using classical wave mechanics
- Different waves traveling in a medium superimpose onto each other
- Special case in which two waves have the same frequency

Interference (cont'd.)



(a) Constructive interference

(b) Destructive interference

Figure 1: Interference patterns for two waves of the same frequency

Experimental setup

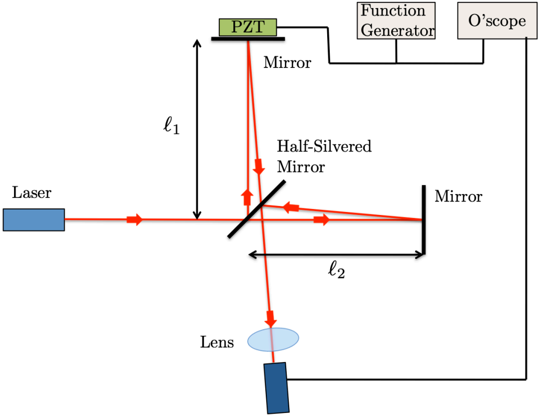


Figure 2: Diagram of Junior Lab Michelson interferometer setup [1]

[1] http://web.mit.edu/8.13/www/JLExperiments/JLExp009.pdf

Michelson interferometer

- Features beamsplitter which reflects half of incident light beam into top arm and allows other half of beam to pass through
- Achieved using thin coating which reflects half of incident light at 45°
- Observe interference where light rays recombine at beamsplitter

Piezoelectric transducer (PZT)

- Piezoelectric materials undergo mechanical strain when subjected to an applied voltage difference, and vice versa
- PZT combines piezoelectric sensor with actuator
- Changes length of arm when different voltages are applied
- Calibration factor of our device was determined as 46.7 ± 4.2 nm/V

Results and analysis

Figure 3: Photodetector and function generator output signal shown on oscilloscope

Results and analysis (cont'd.)

- Generated signal with $V_{pp} = 20$ V, corresponding to displacement of 934 ± 84 nm
- Measured 15.52 ms between peaks in photodetector output, corresponding to displacement of $\Delta_l = 290 \pm 26$ nm
- Relative uncertainty in measurement of period is assumed to be less than 1%
- Wavelength measured as $2\Delta_l = 580 \pm 52$ nm

Results and analysis (cont'd.)

- Achieved maximum peak voltage of 2.680 V, minima at 80 mV
- Final measured visibility of 0.942

$$V = \frac{V_{\text{max}} - V_{\text{min}}}{V_{\text{max}} + V_{\text{min}}}$$

Conclusions

- Wavelength of an unknown coherent light source can be accurately determined using only interference patterns
- Use of Michelson interferometry for calibration limited by precision of optical parts
- Visibility affected by variety of factors including beamsplitter precision and photodetector dark current

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