Speed of Light

Course: PHY 3802L Intermediate Physics Lab

Experiment: Speed of Light

Your Name: Catalina Cisneros

Partner(s): Sophia

Date Performed: Mon Oct 6th, 2025

Date Submitted: Thu Oct 9th, 2025

Introduction and Purpose

The goal of this experiment was to measure the speed of light using Foucault's rotating mirror method. As light travels to a distant mirror and back, the rotating mirror changes its angle slightly, causing a small shift in the reflected image. By measuring how this shift varies with the mirror's rotation speed, the value of the speed of light can be calculated.

Theory

Light travels at a finite speed, and the Foucault method allows its measurement by analyzing the angular displacement caused by a rotating mirror.

When light reflects off a rotating mirror, the mirror's surface orientation changes slightly between the outgoing and returning paths. This rotation introduces a measurable shift (Δx) in the image position at the microscope.

The relationship between the shift and the speed of light is:

$$\Delta x = f_2 \cdot 4\omega \frac{D_1 + D_2}{c}$$

where:

- Δx = measured image displacement
- f_2 = focal length of the second lens
- ω = angular velocity of the rotating mirror
- D_1, D_2 = distances from the rotating mirror to the fixed mirrors
- c = speed of light

Rearranging for c:

$$c = \frac{4\omega f_2 (D_1 + D_2)}{\Delta x}$$

By measuring Δx for multiple ω values (both CW and CCW), plotting Δx vs. ω should yield a straight line. The slope of that line allows determining c.

The uncertainty in each position is determined by:

$$\sigma_{\Delta x} = \frac{\partial x}{\sqrt{12}}$$

Apparatus

The experiment uses a Foucault-type rotating mirror apparatus to measure the speed of light. The setup includes a laser source, lenses, beam splitter, rotating mirror assembly, fixed mirrors, and a microscope for observing image displacement.

Figure 1. Experimental setup for the Foucault method of measuring the speed of light.

Procedure

1. Record the reference position (zero rotation).
2. Set the mirror to rotate in one direction (CW).
3. Gradually increase the frequency in steps (100 Hz, 200 Hz, ... up to 1000 Hz).
4. For each rotation frequency, record the image displacement (micrometer reading).
5. Repeat the measurements for counterclockwise (CCW) rotation.
6. Note all readings and uncertainties.

Data

Frequency vs position

Clockwise (CW) Rotation

Frequency (Hz)	Image Position (mm)
102	0.461
204	0.441
307	0.404
407	0.360
501	0.332
602	0.299
702	0.259
800	0.221
900	0.201
1004	0.188

Counterclockwise (CCW) Rotation

Frequency (Hz)	Image Position (mm)
102	0.536
201	0.547
303	0.600
402	0.639
502	0.669
608	0.699
702	0.730
805	0.754
903	0.792
1007	0.828

- $f_2 = $ 252mm = 0.252m

- Uncertainty in each position: $\sigma_{\Delta x} = \frac{0.277}{\sqrt{12}} = 0.080\text{ mm} = 8.0 \times 10^{-5}\text{ m}$.
- $D_1 = $ 24 ft 1.5 in → 7.3533m.

- $D_2 = $ 23 ft 5.0 in → 7.1374m

Analysis and Results

Using the relationship

$$\Delta x = \frac{4f_2(D_1 + D_2)}{c}\ \omega$$

the slope of the best-fit line corresponds to

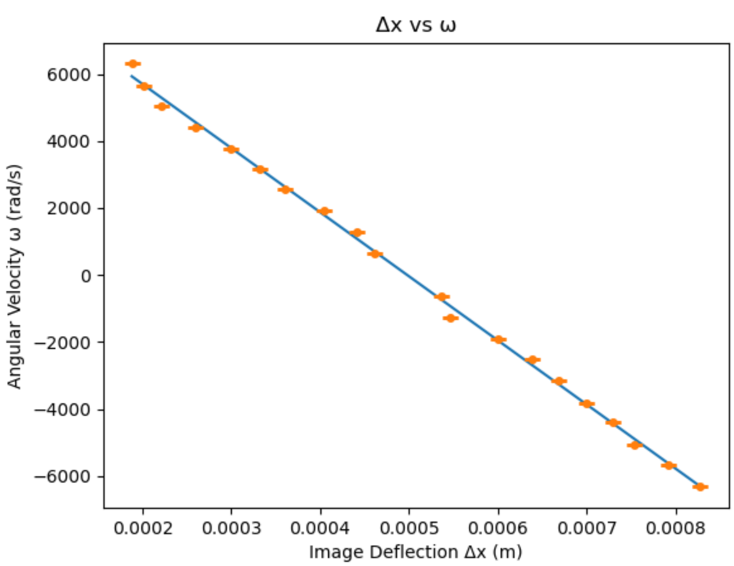
$$m\ = \frac{4f_2(D_1 + D_2)}{c}.$$

By rearranging, the speed of light can be expressed as

$$c = \frac{4f_2(D_1 + D_2)}{m}.$$

The position data were analyzed to perform a weighted linear regression, considering the uncertainties in image displacement. The fits for the CW, CCW, and combined datasets all produced approximately linear relationships, confirming the expected proportionality between Δx and ω.

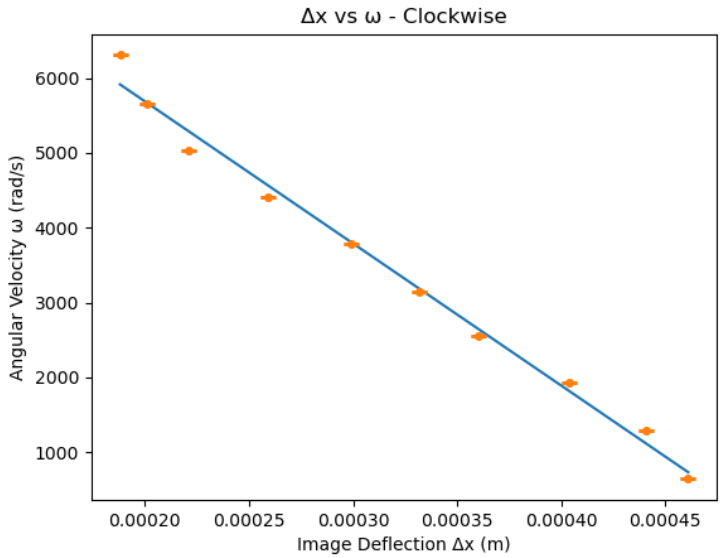
Combined Dataset



From the fitted slope, the measured speed of light was: $c = (2.795 \pm 0.004) \times 10^8$ m/s.

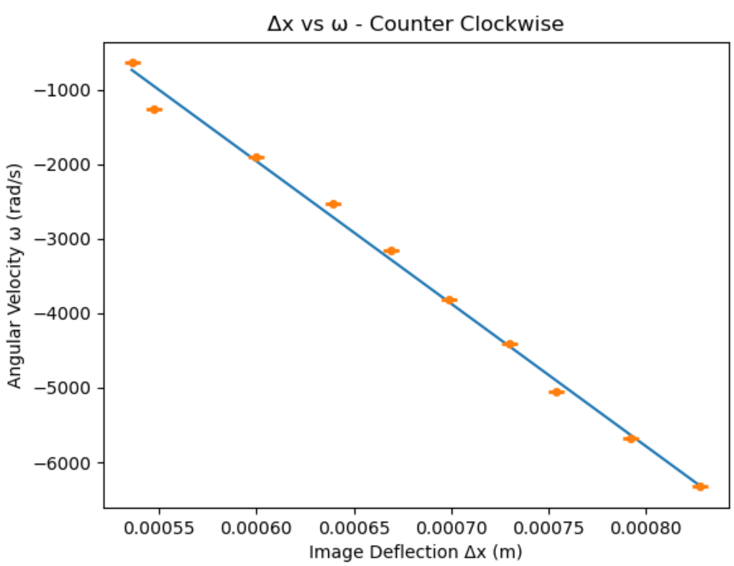
This corresponds to a percent error of 6.76% compared to the accepted value $c_0 = 2.999 \times 10^8$ m/s.

Clockwise Rotation



Resulting speed of light: $c_{\mathrm{CW}} = (2.775 \pm 0.100) \times 10^8$ m/s, with a percent error of 7.45%.

Counterclockwise Rotation



Resulting speed of light: $c_{\mathrm{CCW}} = (2.792 \pm 0.080) \times 10^8$ m/s, with a percent error of 6.86%.

Discussion

The measured values for all configurations were slightly below the accepted value, with percent errors between 6–8%.

The small difference between our measured value and the accepted speed of light can be explained by a few factors:

1. Alignment sensitivity: The setup depends on precise alignment between the laser, lenses, and mirrors. Even a tiny tilt or misalignment changes the path length or where the image lands, which directly affects the measured displacement.
2. Lens imperfections: The lenses may not focus the light perfectly or could have slight curvature or surface flaws, introducing small optical distortions that shift the image slightly.
3. Mechanical vibrations: The rotating mirror spins at high speed, and even minor vibrations or wobble in its motor can cause random fluctuations in the mirror's angle, producing inconsistent image shifts.

Together, these effects introduce small measurement errors that make the experimental value a bit lower than the accepted speed of light but still within a reasonable range.

Conclusion

The experimental speed of light was measured as: $c = (2.80 \pm 0.04) \times 10^8$ m/s. This represents a 6.8% deviation from the accepted value of 2.99×10^8 m/s. The results confirm the finite speed of light and the effectiveness of Foucault's rotating mirror technique in determining it with reasonable precision. The experiment highlights how optical alignment, mechanical stability, and precise measurement are crucial for accurate determination of fundamental constants.

$$\begin{array}{r} 0.698 \\ -\,0.421 \\ \hline 0.277 \end{array}$$

Speed of light - data

CW

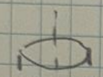
0.277 ± 100/mm

Hz	102	204	307	407	501	602	702	800	900	1004
d	0.461	0.441	0.404	0.360	0.332	0.299	0.259	0.221	0.201	0.183

CCW

0.277 ± 100/mm

Hz	102	201	303	402	502	608	702	805	903	1007
d	0.536	0.547	0.600	0.639	0.619	0.699	0.730	0.754	0.792	0.888



$\underbrace{0.698 \mid 0.421}_{\delta x}$

$0.698 - 0.421 = \delta d = 0.277$

$\delta x = \frac{\delta d}{\sqrt{12}} = \frac{0.277}{\sqrt{12}}$

standard deviation

L_1

L_2

$D_1 = 24.15$ ft

$D_2 = 23.50$ ft

$f_2 = 0.550 + 0.525 = 1.075$ in