PHYS 3650L - Modern Physics Laboratory

Laboratory Advanced Sheet
Speed of Light

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1. Objectives. The objective of this laboratory is to use the Foucault method to measure the speed of light.

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2. Theory. The Foucault method.

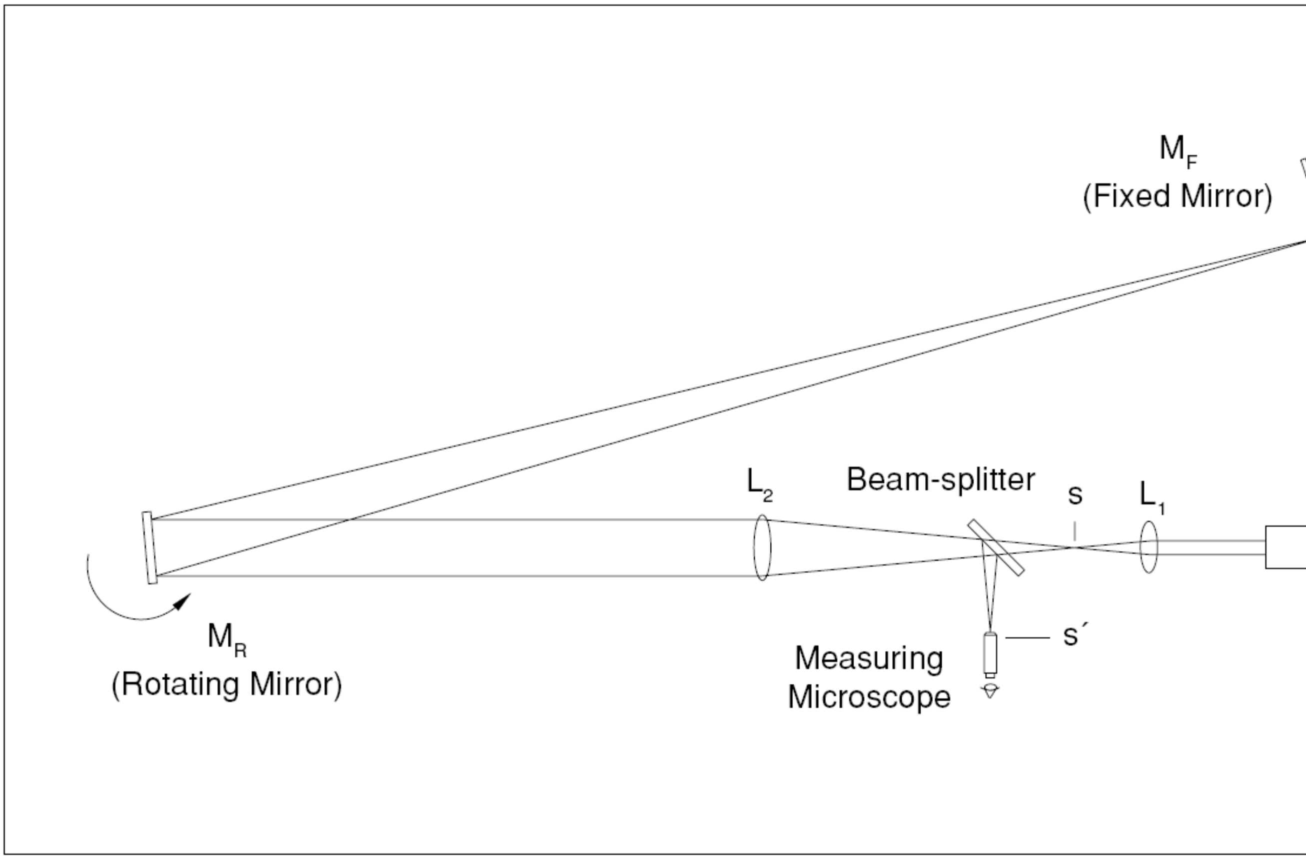

Figure 1. Diagram of the Foucault method.

A method we will be using today was developed by Foucault in 1862. The diagram of the experimental setup is shown in Figure 1. Imagine the rotating mirror M_R stationary. Parallel beam of light from the laser is focused at point *s* by lens L_1. Lens L_2 is positioned so that the image point at *s* is reflected from the rotating mirror M_R and is focused onto the fixed spherical mirror M_F. Mirror M_F reflects the light back along the same path to again focus the image at point *s*. In order that the reflected point image can be viewed through the microscope, a beam splitter is placed in the optical path, so a reflected image of the returning light is also formed at point *s*'. Now, suppose that M_R is rotated slightly so that the reflected beam strikes M_F at a different point. Since the fixed mirror has spherical shape, the beam will still be reflected directly back toward M_R. The return image of the source point will still be formed at points *s* and *s'*. The only significant difference in rotating M_R by a slight amount is that the point of reflection on M_F changes. Now imagine that M_R is rotating continuously at a very high speed. In this case, the return image of the source point will no longer be formed at points *s* and *s'*. This is because, with M_R rotating, a light pulse traveling from M_R to M_F and back finds M_R at a different angle when it returns when it was first reflected. Measuring the displacement of the image point caused by rotation of M_R, the speed of light can be determined. Detailed analysis shows that the speed of light can be calculated by using the following formula:

$$c = \frac{4AD^2\omega}{(D+B)\Delta s'} \tag{1}$$

where

c is the speed of light,

ω is the rotational speed of the rotating mirror

A is the distance between lens L_2 and lens L_1, minus the focal length of lens L_1,

B is the distance between lens L_2 and rotating mirror M_R,

D is the distance between the rotating mirror M_R and fixed mirror M_F, and

$\Delta s'$ is the displacement of the image point when rotating mirror is rotating relative to the position of the image point when the rotating mirror is stationary, as viewed through the microscope.

By rotating the mirror first in one direction and then in the opposite direction, the total beam deflection is doubled, thereby doubling the accuracy of the measurement. Under these conditions, the equation (1) becomes

$$c = \frac{8\pi A D^2 (\omega_{CW} + \omega_{CCW})}{(D+B)(s'_{CW} - s'_{CCW})} \qquad \textbf{(2)}$$

where ω_{CW} and ω_{CCW} are expressed in revolutions per second.

3. Apparatus and experimental procedures.

a. Equipment.

1) High speed rotating mirror assembly.

2) Fixed mirror.

3) Measuring microscope.

4) He-Ne laser.

5) Optics bench.

6) Laser alignment bench with bench couplers.

7) 48 and 252 mm lenses.

8) Calibrated polarizers (2).

9) Component holders (3).

10) Alignment jigs (2).

11) Measuring tape.

b. Experimental setup. To be provided by the student.

c. Capabilities. To be provided by the student.

d. Procedures. Detailed instructions are provided in paragraph 4 below.

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4. Requirements.

a. In the laboratory.

1) Your instructor will introduce you to the equipment to be used in the experiment and help you to set up and align the equipment.

2) Record the position of rotating mirror and lenses on the optics bench.

3) Measure the distance between rotating and fixed mirrors.

4) Switch the rotating mirror power supply to *CW*, turn the motor on and let it warm up at about 600 rev/s for at least 3 minutes.

5) Bring the speed of rotation to about 1000 rev/s and use the microscope to measure the deflection. Record the speed at which the motor is running and micrometer reading. Turn off the motor and let it cool off for about a minute.

6) Switch the direction of rotation to *CCW*. Turn the motor on and repeat your measurements in step 5.

7) Repeat the measurements in steps 5 and 6 two more times.

b. After the laboratory. The items listed below will be turned in at the beginning of the next laboratory period. A complete laboratory report is **not** required for this experiment.

Para 3. Apparatus and experimental procedures.

1) Provide a figure of the experimental apparatus (para 3b).

2) Provide descriptions of the capabilities of equipment used in the experiment (para 3c).

Para 4. Data. Data tables are included at Annex A for recording measurements taken in the laboratory. A copy of these tables must be included with the lab report. Provide the items listed below in your report in the form a Microsoft Excel^{TM} spreadsheet showing data, calculations and graphs. The spreadsheet will include:

1) Recorded positions of rotating mirror and two lenses.

2) Focal lengths of two lenses.

3) Measured value of the distance between fixed and rotating mirrors.

4) Calculation of the parameters A and B.

5) Table which includes the speeds of rotation for both clockwise and counterclockwise directions with corresponding deflections.

6) Calculation of the speed of light.

7) Calculation of the percent discrepancy in the speed of light. Your instructor will provide the actual value.

Para 5. Results and Conclusions.

5. Results and Conclusions.

a. Results.

1) A statement of the measured value for the speed of light.

2) A statement of the percent discrepancy in the speed of light.

b. Conclusions.

1) Assess the accuracy of your experiment.

2) Describe the sources of error in the experiment.

Annex A
Data

1. Position of Lens 1.

L_1 = ____ m

2. Position of Lens 2.

L_2 = ____ m

3. Position of Rotating Mirror.

M_R = ____ m

4. Distance between Rotating and Fixed Mirrors.

D = ____ m

5. Deflection Measurements.

Trial	ω_{cw} (rev/s)	s'_{cw} (m)	ω_{ccw} (rev/s)	s'_{ccw} (m)
1				

2				
3				

Last update: September 08, 2008