Faraday Rotation

Kishore Padmaraju[1, *]

[1]*Department of Physics and Astronomy, University of Rochester, Rochester, NY 14627*

When light passing through certain materials is exposed to a parallel magnetic field a Faraday Rotation occurs. A Faraday Rotation is a magneto-optical phenomenon that rotates the polarization of light. We produced the Faraday Rotation using a SF-59 glass rod embedded in the core of the solenoid. The rotation is linearly related to the magnetic field by the Verdet constant. Using a set of polarizers, we measure a Verdet constant of $19\frac{rad}{Tm}$.

In 1845, Michael Faraday discovered the first physical phenomenon linking light and magnetism. He was able to rotate the polarization of light when he induced a magnetic field in the same direction as the path of the light. This effect, known as the Faraday Rotation or Faraday Effect, only occurs when light passes through transparent dielectrics. Applying a magnetic field to the dielectric causes it to exhibit circular birefringence. Birefringent materials decompose light into ordinary and extraordinary rays. In circular birefringent materials, these rays have the additional property of being circularly polarized with opposite rotations. Different indices of refraction exist for the left and right circularly polarized rays. As a result, these rays propagate at different speeds through the medium. The two rays combine at the end, yielding a ray that is offset in polarization from the incident ray. The relationship between the rotation of the ray and magnetic field is given as:

$$\theta = \nu B l \tag{1}$$

ν is known as the Verdet constant and it varies for different dielectric materials. Our objective was to not only verify the Faraday Rotation, but to determine the Verdet constant for glass. To achieve this objective we use the experimental setup depicted in the schematic below. For our light source we use a 3mW red laser with a nominal wavelength of about 650nm. The first polarizer is
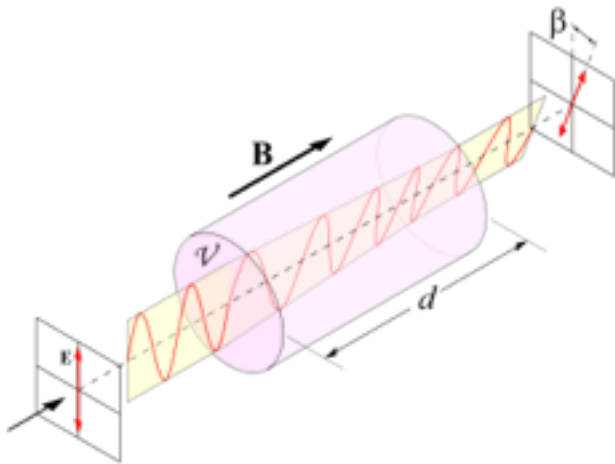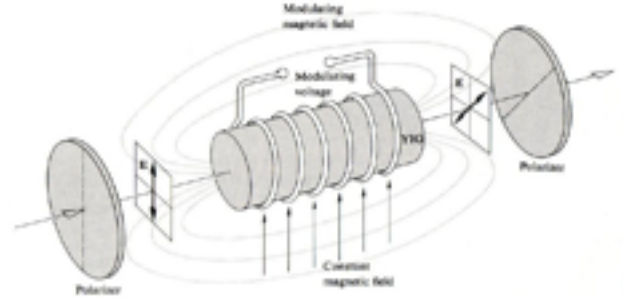

FIG. 1: Faraday Rotation.

FIG. 2: Essential components of the experimental setup we used.

adjusted to correlate with the partial polarization of the laser light. The solenoid has 1400 turns distributed over .15 m. It is difficult to directly measure the magnetic field within the solenoid. Rather, we use a multimeter in series with the power supply to measure the current flowing through the solenoid. From the current, the following relation calculates the magnetic field:

$$B = (11.1\frac{mT}{A})I \tag{2}$$

The combination of a second polarizer and photodiode at the exit end of the solenoid measures the rotation of the polarization.

To verify the validity of our experimental setup we experimentally test Malus's Law.

$$I = I_\circ cos^2(\Delta\phi) \tag{3}$$

The solenoid is turned off so that the polarization of the light is not affected by the Faraday Effect. The polarizers are set orthogonal so that full extinction occurs. We then rotate the second polarizer while recording the intensity of the light.

Our excellent agreement with Malus's Law provides justification in our experimental method for finding the Verdet constant.

A 5 mm SF-59 glass rod is inserted into the solenoid. Keeping the polarizers constant, we measure the intensity of the light as the current in the solenoid is varied. For our experiment, we varied the current from 0 A to 3 A
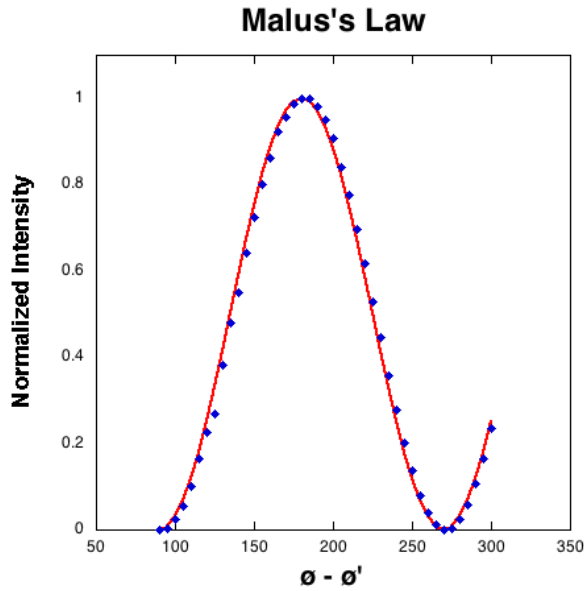
FIG. 3: Our normalized data is shown in blue. Malus's Law is depicted in red

FIG. 5: The relation between magnetic field and angle of rotation when polarizers are 45° to each other.
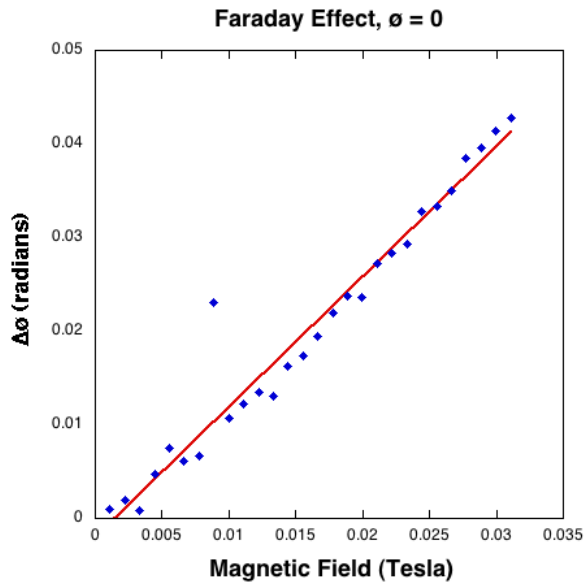

FIG. 4: The relation between magnetic field and angle of rotation when polarizers are orthogonal to each other.

by increments of .1 A. By rearranging Malus's Law we can find the rotation in polarization.

$$\Delta\phi = \arccos\sqrt{\frac{I}{I_\circ}} \quad (4)$$

In our first trial of our experiment the polarizers are orthogonal to each other.

The Verdat constant is calculated from the slope of the linear fit. For this trial, the Verdat constant is $14\ \frac{rad}{Tm}$.

However, orthogonal polarizers are not the most opti-

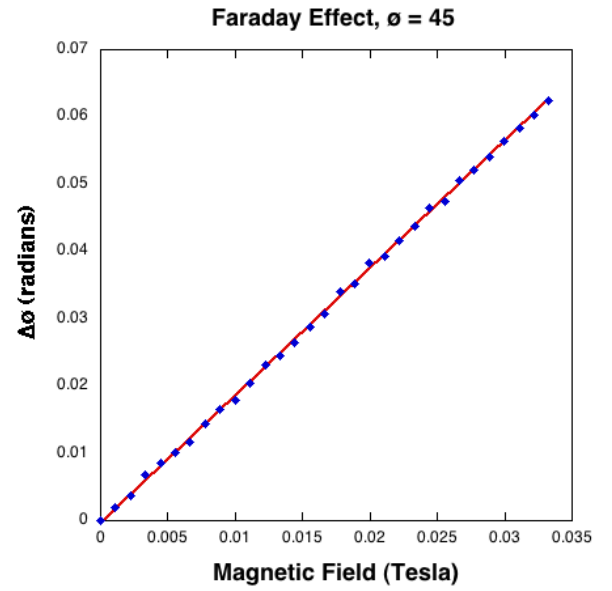mal way to measure the Verdat constant. The intensities near extinction are so low that the measurements are susceptible to the background noise present in the photodiode. Additionally, the change in intensity in relation to the change in polarization is at a minimum at extinction. For our second trial, the polarizers were set 45° to each other.

The data in this trial follows a linear fit much better than that of the previous trial. This can be attributed to two factors. The intensity measurements are much larger and thus less susceptible to noise. Also, the change in intensity in relation to the change in polarization is largest when the polarizers are 45° to each other. The Verdat constant for this trial is $19\ \frac{rad}{Tm}$. As the data for the trial is much cleaner, we accept this value as our most accurate measure of the Verdat constant. Our result is within 20% of $23\ \frac{rad}{Tm}$, the actual value of the Verdat constant for SF-59 glass.

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* Electronic address: kpadmara@mail.rochester.edu
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