Polarization

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Abstract

1 Introduction

A wave is a disturbance of a continuous medium that propagates with a fixed shape at constant velocity. If the medium is the *electromagnetic field*, the wave is called an *electromagnetic wave*.

An electromagnetic wave is comprised of two synchronized oscillations of electric and magnetic fields. Both fields are perpendicular to each other and to the direction of the propagation. Hence, an electromagnetic wave is a *transverse wave*.

An electromagnetic wave can be represented by two perpendicular components. If there is a well-defined relationship between the two components, the wave is said to be *polarized*. An electromagnetic wave that is not polarized is called *unpolarized wave*. The electric field of an unpolarized wave oscillates in all planes perpendicular to the direction of the propagation; it is a mixture of waves with different polarizations. Such a wave can be polarized by passing through a special filter called a *polarizer*.

Essentially, polarization is the phenomenon of restricting, or fixing the oscillation of the electric field of light to a single plane. There are several types of polarization:

- Linear polarization. The electric field vector traces a straight line.

- Circular polarization. The electric field vector traces a circle.

- Elliptical polarization. The electric field vector traces an ellipse.

Light is one of the types of electromagnetic waves, and in this experiment, we will study its linear polarization. The primary goal of the experiment is to verify the Malu's law. The equipment is comprised of two polarizers, a laser, a photodetector, an interface, and a rotary motion sensor. The first polarizer will produce linearly polarized light by allowing only the light oscillating in the vertical plane to pass through. The second polarizer will be used to measure
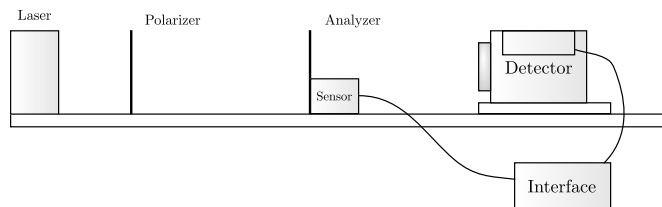
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Figure 1: Experimental setup.

the intensity of the light after passing through the first polarizer; it serves as an analyzer.

Let's denote the angle between the axis of the first polarizer and axis of the analyzer as θ. If the intensity of the light before passing the analyzer is I_0, and the intensity of the light after passing the analyzer is I, then the Malu's law states that the intensity of the light after passing the analyzer is given by the equation[1]

$$I = I_{in}\left[H_{90} + (H_0 - H_{90})\right] \tag{1}$$

The procedure of the experiment as follows. First, we turn on the laser and adjust the polarizers so that their axes are parallel. Next, we turn on the interface, namely Pasco® Xplorer GLX, and start the data collection. We rotate the analyezer by 400°. Then we stop the data collection and conclude the experiment.

2 Data & Results

After extracting the data and plotting it using Python, we obtained the following plot of the intensity of the light after passing the analyzer as a function of the angle between the axes of the polarizer and the analyzer (see Figure 2). Plot appears to be in form of a sinusoidal function. After fitting to data using Python again it can observed that best fit line is in form of $I(\theta) = a + b\cos^2(\theta)$ (see Figure 3), or more precisely:

$$I(\theta) = 2.3271\cos^2(1.001 \cdot \theta + 1.42) \tag{2}$$

Which tells us that the Malu's law is verified, and also suggests that our incident light is linearly polarized.
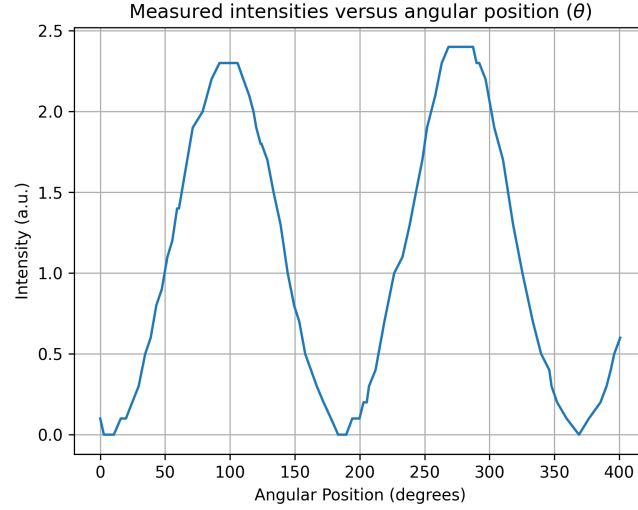
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Figure 2: Plot of the intensity of the light after passing the analyzer as a function of the angle between the axes of the polarizer and the analyzer.

3   Discussion & Conclusion

Due to computerized nature of this experiment, error is minimized. However, there are still some sources of error. First one being manual allignment of polarizers at the start of the experiment, which is the reason for phase shift in the best fit line. Another point of error is manual rotation of the analyzer, which wasn't uniform is the reason behind the fluctations at some points, and also higher density of points in some regions that others.

Anotther point of error lies in best fit line. It being best fit line, it is not the exact representation of the data. However due to more than 100 data points we can fairly assume that it is close to the real value.

In conclusion, experiment was successful in verifying the Malu's law, and also in determining that the incident light is linearly polarized, and also was fully in line with the theory.

References

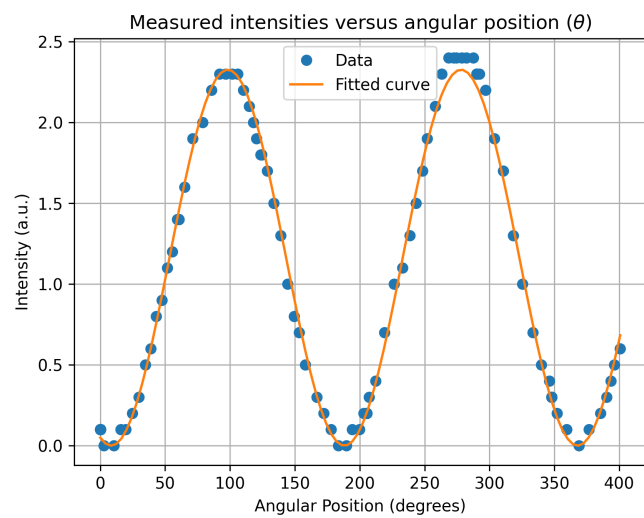[1]   Eugene Hecht. *Optics*. 5th ed. Pearson Education, 2017, pp. 346–348. ISBN: 1-292-09693-4.

Figure 3: Best fit of the data to the Malu's law.