PHY 300 Polarization: Lab 2

Carl Liu : Partner Saketh Bhattiprolu, Abdullah Samit

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Introduction

In this lab we study the intensity of the light transmitted through polarizers as a function of the angle between polarizers. For the first experiment we have two linear polarizer that is rotated θ degrees with respect to one another. This is described using the matrix

$$M_x' M_x = \begin{bmatrix} \cos(\theta) & \sin(\theta) \\ 0 & 0 \end{bmatrix} \begin{bmatrix} 1 & 0 \\ 0 & 0 \end{bmatrix} = \begin{bmatrix} \cos^2(\theta) & 0 \\ \sin(\theta)\cos(\theta) & 0 \end{bmatrix}$$

Then we have

$$E = \frac{1}{\sqrt{2}} \begin{bmatrix} \cos^2(\theta) \\ \sin(\theta)\cos(\theta) \end{bmatrix}$$

meaning

$$I \propto E^2 = (E_x^2 + E_y^2)/2 = (\cos^4(\theta) + \cos^2(\theta)\sin^2(\theta))/2 = \cos^2(\theta)/2$$

Essentially it is saying that when two linear polarizer are parallel/anti-parallel, the intensity will be a maximum while no light should get through when they are perpendicular. We also have two linear polarizers at 90^o to one another with a half-wave plate in between. This is represented as

$$M_y M_h' M_x = \begin{bmatrix} 0 & 0 \\ 0 & 1 \end{bmatrix} \begin{bmatrix} \cos^2(\theta) - \sin^2(\theta) & 2\sin(\theta)\cos(\theta) \\ 2\sin(\theta)\cos(\theta) & \sin^2(\theta) - \cos^2(\theta) \end{bmatrix} \begin{bmatrix} 1 & 0 \\ 0 & 0 \end{bmatrix} =$$

$$\begin{bmatrix} 0 & 0 \\ 0 & 1 \end{bmatrix} \begin{bmatrix} \cos^2(\theta) - \sin^2(\theta) & 0 \\ 2\sin(\theta)\cos(\theta) & 0 \end{bmatrix} = \begin{bmatrix} 0 & 0 \\ 2\sin(\theta)\cos(\theta) & 0 \end{bmatrix}$$

Then we have

$$E = \frac{1}{\sqrt{2}} \begin{bmatrix} 2\sin(\theta)\cos(\theta) \\ 0 \end{bmatrix} = \frac{1}{\sqrt{2}} \begin{bmatrix} \sin(2\theta) \\ 0 \end{bmatrix}$$

That in turn means

$$I \propto E^2 = (E_x^2 + E_y^2)/2 = \sin^2(2\theta)/2$$

Methods/Measurements

We started off by turning off the light from the emitter, taking off all the polarizers and allowing the sensor to measure the background light. Zero the sensor at this value. Put in two linear polarizer. Fix the first one at 0 degrees so that the angle does not change. Start the second polarizer at 0 degrees.

Turn on the emitter and measure the light level at the sensor. Increment the polarizer by 10 degrees and measure the light level again. Repeat up to 180 degrees. Graph the results. Next set the second polarizer to 90 degrees and fix it there. Put a half-wave plate between the two linear polarizer and start it at 0 degrees. Measure the light level at the sensor then increment by 10 degrees and measure again. Repeat up to 180 degrees. Graph the results

The data we obtained is

Two Polarizers

$Polarizer\ angle(^o)$	$Uncertainty(^o)$	$value(lux)$	$Uncertainty(lux)$
0	±0.5	194	±0.05
10	±0.5	185	±0.05
20	±0.5	163	±0.05
30	±0.5	138	±0.05
40	±0.5	107.1	±0.05
50	±0.5	73.9	±0.05
60	±0.5	45	±0.05
70	±0.5	21.8	±0.05
80	±0.5	9.4	±0.05
90	±0.5	8.8	±0.05
100	±0.5	21	±0.05
110	±0.5	40.5	±0.05
120	±0.5	70.2	±0.05
130	±0.5	102.2	±0.05
140	±0.5	133.7	±0.05
150	±0.5	159.7	±0.05
160	±0.5	183.2	±0.05
170	±0.5	195.8	±0.05
180	±0.5	197.2	±0.05

and for the two linear polarizer with a waveplate in between, we obtained

Three Polarizer

$Polarizer\ angle(^o)$	$Uncertainty(^o)$	$value(lux)$	$Uncertainty(lux)$
0	±0.5	10.3	±0.05
10	±0.5	17.6	±0.05
20	±0.5	34	±0.05
30	±0.5	56.7	±0.05
40	±0.5	72	±0.05
50	±0.5	68.9	±0.05
60	±0.5	54.1	±0.05
70	±0.5	32.7	±0.05
80	±0.5	14.4	±0.05
90	±0.5	10.2	±0.05
100	±0.5	18.9	±0.05
110	±0.5	40	±0.05
120	±0.5	57.3	±0.05
130	±0.5	67.9	±0.05
140	±0.5	70.1	±0.05
150	±0.5	54.2	±0.05
160	±0.5	36.6	±0.05
170	±0.5	15.6	±0.05
180	±0.5	10.8	±0.05

Analysis/Discussion

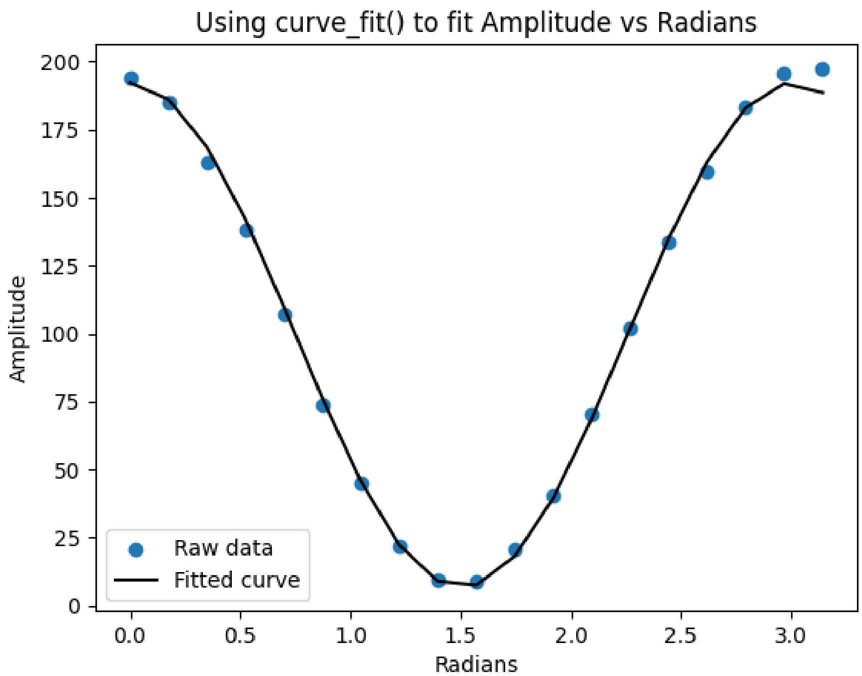

Figure 1: Fitted to $A\cos^2(k\theta) + B = 185.61\cos^2(1.0445\theta) + 6.62$

For the two linear polarizer we were able to fit it to a $\cos^2(1.0445\theta)$ curve. The expected curve for intensity was $\cos^2(\theta)$ meaning we have a percent difference in ω of 4% which means that our experiments matches the theory.

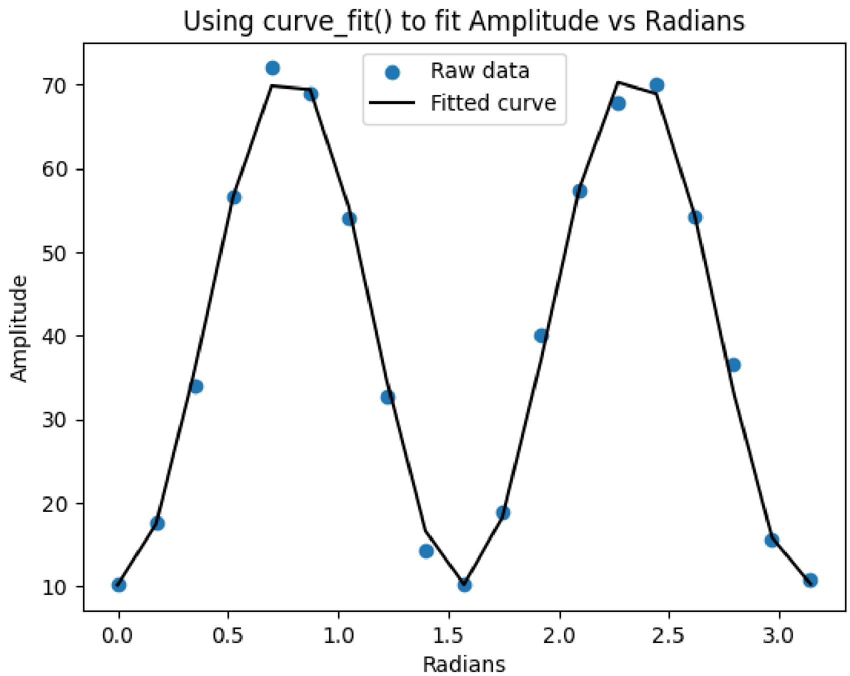

Figure 2: Fitted to $A\sin^2(k\theta) + B = 61.3\sin^2(2.01350\theta) + 10.208$

For the two linear polarizer with a half-wave plate in between, we obtained a fit to a $\sin^2(2.01350\theta)$ curve and since our expected curve was $\sin^2(2\theta)$, we have an error in ω of 0.7% which once again is accurate and shows that our experiment matches with the theory. Some uncertainty in these measurement may have been introduced though due to background light. This could have affected the reading of the sensor. The zeroing of the sensor may also have been off, causing an offset in our data.

Conclusion

We can thus conclude that our experiments matches with the proportionality of $I \propto \cos^2(\theta)/2$ for the two linear polarizer and $I \propto \sin^2(2\theta)/2$ for the two linear polarizer with a half-wave plate in between the two. We obtained for the two linear polarizer $\omega = 1.0445$ which had only a 4% error with the expected of $\omega = 1$. For the two linear polarizer with a half-wave plate in between, we were able to obtain $\omega = 2.0135$ with a percent error of 0.7% from the expected of $\omega = 2$. Thus the experiment gives strong proof to the theory.