UM-SJTU JOINT INSTITUTE

PHYSICS LABORATORY
(Vp241)

LABORATORY REPORT

EXCERCISE 4

POLARIZATION OF LIGHT

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Date: December 1, 2024

[rev4.1]

1 Introduction

Polarization (also polarisation) is a property applying to transverse waves that specifies the geometrical orientation of the oscillations.

The polarization of light is a key knowledge to understand the nature of light. It is widely used in various fields such as optical communication, photography and so on.

In this experiment, we will study the polarization of light and the Malus's Law. We will also look into the relationship between the intensity of light and the angle of the polarizer. Besides all that above, we will pay attention to the way half- and quarter-wave plates work.

2 Experimental setup

2.1 Equipments used in the experiment

Devices used in the experiment include the following: a semiconductor laser, a tungsten iodine lamp, a silicon photo-cell, a UT51 digital universal meter, as well as two polarizers, 1/2-wave and 1/4–wave plates (the uncertainty of the the angle is 2o) and a lens with a glass sheet. The elements are placed on an optical bench for later measurements and corresponding adjustments.

2.2 Measurement procedure

2.3 Malus's Law

We first set up the experiment as shown in the figure below. Then we do the following three steps:

- Rotate the analyzer for 360° and observe the change in light intensity to find the maximum electric current I_0.
- Set the angle of the analyzer to 90° and adjust the angle of the polarizer until the electric current measured by the multimeter reaches its minimum. At this point, the polarizing axes of the polarizer and the analyzer are perpendicular to each other.

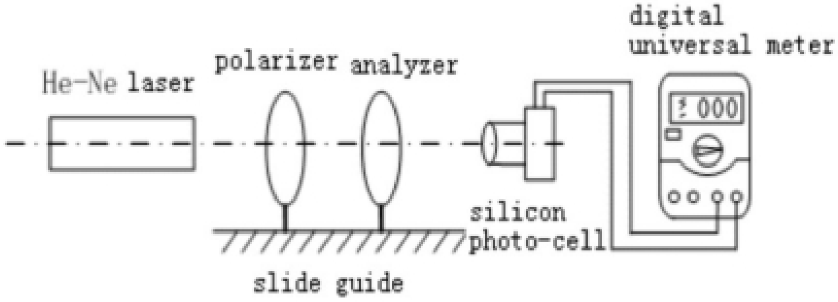

Figure 1: Malus's Law

- Rotate the analyzer from 90° to 0° and record the magnitude of the current I every 5°. Record the values in a table and plot the graph of I/I_0 versus $\cos^2(\theta)$. Perform linear fitting and compare the data with the theoretical result.

2.4 Linearly Polarized Light and the Half-wave Plate

For this part of the experiment, we will do the following steps:

1. Set up the equipment on the optical bench as shown in Figure 2.
   - **A** is the analyzer, and **P** is the polarizer.
   - Set the polarizing axes of **A** and **P** perpendicular to each other before placing the 1/2-wave plate in the apparatus; extinction of the light can be observed on the screen.
2. After inserting the 1/2-wave plate, rotate it to make the light extinction appear again and set this position as the initial position.
3. Rotate the 1/2-wave plate for $\theta = 10°$ from the initial position and the light extinction will be broken. Then rotate **A** to make the light extinction appear again, record the angle of rotation θ in a table.
4. Rotate the 1/2-wave plate for $\theta = 20°$ from the previous position (now $\theta = 20°$) and repeat Step 3. Repeat this step (increase θ) for 8 times. Plot the graph of θ versus the corresponding angle of the analyzer.

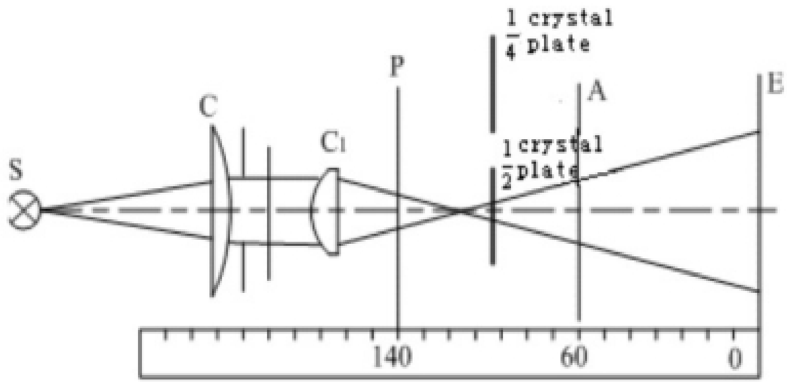

Figure 2: Setup for 1/2 and 1/4-wave plates

2.5 Circularly and Elliptically Polarized Light and the 1/4-wave Plate

For this part of the experiment, we will do the following steps:

1. Set up the equipment on the optical bench as shown in Figure 2.
   - **A** is the analyzer, and **P** is the polarizer.
   - Set the polarizing axes of **A** and **P** perpendicular to each other before placing the 1/4-wave plate in the apparatus; extinction of the light can be observed on the screen. At this point, the angle $\theta = 90°$.
2. After inserting the 1/4-wave plate, rotate it to make the light extinction appear again and set this position as the initial position. At this point, $\theta = 0°$. Rotate the 1/4-wave plate and observe the change in the light intensity.
3. Rotate the analyzer for 360° and record the light intensity (which is indicated by the current **I**) for every 10°. Record the data in a table.
4. Rotate the 1/4-wave plate for 20° and repeat Step 3.
5. Rotate the 1/4-wave plate for 45° and repeat Step 3.
6. Rotate the 1/4-wave plate for 70°. Then rotate the analyzer and record its position and the magnitude of the current when the light intensity reaches a maximum.

Uncertainty of θ is [2]°.

Maximum Electric Current I_0		1.43 ± 0.01 [mW]	
θ	I [mW] ± 0.01 [mW]	θ	I [mW] ± 0.01 [mW]
0°	1.40	50°	0.66
5°	1.39	55°	0.53
10°	1.38	60°	0.40
15°	1.33	65°	0.33
20°	1.28	70°	0.20
25°	1.18	75°	0.15
30°	1.12	80°	0.10
35°	1.00	85°	0.05
40°	0.87	90°	0.03
45°	0.78		

Figure 3: Malus's Law

7. Use a computer to plot the relation between the rotation angle of the analyzer and the light amplitude in polar coordinates. Normalize the amplitude by its maximum value. Mark the position recorded in Step 6 and compare it with the data recorded in Step 4.

8. Compare the result of Step 5 with that for the circular polarization. Plot a linear fit to the data when the angle is 45°.

3 Measurements and Results

3.1 Malus's Law

We will apply an important equation for the demonstration of the Malus's Law:

$$I = I_0 \cos^2(\theta)$$

where I is the intensity of the light after passing through the analyzer, I_0 is the maximum intensity of the light, and θ is the angle between the polarizing axes of the polarizer and the analyzer. The original data and plotted is shown as following with name of Figure 3 and 4

From the figure we can see that the value of $\frac{I}{I_0}$ is proportional to $\cos^2(\theta)$, which is consistent with the theoretical prediction. This should help demonstrate the Malus's Law as mentioned above.

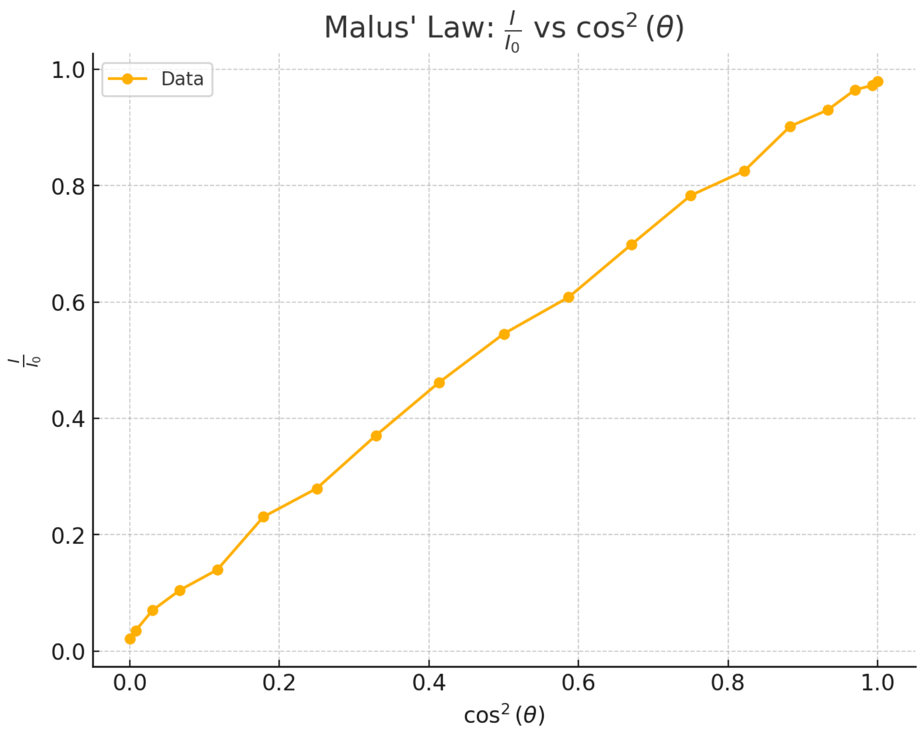

Figure 4: Malus's Law

Rotation angle of the 1/2–wave plate	Rotation angle of the analyzer [°] ±[2]°
initial	0°
10°	11°
20°	35°
30°	54°
40°	76°
50°	93°
60°	116°
70°	133°
80°	153°
90°	173°

Table 2. Measurement data for the 1/2–wave plate.

Figure 5: Half-wave plate

3.2 Linearly Polarized Light and the Half-wave Plate

In this measurement part, we are looking at the relationship between the rotation angle of 1/2-wave plate and the angle of the analyzer. The original data and plotted is shown as following with name of Figure 5 and 6. From the plotted data we can see that the two sets of data are linearly related. The slope of the line is close to 2, which means that the rotation angle of the analyzer is 2 times the rotation angle of the 1/2-wave plate. This indicates that the polarization axis get rotated by twice of the origin angle(2α) after the light passes through the 1/2-wave plate.

3.3 Circularly and Elliptically Polarized Light and the 1/4-wave Plate

There are three different experiments in this part. The first one is to observe the light intensity when the 1/4-wave plate is not rotated. The second is when the 1/4-wave plate is rotated by 20°. The third is when the 1/4-wave plate is rotated by 45°. Since the original data takes too much space, we will just display them in the appendix. The plotted data is shown as following with name of Figure 7: From the plotted graph, we may draw some conclusions:

- When the rotation angle of the 1/4 wave plate is 0°, the maximal light intensity is observed at about 90 and 270 degrees. Also from the figure we may see that the light source is linearly polarized.

- When the rotation angle of the 1/4 wave plate is 20°, the maximal light

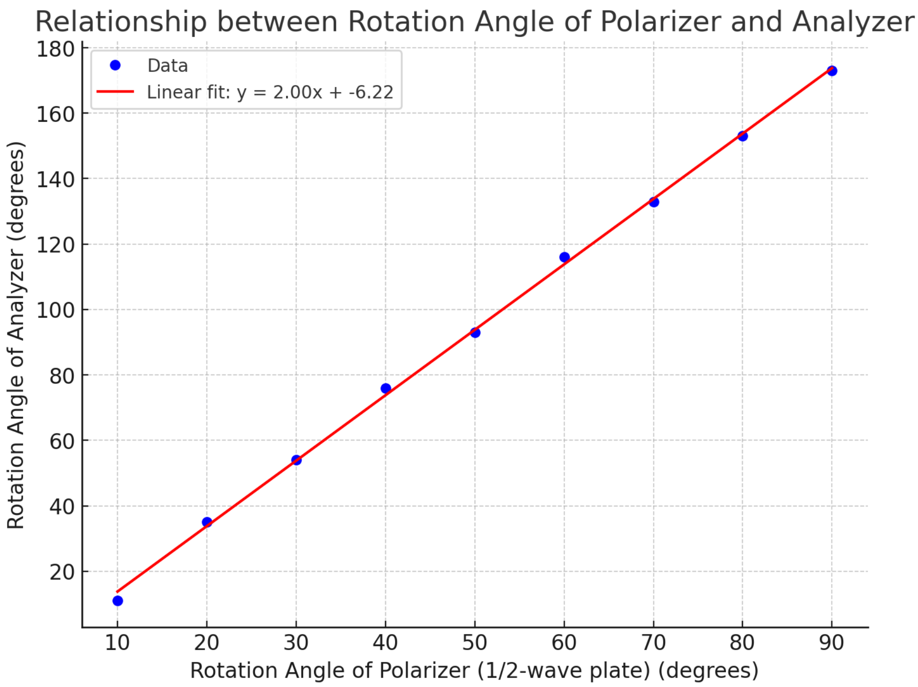

Figure 6: Half-wave plate

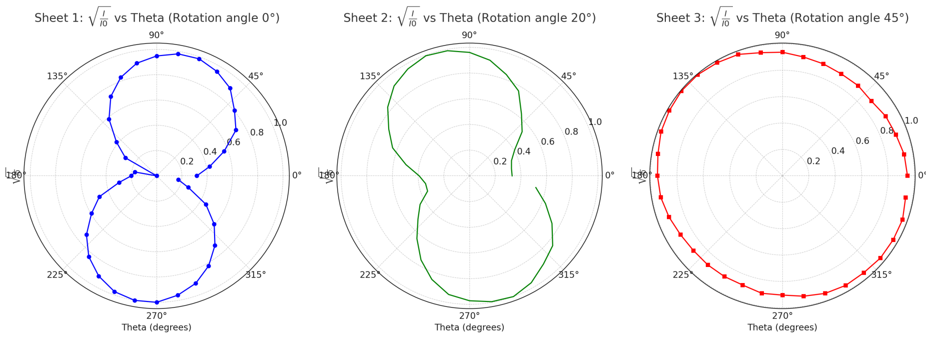

Figure 7: Quarter-wave plate

intensity is observed at about 110 and 290 degrees. The light source is elliptically polarized.

- When the rotation angle of the 1/4 wave plate is 45°, the maximal light intensity is observed at about 135 and 315 degrees. The light source is circularly polarized.

All the results are consistent with the theoretical prediction.

4 Conclusions and discussion

4.1 Conclusions

In this experiment, we have studied the polarization of light and the Malus's Law. We have also looked into the relationship between the intensity of light and the angle of the polarizer. We discovered the different physical behavior when the light source goes through the half- and quarter-wave plates, and the corresponding polarization states of the light source. From the data we have collected, we have verified the Malus's Law and the theoretical prediction of the half- and quarter-wave plates.

4.2 Discussion

Compared to the sample graph given, there are some discrepancies in the data we have collected. The mistakes may have been caused by various reasons:

- The light source may not be perfectly linearly polarized, which may lead to some errors in the data.
- The angle of the polarizer and the analyzer may have some errors in rotation, which cause mistakes.
- The equipment may not be perfectly calibrated due to long terms of use, which may lead to some errors in the data.

Here are some possible improvements to the experiment:

- Use a more stable light source to ensure the light is linearly polarized.
- Use a more precise device to measure the angle of the polarizer and the analyzer.
- Calibrate the equipment more frequently to ensure the accuracy of the data.

5 Works cited

Department of Physics, Shanghai Jiaotong University, Exercise 4 (Polarization of Light) - lab manual [rev. 2.8], 2024

Python Software Foundation. (2020). Python Language Reference, version 3.9. Available at http://www.python.org

All the figures displayed in the article (excluding the appendix) are given using Python 3.9.

A Datasheet

UM-SJTU PHYSICS LABORATORY
DATA SHEET (EXERCISE 4)

Name: 王恺轩 Kaixuan Wang   Student ID: 523370910219

Name: ____________   Student ID: ____________

Group: 8   Date: 11.27

NOTICE. Please remember to show the data sheet to your instructor before leaving the laboratory. The data sheet will not be accepted if the data are recorded with pencil or modified by correction fluid/tape. If a mistake is made in recording a datum item, cancel the wrong value by drawing a fine line through it, record the correct value legibly, and ask your instructor to confirm the correction. Please remember to take a record of the precision of the instruments used.
You are required to hand in the original data with your lab report, so please keep the data sheet properly.

Uncertainty of θ is [2]°.

Maximum Electric Current I_0		1.43 ± 0.01 [mW]	
θ	I [mW] ± 0.01 [mW]	θ	I [mW] ± 0.01 [mW]
0°	1.40	50°	0.66
5°	1.39	55°	0.53
10°	1.38	60°	0.40
15°	1.33	65°	0.33
20°	1.29	70°	0.20
25°	1.18	75°	0.15
30°	1.12	80°	0.10
35°	1.00	85°	0.05
40°	0.87	90°	0.03
45°	0.78		

Table 1. Measurement data Malus' law demonstration.

Instructor's signature: ____________

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Rotation angle of the 1/2–wave plate	Rotation angle of the analyzer [°] ±[2]°
initial	0°
10°	11°
20°	35°
30°	54°
40°	76°
50°	93°
60°	116°
70°	133°
80°	153°
90°	173°

Table 2. Measurement data for the 1/2–wave plate.

Instructor's signature: ____________________

Rotation angle of 1/4–wave plate: 0°			
Maximum Electric Current I_0	0.99 $\pm$ 0.01 [mW]		
θ	I [mW] $\pm$ 0.01 [mW]	θ	I [mW] $\pm$ 0.01 [mW]
0°	0.10	180°	0.04
10°	0.18	190°	0.09
20°	0.32	200°	0.23
30°	0.52	210°	0.35
40°	0.64	220°	0.52
50°	0.81	230°	0.69
60°	0.90	240°	0.83
70°	0.96	250°	0.94
80°	0.95	260°	0.99
90°	0.89	270°	0.99
100°	0.81	280°	0.91
110°	0.68	290°	0.81
120°	0.52	300°	0.67
130°	0.34	310°	0.51
140°	0.17	320°	0.35
150°	0.08	330°	0.20
160°	0.00	340°	0.07
170°	0.03	350°	0.03

Table 3. Measurement data for the 1/4–wave plate (rotation angle 0°).

Instructor's signature: ____________________

Rotation angle of the 1/4–wave plate: 20°			
Maximum Electric Current I_0	0.91 ± 0.01 [mW]		
θ	I [mW] ± 0.01 [mW]	θ	I [mW] ± 0.01 [mW]
0°	0.10	180°	0.14
10°	0.10	190°	0.11
20°	0.11	200°	0.11
30°	0.15	210°	0.18
40°	0.26	220°	0.25
50°	0.36	230°	0.37
60°	0.53	240°	0.52
70°	0.64	250°	0.67
80°	0.76	260°	0.80
90°	0.84	270°	0.86
100°	0.89	280°	0.90
110°	0.90	290°	0.91
120°	0.84	300°	0.84
130°	0.76	310°	0.73
140°	0.63	320°	0.65
150°	0.48	330°	0.50
160°	0.37	340°	0.36
170°	0.23	350°	0.25

Table 4. Measurement data for the 1/4–wave plate (rotation angle 20°).

Instructor's signature: ____________________

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Rotation angle of the 1/4–wave plate: 45°			
Maximum Electric Current I_0		0.49 ± 0.01 [mW]	
θ	I [mW] ± 0.01 [mW]	θ	I [mW] ± 0.01 [mW]
0°	0.44	180°	0.44
10°	0.43	190°	0.43
20°	0.41	200°	0.41
30°	0.40	210°	0.39
40°	0.38	220°	0.38
50°	0.39	230°	0.38
60°	0.39	240°	0.38
70°	0.40	250°	0.38
80°	0.41	260°	0.40
90°	0.43	270°	0.40
100°	0.44	280°	0.42
110°	0.47	290°	0.44
120°	0.48	300°	0.45
130°	0.49	310°	0.45
140°	0.49	320°	0.46
150°	0.48	330°	0.46
160°	0.47	340°	0.46
170°	0.45	350°	0.44

Table 5. Measurement data for the 1/4–wave plate (rotation angle 45°).

Rotation angle of the 1/4–wave plate: 70°	
θ [°] ± [2]°	68
I [mW] ± 0.01 [mW]	0.66

Table 6. Measurement data for the 1/4–wave plate (rotation angle 70°).

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