UM-SJTU Joint Institute

Physics laboratory

Vp241

Lab Report 4

Polarization of Light

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I. Objective

Understand some properties of light, in particular to study the polarization phenomenon and verify Malus' law, as well as to understand the way half- and quarter-wave plates work in optical systems. Generation and detection of elliptically and circularly polarized light will also be investigated.

II. Theoretical Background

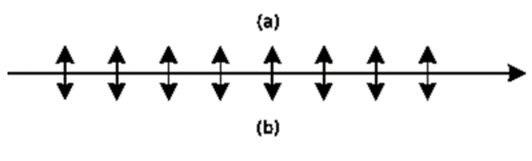
Light can be described in terms of electromagnetic waves, with the plane of oscillations of the electric field vector (as well as the magnetic field vector) perpendicular to the direction of light propagation. Therefore, light is an example of a transverse wave. For light sources producing the so-called natural light, the emitted light is a random mixture of waves with the electric field vector oscillating in all possible transverse directions. This is due to the randomness of the radiation mechanism. Such natural light is also called unpolarized light. For unpolarized light the distribution of the directions of the electric field vector, in the plane perpendicular to the direction of propagation, is uniform. If the distribution is not uniform, the light is said to be polarized. Studies of the polarization of light played an important role in the development of wave optics. They have resulted in a wide range of applications in numerous areas, such as optical measurement techniques, crystal structure research, and experimental stress analysis.

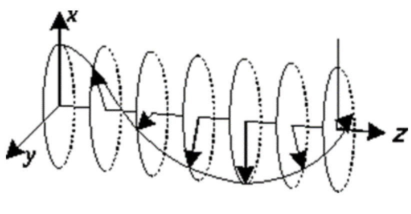
1. Polarization of Light

The electric field vector E, which in the context of electromagnetic waves corresponding to the visible part of the spectrum is sometimes referred to as the light vector describes a time-dependent, propagating electric field. In the plane perpendicular to the propagation direction of a light wave, the light vector may have different directions along which its magnitude oscillates. The light, for which the light vector maintains a certain oscillation direction, is called linearly polarized and the axis defining the direction is called the polarization axis.

The light with the light vector direction rotating about the propagation direction, so that its endpoint traces a circle, is called circularly polarized light. If the vector traces an ellipse, the light said to be elliptically polarized.

Light emitted from ordinary light sources (natural light) is unpolarized. However, it can be regarded as a statistical equal-weight mixture of linearly polarized waves with equal amplitudes. There the light may be also partially polarized, which means it can be regarded as a combination of a polarized and the natural (unpolarized) light. The direction corresponding to the maximum amplitude of the light vector of such partially polarized light is the oscillation direction of the polarized component.





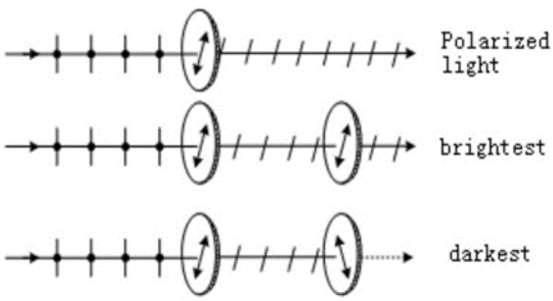
2. Polarizer

A device commonly used to produce polarized light is a polaroid (also called a polarizer). It polarizes the light using the principle of dichroism: a selective absorption mechanism tends to allow the light polarized in a certain direction (direction of the crystal alignment) to pass through the material, while the light polarized in all other directions is absorbed. This turns the incident natural light into linearly polarized.

A polarization device can not only change incident natural light to polarized light (it then acts as a polarizer), but may also be used to detect and analyze linearly polarized, natural, and partially polarized light (it is then called an analyzer).

3. Malus' law

A visible effect in the light coming out of a polarization device is a change of the light brightness.



Suppose that we have two polarizers arranged so that their planes are parallel — the left one plays the role of a polarizer, the other one is an analyzer (see Figure 3). Let the angle between their transmission directions (polarization axes) be θ. The light is incident normally on the polarizer and then continues to the analizer. The intensity of the linearly polarized light leaving the analyzer is: $I_1 = I_0 cos^2\theta$,where Ilight,0 is the intensity of the linearly polarized light incident on the analyzer. Obviously, for a single polarizer, if polarized light is incident on it, then the transmitted light intensity will change periodically when rotating the polarizer. If the incident light is partially or elliptically polarized, the minimum intensity will not be zero as there will be always some component of the light polarized in the transmission direction. The incident light must be natural or circularly polarized if the intensity does not change at all. Hence, by using a polarizer, one can distinguish linearly polarized light from the natural and circularly polarized light.

4. Generation of Elliptically and Circularly Polarized Light. Half-wave and Quarter-wave Plates

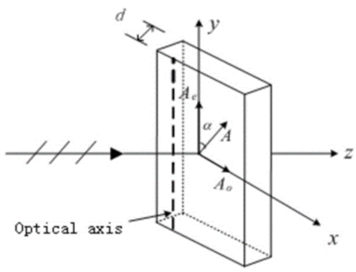
Suppose that linearly polarized light is incident normally on a crystal plate whose surface is parallel to its optical axis, and the angle between the polarizing axis and the optical axis of the plate is α. Then the linearly polarized light is resolved into two waves: an e-wave with the oscillation direction parallel to the optical axis of the plate (extraordinary axis) and an o-wave whose oscillation direction is perpendicular to the optical axis (ordinary axis). They propagate in the same direction, but with different speeds. The resulting optical path difference over the thickness d of the plate is:

$$\Delta = (n_e - n_o)d$$

and, consequently, the phase difference

$$\delta = \frac{2\pi}{\lambda}$$

where λ is the wavelength, ne is the refractive index for the extraordinary axis, and no is the refractive index for the ordinary axis. In a so-called positive crystal δ > 0, whereas in a negative one δ < 0.



crystal plate

when the light propagates through the crystal plate, the two components of the light vector are

$$E_x = A_o \cos \omega t$$

$$E_y = A_e \cos(\omega t + \delta),$$

where Ae = A cos α, Ao = A sin α. Eliminating time from the above equations one obtains

$$\frac{E_x^2}{A_o^2} + \frac{E_y^2}{A_e^2} - 2\frac{E_x E_y}{A_o A_e} \cos \delta = \sin^2 \delta.$$

Note that is the equation of an ellipse for δ =π/2.

When the thickness of the plate changes, the optical path difference changes as well. Some cases of particular interest, are discussed below:

If Δ = kλ, where k = 0, 1, 2, . . ., the phase difference δ = 0, and Eq. (2) reduces to

$$E_y = \frac{A_E}{A_o} E_x$$

which is a linear equation. Hence the transmitted light is linearly polarized with the oscillation direction remaining unchanged. A waveplate that satisfies this condition is called a full-wave plate. The light goes through a full-wave plate without changing its polarization state.

If Δ = (2k + 1)λ/2, where k = 0, 1, 2, . . ., the phase difference δ = π, then:

$$E_y = -\frac{A_E}{A_o}E_x$$

The transmitted light is also linearly polarized with the polarization axis rotated by the angle of 2α. A waveplate that satisfies the condition is called 1/2-wave plate or half-wave plate. When a polarized light passes through a half-wave plate, its polarization axis gets rotated by an angle 2α. If α = π/4, then the polarization axis of the transmitted light is perpendicular to that of the incident light.

Finally, if Δ = (2k + 1)λ/4, where k = 0, 1, 2, . . ., the phase difference δ = π/2, then:

$$\frac{E_x^2}{A_o^2} + \frac{E_y^2}{A_e^2} = 1.$$

The transmitted light is elliptically polarized. A waveplate that satisfies the above condition is called a 1/4-wave plate or a quarter-waveplate and is an important optical element in many polarization experiments.

If $A_e = A_o = A$, then $E_x{}^2 + E_y{}^2 = A^2$, and the transmitted light is circularly polarized. Since the amplitudes of the *o*-wave and the *e*-wave are both functions of *α*, the polarization state after passing through a 1/4-wave plate will vary, depending on the angle:

► if α = 0, the transmitted light is linearly polarized with the polarization axis parallel to the optical axis of the 1/4–wave plate;

► if α = π/2, the transmitted light is linearly polarized with the polarization axis perpendicular to the optical axis of the 1/4–wave plate;

► if α = π/4, the transmitted light is circularly polarized;

► otherwise, the transmitted light is elliptically polarized.

III. Apparatus

The measurement setup consists of: 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.

IV. Procedure

1. Adjustment

(a) Adjust the photo-cell by choosing the appropriate aperture. There are different apertures on the photo-cell (see the figure below) used in different experiments. In this experiment, only the Ø 6.0 aperture, which preserves the incident light intensity, is needed. If other aperture is chosen, the intensity of light may get reduced, resulting in a zero reading on the universal meter. Therefore, before proceeding to the next steps, adjust the laser and the photo-cell so the light can pass through the Ø 6.0 aperture.

(b) With the laser fixed at one of the ends of the bench, place the lens and the glass sheet in front of it. Make sure that the light passes through the center of the lens

(c) Rotate the polarizer for at least whole circle so that the current in the digital meter can reach 0 and the maximum current should be more than 0.800 μA, which ensure that the change of current could be obvious in the following experiments.

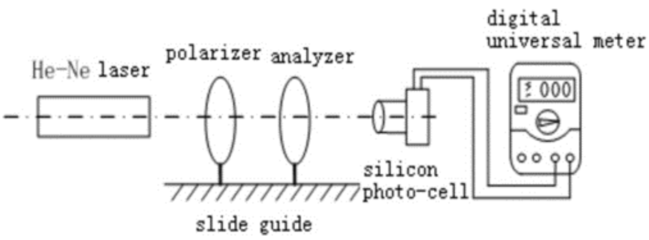
2. Demonstration of Malus' Law

(a) Assemble the measurement setup as shown in Figure below. Make sure that the laser ray passes through the polarizer to generate linearly polarized light before continuing to the analyzer and the silicon photo-cell.

(b) Rotate the analyzer for 360◦ and observe a change in the light intensity to find the maximum electric current I_0. The distance between the light source and the photovoltaic device is 120 cm; Measure the solar power by the provided solar power meter.

(c) Set the angle of 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. The distance between the light source and the photovoltaic device is 120 cm, with two devices in series.

(d) 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 I/I_0 vs. $\cos^2$ θ. Perform linear fitting and compare the data with the theoretical result.



3. Linearly Polarized Light and the Half-wave Plate

(a) Set up the equipment on the optical bench as shown in below Figure. 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 screen.

(b) After inserting the 1/2-wave plate, rotate it to make the light extinction appear again and set this position as the initial position.

(c) Rotate the 1/2-wave plate for α = 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 Δθ in a table.

(d) Rotate the 1/2-wave plate for 10◦ from the previous position (now α = 20◦) and repeat Step (c) Repeat this step (increase α) for 8 times. Plot the graph Δθ vs. θ.

(e) Analyze the data

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

(a) Keep the position of other plates remaining. Replace the 1/2-wave plate by the 1/4-wave plate, rotate it to make the current in the electrical meter to be 0. Set the this position to be θ = 90°, rotate the analyzer for 360° and record the light intensity for every 10°

(b) Rotate the 1/4-wave plate for 20°, repeat the step 1.

(c) Rotate the 1/4-wave plate for 45°, repeat the step 1.

(d) Rotate the Rotate the 1/4-wave plate for 70°, rotate the analyzer and record its position and the magnitude of the current when the light intensity reaches maximum.

V. Results & Analysis

1.Measurement Uncertainty for equipment:

QUANTITY	PRECISION
The electric Current	±0.001[μA]
angle	2 [°]

2. Demonstration of Malus Law

Below shows the origin data:

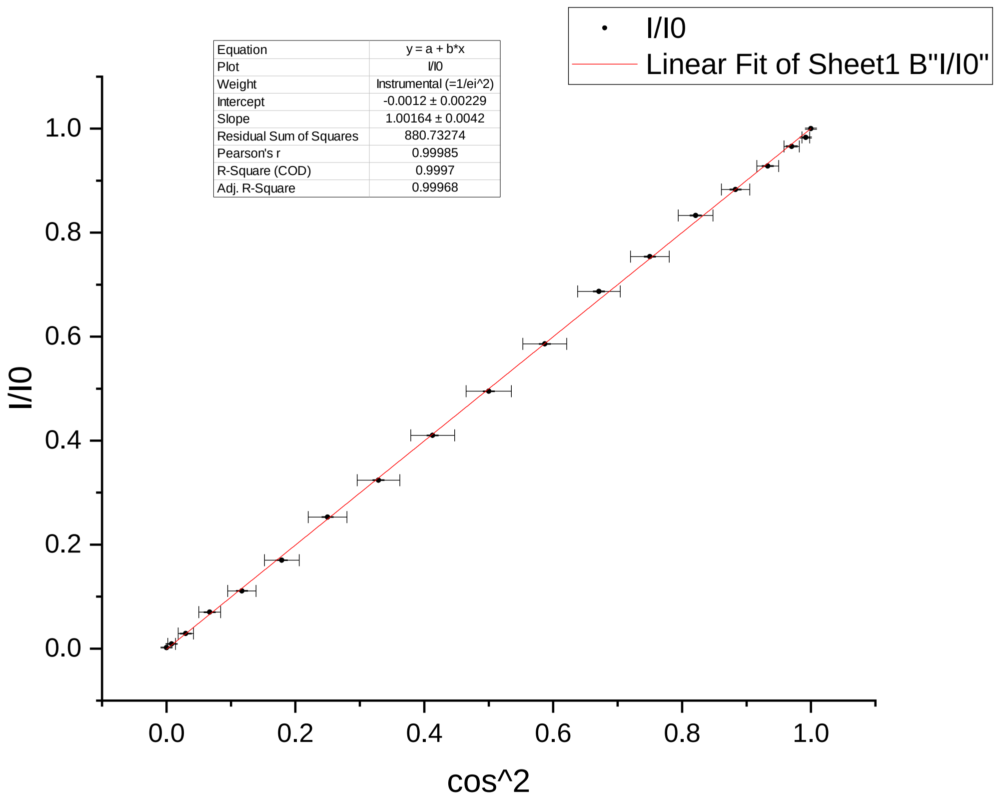
Maximum Electric Current $I_0 =$	$1.315 \pm 0.001[\mu A]$		
θ	$I\ [\mu A] \pm 0.001[\mu A]$	θ	$I\ [\mu A] \pm 0.001[\mu A]$
0°	1.315	50°	0.539
5°	1.293	55°	0.426
10°	1.270	60°	0.333
15°	1.220	65°	0.223
20°	1.161	70°	0.146
25°	1.096	75°	0.093
30°	0.991	80°	0.038
35°	0.903	85°	0.012
40°	0.771	90°	0.002
45°	0.651		

After calculating, we can generate the following table:

θ	$\cos^2\theta$	$\frac{I}{I_0}$
0°	1.000	1
5°	0.992	0.983
10°	0.970	0.966
15°	0.933	0.928

20°	0.883	0.883
25°	0.821	0.833
30°	0.750	0.754
35°	0.671	0.687
40°	0.587	0.586
45°	0.500	0.495
50°	0.413	0.410
55°	0.329	0.324
60°	0.250	0.253
65°	0.179	0.170
70°	0.117	0.111
75°	0.067	0.070
80°	0.030	0.029
85°	0.008	0.009
90°	0.000	0.002

Then using origin to make the linear fit plot:



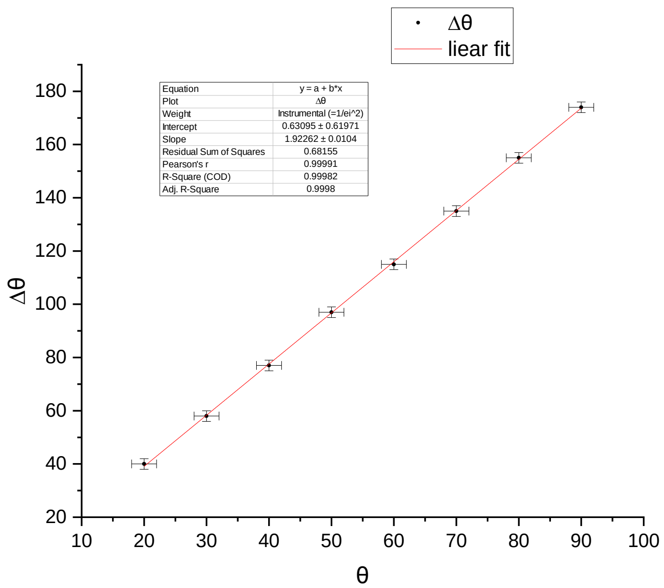
Where slope = 1.00164

3. Linearly polarized light with Half-wave Plate input solar power

Below shows the origin data:

Rotation angle of the ½-wave plate	Rotation angle of the analyzer
initial	0
10°	20°
20°	40°
30°	58°
40°	77°
50°	97°
60°	115°
70°	135°
80°	155°
90°	174°

Then using origin to make the linear fit plot:



Where slope = 1.92262

4. Circularly & Elliptically Polarized Light with ¼-wave plate: 0°

Below shows the origin data:

Rotation angle of ¼-wave plate: 0°			
Maximum Electric Current $I_0 =$	$1.005 \pm 0.001[\mu A]$		
θ	$I\ [\mu A] \pm 0.001[\mu A]$	θ	$I\ [\mu A] \pm 0.001[\mu A]$
0°	0.004	180°	0.007
10°	0.035	190°	0.056

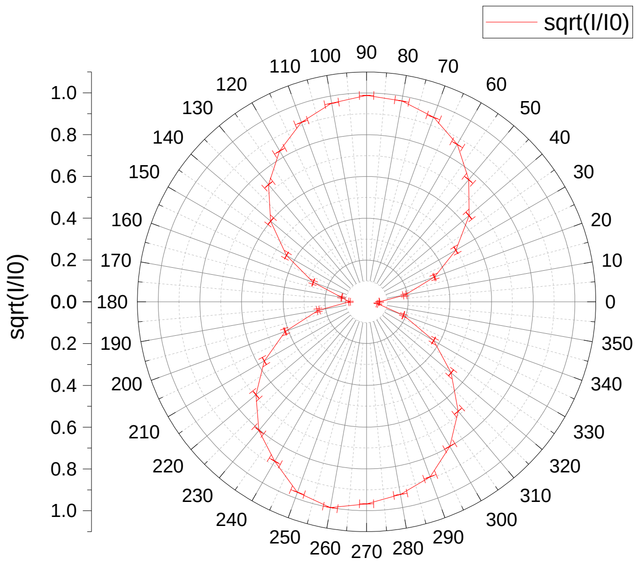
20°	0.121	200°	0.174
30°	0.246	210°	0.323
40°	0.414	220°	0.483
50°	0.585	230°	0.650
60°	0.760	240°	0.780
70°	0.888	250°	0.945
80°	0.958	260°	1.005
90°	0.981	270°	0.940
100°	0.935	280°	0.880
110°	0.840	290°	0.800
120°	0.699	300°	0.641
130°	0.538	310°	0.470
140°	0.363	320°	0.282
150°	0.198	330°	0.139
160°	0.075	340°	0.036
170°	0.015	350°	0.003

After calculating, we can generate the following table:

θ	$\sqrt{\frac{I}{I_0}}$	θ	$\sqrt{\frac{I}{I_0}}$
0°	0.063	180°	0.083
10°	0.187	190°	0.236
20°	0.347	200°	0.416
30°	0.495	210°	0.567
40°	0.642	220°	0.693
50°	0.763	230°	0.804
60°	0.870	240°	0.881
70°	0.940	250°	0.970
80°	0.976	260°	1.000
90°	0.988	270°	0.967
100°	0.965	280°	0.936
110°	0.914	290°	0.892
120°	0.834	300°	0.799
130°	0.732	310°	0.684
140°	0.601	320°	0.530
150°	0.444	330°	0.372
160°	0.273	340°	0.189

170°	0.122	350°	0.055

Then using origin to make the polar coordinate plot:



5. Circularly & Elliptically Polarized Light with ¼-wave plate: 20°

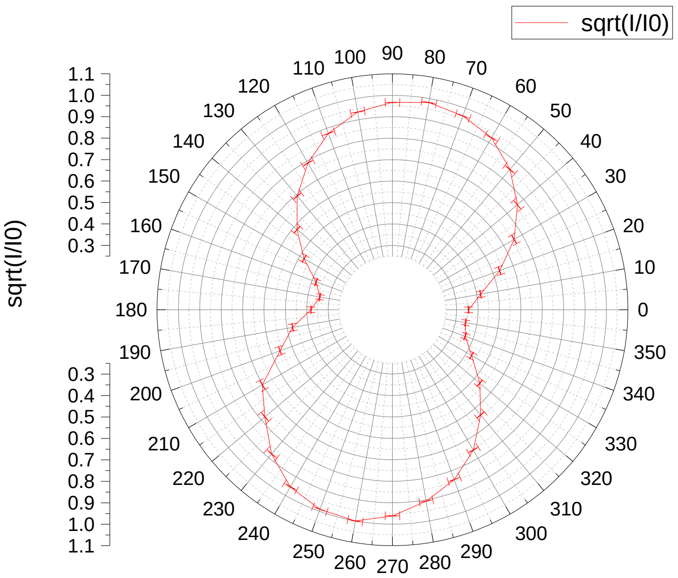
Below shows the origin data:

Rotation angle of ¼-wave plate: 20°			
Maximum Electric Current $I_0 = \quad 0.914 \pm 0.001[\mu A]$			
θ	I $[\mu A] \pm 0.001[\mu A]$	θ	I $[\mu A] \pm 0.001[\mu A]$
0°	0.116	180°	0.133
10°	0.160	190°	0.205
20°	0.260	200°	0.286
30°	0.395	210°	0.450
40°	0.531	220°	0.553
50°	0.666	230°	0.705
60°	0.784	240°	0.832
70°	0.845	250°	0.896
80°	0.880	260°	0.914
90°	0.855	270°	0.844
100°	0.801	280°	0.750
110°	0.700	290°	0.649
120°	0.570	300°	0.523
130°	0.438	310°	0.376
140°	0.310	320°	0.260
150°	0.208	330°	0.167
160°	0.132	340°	0.120
170°	0.108	350°	0.110

After calculating, we can generate the following table:

θ	$\sqrt{\frac{I}{I_0}}$	θ	$\sqrt{\frac{I}{I_0}}$
0°	0.356	180°	0.381
10°	0.418	190°	0.474
20°	0.533	200°	0.559
30°	0.657	210°	0.702
40°	0.762	220°	0.778
50°	0.854	230°	0.878
60°	0.926	240°	0.954
70°	0.962	250°	0.990
80°	0.981	260°	1.000
90°	0.967	270°	0.961
100°	0.936	280°	0.906
110°	0.875	290°	0.843
120°	0.790	300°	0.756
130°	0.692	310°	0.641
140°	0.582	320°	0.533
150°	0.477	330°	0.427
160°	0.380	340°	0.362
170°	0.344	350°	0.347

Then using origin to make the polar coordinate plot:



6. Circularly & Elliptically Polarized Light with ¼-wave plate: 45°

Below shows the origin data:

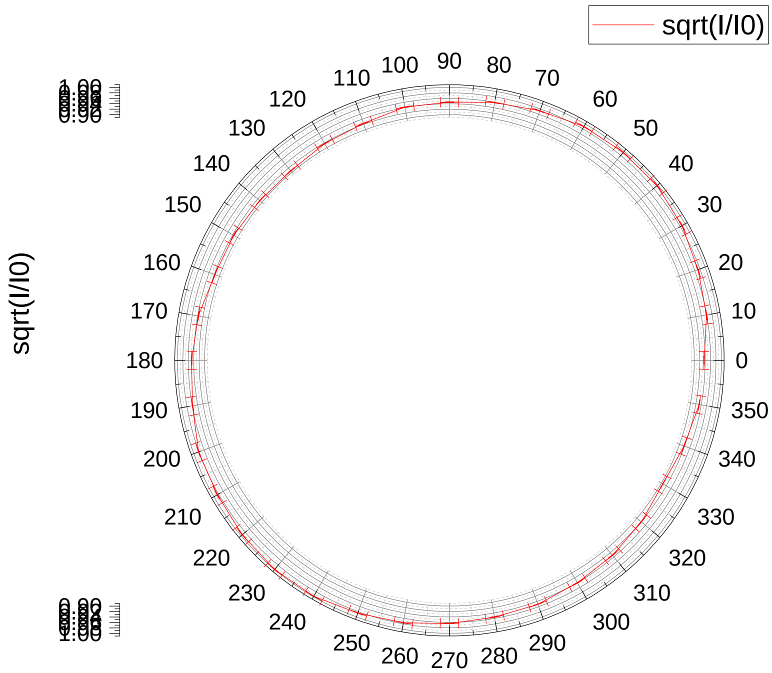
Rotation angle of ¼-wave plate: 45°			
Maximum Electric Current $I_0 = \quad 0.570 \pm 0.001[\mu A]$			
θ	I $[\mu A] \pm 0.001[\mu A]$	θ	I $[\mu A] \pm 0.001[\mu A]$
0°	0.499	180°	0.512
10°	0.525	190°	0.524
20°	0.538	200°	0.548
30°	0.555	210°	0.553
40°	0.566	220°	0.563
50°	0.563	230°	0.570
60°	0.557	240°	0.568
70°	0.540	250°	0.553
80°	0.524	260°	0.543
90°	0.510	270°	0.530
100°	0.506	280°	0.520
110°	0.487	290°	0.515
120°	0.479	300°	0.505
130°	0.469	310°	0.495
140°	0.472	320°	0.484
150°	0.478	330°	0.468
160°	0.480	340°	0.480
170°	0.500	350°	0.495

After calculating, we can generate the following table:

θ	$\sqrt{\frac{I}{I_0}}$	θ	$\sqrt{\frac{I}{I_0}}$
0°	0.936	180°	0.948
10°	0.960	190°	0.959
20°	0.972	200°	0.981
30°	0.987	210°	0.985
40°	0.996	220°	0.994
50°	0.994	230°	1
60°	0.989	240°	0.998
70°	0.973	250°	0.985
80°	0.959	260°	0.976
90°	0.946	270°	0.964
100°	0.942	280°	0.955

110°	0.924	290°	0.951
120°	0.917	300°	0.941
130°	0.907	310°	0.932
140°	0.910	320°	0.921
150°	0.916	330°	0.906
160°	0.918	340°	0.918
170°	0.937	350°	0.932

Then using origin to make the polar coordinate plot:



7. Circularly & Elliptically Polarized Light with ¼-wave plate: 70°

The data of the rotation angle and the current is listed below:

Rotation angle of ¼-wave plate: 70°	
$\theta[\ ^{\circ}] \pm [2^{\circ}]$	100°
$\mathrm{I}\ [\mu\mathrm{A}]$+-0.001$[\mu\mathrm{A}]$	0.805

VI. Uncertainty Analysis

1. Demonstration of Malus Law

QUANTITY	PRECISION
The electric Current	±0.001[μA]
angle	2 [°]

For $u_{\frac{I}{I_0}}$, we have, $u_{\frac{I}{I_0}} = \frac{I}{I_0}\sqrt{(\frac{1}{I})^2 {u_I}^2 + (\frac{1}{{I_0}^2})^2 {u_{I_0}}^2}$ = $0.001\sqrt{(\frac{1}{I_0})^2 + (\frac{I}{{I_0}^2})^2}$

Therefore, we can have the following table,

θ	$u_{\frac{I}{I_0}}$
0°	0.0011
5°	0.0011
10°	0.0011
15°	0.0010
20°	0.0010
25°	0.0010
30°	0.0010
35°	0.0009
40°	0.0009
45°	0.0008
50°	0.0008
55°	0.0008
60°	0.0008
65°	0.0008
70°	0.0008
75°	0.0008
80°	0.0008
85°	0.0008
90°	0.0008

For $u_{\cos^2\theta}$, we have,

$$u_{\cos^2\theta} = 2cos\theta sin\theta \ \ u_\theta,$$

Hence, we can have the following table.

θ	$u_{\cos^2\theta}$
0°	0.000
5°	0.006
10°	0.012

15°	0.017
20°	0.022
25°	0.027
30°	0.030
35°	0.033
40°	0.034
45°	0.035
50°	0.034
55°	0.033
60°	0.030
65°	0.027
70°	0.022
75°	0.017
80°	0.012
85°	0.006
90°	0.000

2. Linearly polarized light with Half-wave Plate

The uncertainty of the rotation angle is $u_\theta = 2^\circ$

3. Circularly and elliptically polarized light with ¼-wave plate (0°)

For $u_{\sqrt{\frac{I}{I_0}}}$, we have,

$$u_{\sqrt{\frac{I}{I_0}}} = \sqrt{\frac{I}{I_0} * \frac{u_{\frac{I}{I_0}}}{2\frac{I}{I_0}}} = \frac{0.001}{2}\sqrt{\frac{1}{I * I_0} + \frac{I}{{I_0}^3}}$$

Hence, we can have the following table.

θ	$u_{\sqrt{\frac{I}{I_0}}}$	θ	$u_{\sqrt{\frac{I}{I_0}}}$
0°	0.0079	180°	0.0060
10°	0.0027	190°	0.0021
20°	0.0014	200°	0.0012
30°	0.0010	210°	0.0009
40°	0.0008	220°	0.0008
50°	0.0008	230°	0.0007
60°	0.0007	240°	0.0007
70°	0.0007	250°	0.0007

80°	0.0007	260°	0.0007
90°	0.0007	270°	0.0007
100°	0.0007	280°	0.0007
110°	0.0007	290°	0.0007
120°	0.0007	300°	0.0007
130°	0.0008	310°	0.0008
140°	0.0009	320°	0.0010
150°	0.0011	330°	0.0014
160°	0.0018	340°	0.0026
170°	0.0041	350°	0.0091

4. Circularly and elliptically polarized light with ¼-wave plate (20°)

For $u_{\sqrt{\frac{I}{I_0}}}$, we have,

$$u_{\sqrt{\frac{I}{I_0}}} = \sqrt{\frac{I}{I_0}} * \frac{u_{\frac{I}{I_0}}}{2\frac{I}{I_0}} = \frac{0.001}{2}\sqrt{\frac{1}{I * I_0} + \frac{I}{{I_0}^3}}$$

Hence, we can have the following table.

θ	$u_{\sqrt{\frac{I}{I_0}}}$	θ	$u_{\sqrt{\frac{I}{I_0}}}$
0°	0.0015	180°	0.0014
10°	0.0013	190°	0.0012
20°	0.0010	200°	0.0010
30°	0.0009	210°	0.0009
40°	0.0008	220°	0.0008
50°	0.0008	230°	0.0008
60°	0.0008	240°	0.0008
70°	0.0008	250°	0.0008
80°	0.0008	260°	0.0008
90°	0.0008	270°	0.0008
100°	0.0008	280°	0.0008
110°	0.0008	290°	0.0008
120°	0.0008	300°	0.0008
130°	0.0009	310°	0.0009
140°	0.0010	320°	0.0011
150°	0.0012	330°	0.0013
160°	0.0015	340°	0.0015

170°	0.0016	350°	0.0016

5. Circularly and elliptically polarized light with ¼-wave plate (45°)

For $u_{\sqrt{\frac{I}{I_0}}}$, we have,

$$u_{\sqrt{\frac{I}{I_0}}} = \sqrt{\frac{I}{I_0} * \frac{u_{\frac{I}{I_0}}}{2\frac{I}{I_0}}} = \frac{0.001}{2}\sqrt{\frac{1}{I * I_0} + \frac{I}{{I_0}^3}}$$

Hence, we can have the following table.

θ	$u_{\sqrt{\frac{I}{I_0}}}$	θ	$u_{\sqrt{\frac{I}{I_0}}}$
0°	0.0012	180°	0.0012
10°	0.0012	190°	0.0012
20°	0.0012	200°	0.0012
30°	0.0012	210°	0.0012
40°	0.0012	220°	0.0012
50°	0.0012	230°	0.0012
60°	0.0012	240°	0.0012
70°	0.0012	250°	0.0012
80°	0.0012	260°	0.0012
90°	0.0012	270°	0.0012
100°	0.0012	280°	0.0012
110°	0.0012	290°	0.0012
120°	0.0012	300°	0.0012
130°	0.0012	310°	0.0012
140°	0.0012	320°	0.0012
150°	0.0012	330°	0.0012
160°	0.0012	340°	0.0012
170°	0.0012	350°	0.0012

VII. Conclusion

1.Answer to the question in the procedure,

(a) 4 times

(b) 2 times

(c) The transmitted light will be linearly polarized with the polarized axis rotated by the angle of 2 alpha.

2.Demonstration of Malus' Law

From the linear fit, it can be figure out that there is a linear relationship between I/I_0 and $cos^2\theta$ which is correspond to the Malus's law. With slope equals to 1.00164 in our result, we can calculate the relative error:

$$E = \frac{|\eta_{exp} - \eta_{theory}|}{\eta_{theory}} \times 100\% = E = \frac{|1-1.00164|}{1} \times 100\% = 0.164\%,$$

, which is consider quite low.

3.Linearly Polarized Light and the Half-wave Plate

From the graph, we have slope: 1.92262 ± 0.029, with the theorem $\Delta\theta = 2\theta$, which indicate that slope between $\Delta\theta$ and 2θ should be 2. Then, we have $E = \frac{|2- \ 1.92262|}{2} \times 100\% = 3.869\%$, which is small that still can help us verified the relationship successful.

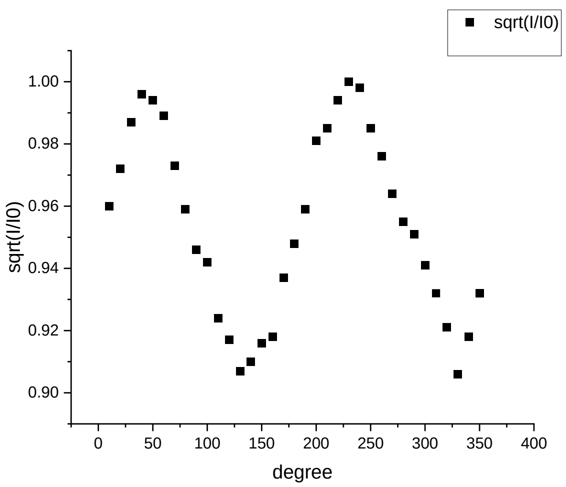
4.Circularly and elliptically polarized light with ¼-wave plate (0, 20, 45, 70 degree)

For rotation angle of 0 degree and 20 degrees, the maximum current should occur twice with theta 180 degree between them. In 0 degree, the maximums happen in 90 and 260 degrees, which has little shift. In 20 degrees, the maximums happen in 80 and 260 with perfect 180 degrees different.

However, the maximum current of 0 degree occur when $\theta = 0$ or 180 degree while the 20 degree maximum current occur when $\theta = 20$ or 200 degree. The reason that our data can't meet the theory is due to the additional step during experiments. Our group adjust the current = 0 as the initial condition which is unnecessary. So the maximum current will shift in our data.

Theoretically, when alpha is 0 degree, the transmitted light will be linearly polarized. As the graph in the result part, it is corresponded to the theorem. For rotation angle of 20 degree, the transmitted light will be elliptically polarized. As in the result part, it is corresponded to the theorem.

For rotation angle of 45 degrees, the result change within a quite small range(0.9~1.0), which means the light intensity remain almost the same. It is in an acceptable range of relative error. Hence, we have verified the relationship successful.



VIII. Discussion

There main two reason that might affects the error ought to be the light from cellphone, the unstable current source and human adjust error.

During the experiment there might be the chance for student to shake the light that influence the detector. It is quite hard to avoid while some students want to observe the current value on the detector, the other wants to light their own machine to adjust it. Therefore, cause the unavoidable error.

During the lab, our group find that our current source generates the current gradually small. In 1/4 wave-plate, the max current of 70 degrees is 0.850 which is further small than the 20degrees of 1/4 wave-plate. I have asked one of my classmate and found the same problem. Some current source does generate unstable current.

Due to all the lab was operating on dark with light from cellphone, there might be a great chance for people to adjust the angle with error. With the uncertainty of angle be 2, which is already consider not small, the human error might cause much more. Maybe there can be some electrical device to help student adjust the angle in the dark with much more precision in future.

IX. Reference

1. Exercise 4 –Lab Manual.pdf
2. https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=2&cad=rja&uact=8&ved=2ahUKEwi0ivGzwYzmAhVCIqYKHUK5AoAQFjABegQIDxAE&url=https%3A%2F%2Fen.wikipedia.org%2Fwiki%2FPolarization_(waves)&usg=AOvVaw3yPUPmRQH6yrnlfavTk6Jd

X. Data sheet

Attach at end