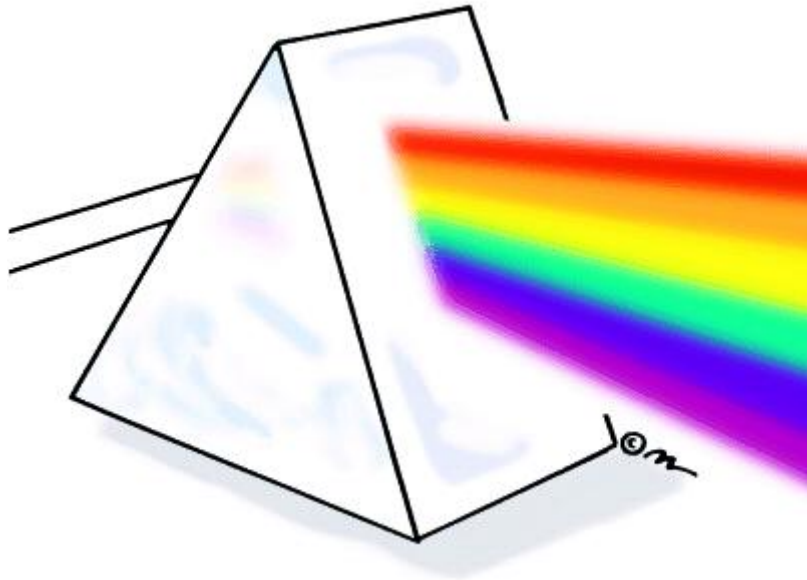


**OPAC103
GEOMETRIC OPTICS
LABORATORY MANUAL**

Polarization of Light



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**Course Web page:
<http://www1.gantep.edu.tr/~bingul/opac103>**

Sep 2015

Some parts of the following pages are extracted from www.pasco.com and METU PHYS 222 lecture notes.

PURPOSE

To verify the Malus' law and observe Birefringence.

EQUIPMENT

Polarization Analyzer
Basic Optics Bench
Aperture Bracket
Red Diode Laser
Light Sensor
Rotary Motion Sensor
ScienceWorkshop 500 Interface
DataStudio or Capstone Software

INTRODUCTION

Laser light (peak wavelength = 650 nm) is passed through two polarizers. As the second polarizer (the analyzer) is rotated by hand, the relative light intensity is recorded as a function of the angle between the axes of polarization of the two polarizers. The angle is obtained using a Rotary Motion Sensor that is coupled to the polarizer with a drive belt. The plot of light intensity versus angle can be fitted to the square of the cosine of the angle.

THEORY

According to the wave model, light is a transverse electromagnetic wave. Electric and magnetic fields associated with it oscillate perpendicular to the direction of propagation. Electric field of an electromagnetic wave, in particular, can be represented by two orthogonal components. These two orthogonal components do not interfere in amplitude but are additive according to vector algebra. In an unpolarized (or randomly polarized) light there is no well-defined phase relationship between these two components. The planes of oscillations of the resultant field change randomly. Light is said to be polarized when a fixed phase and amplitude relationship is maintained between the two orthogonal field components. Resultant wave formed by the orthogonal components can have various states of polarization. Referring to Fig. 1, three basic types of polarized light are:

1. Linearly, or plane, polarized light. Oscillation is confined to a plane. The resultant electric field vector traces out a straight line.
2. Circularly polarized light. The resultant electric field vector traces out a circle.
3. Elliptically polarized light. The resultant electric field vector traces out an ellipse. This is the most general state of polarized light.

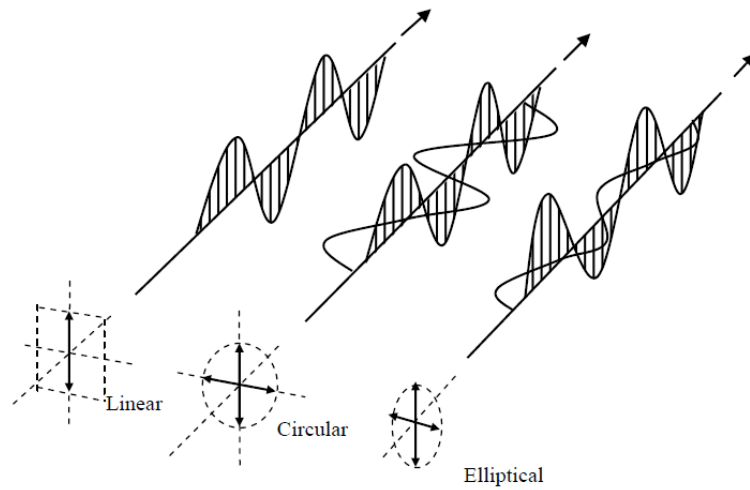


Figure 1

Processes of preferential absorption in a dichroic material, reflection and transmission at oblique incident, double refraction in a birefringent material, and scattering by particles can be used for producing polarization. An ideal polarizer transmits only light whose electric field is parallel to the transmission axis of the polarizer and blocks light with the orthogonal field, Fig. 2.

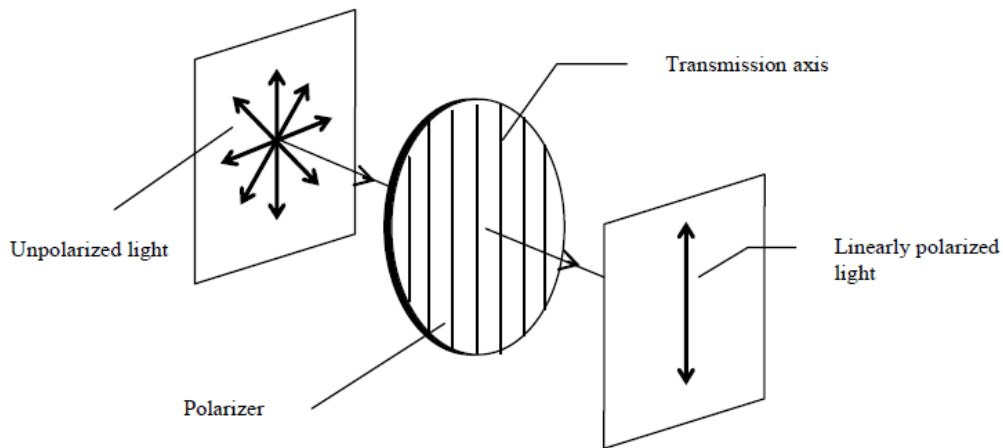


Figure 2

Real polarizers are not perfect and transmit light with minimum intensity when polarizer axis is perpendicular to the polarization of purely linearly polarized light. The maximum transmitted intensity occurs when the polarizer axis is parallel to the incident polarization direction.

In present experiment **Malus' law** is verified. Suppose, as illustrated in Fig. 3, we have two linear polarizers made of dichroic material. The first is called polarizer and produces plane polarized light by strongly absorbing the component of the incident electric field perpendicular to its axis. The second is called the analyzer.

Let the angle between the axis of the polarizer and analyzer is θ . It is easily shown that if the intensity of the unpolarized light incident on the analyser is I_1 , then the intensity, I_2 out, of the polarized light leaving the analyser is given by:

$$I_2 = I_1 \cos^2(\theta) \tag{1}$$

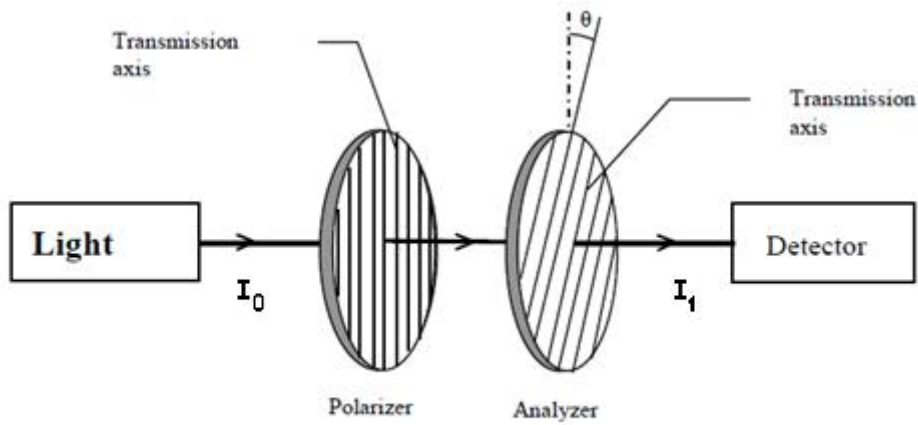


Figure 3

Unpolarized light can pass through 3 polarizers (see Fig.4).

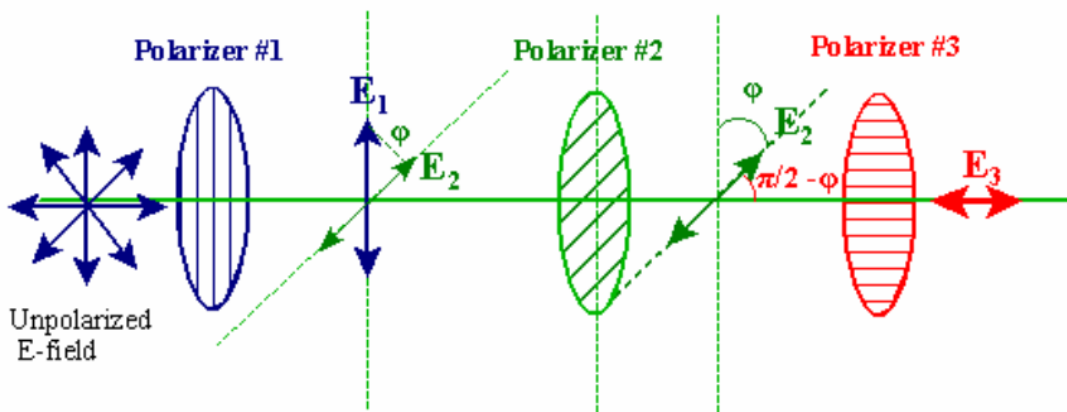


Figure 4

The first and last polarizers are oriented at 90° with respect each other. The second polarizer has its polarization axis rotated an angle θ from the first polarizer. The intensity after passing through the third polarizer is

$$I_3 = \frac{I_1}{4} \sin^2(2\theta) \tag{2}$$

EXPERIMENT 1 (Two Polarizers)

Procedure

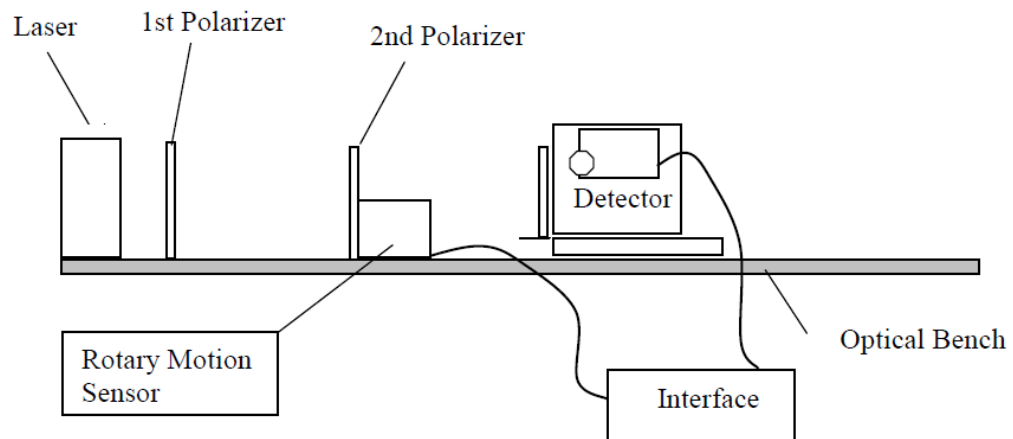


Figure 4



1. Turn on the laser. Adjust the position of the both polarizers so that their transmission axes become parallel.
2. Turn on the interface. Before starting to take data, open the graph icon from the main menu.
3. Then start taking data by pushing the play button once on the keyboard of the interface.
4. Next slowly rotate the 2nd Polarizer up to 400° (i.e. polarizer which is connected to the rotary motion sensor.)
5. In order to stop the measurement, push again the play button once.
6. Go back to the main menu by pushing the home button on the interface and choose the files icon. In this sub menu you will see your measurement data as untitled file. You should rename and save it. Then plug in your flash disk to the interface and send your saved file to it.

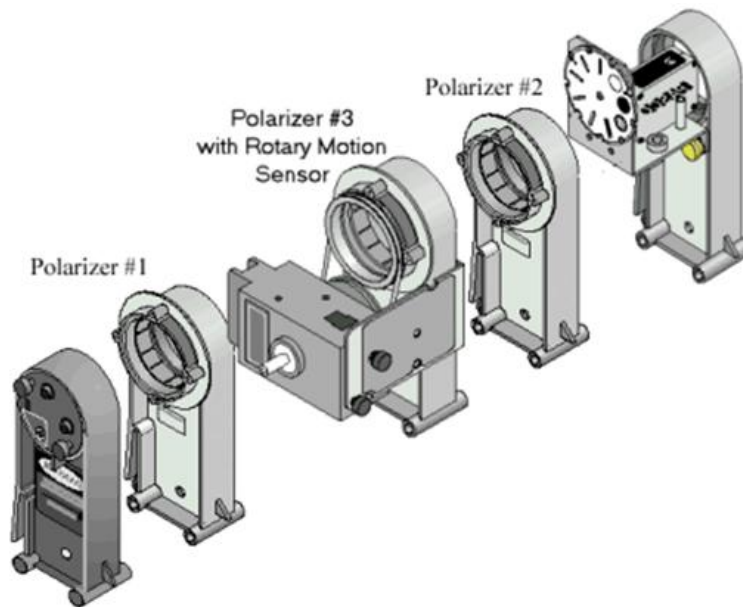
6. Go back to the main menu by pushing the home button on the interface and choose the files icon. In this sub menu you will see your measurement data as untitled file. You should rename and save it. Then plug in your flash disk to the interface and send your saved file to it.
7. Turn off the laser and the interface.

Analysis

1. Plot a graph with measured intensities $I(\theta)$ as ordinates and the angle θ between the polarizers as abscissa. Fit your data to the nonlinear function $I(\theta) = A + B \cos^2\theta$? If yes explain. What is the physical meaning of A?
2. Plot a graph $I(\theta)$ vs $X = \cos^2(\theta)$. Fit your data to the linear function $I(\theta) = A + B X$?
3. Which type of polarization do you observe? (i.e. Linear, circular or elliptical polarization)

EXPERIMENT 2 (Three Polarizers)

Procedure



1. Now repeat the experiment with 3 polarizers. Place one polarizer on the track and rotate it until the transmitted light is a maximum.
2. Then place a second polarizer on the track and rotate it until the light transmitted through both polarizers is a minimum.
3. Then place a third polarizer on the track between the first and second polarizers. Rotate it until the light transmitted through all three polarizers is a maximum
4. Press Start and record the Intensity vs. angle for 400 degrees as you rotate the third polarizer that has the Rotary Motion Sensor.
5. Select your data from 2 polarizers and from 3 polarizers. What two things are different for the Intensity vs. Angle graph for 3 polarizers compared to 2 polarizers?.

Analysis

1. Plot a graph I_3 vs θ . Fit your data to the linear function $I_3 = A + B \sin^2(2\theta)$.
2. For 3 polarizers, what is the angle between the middle polarizer and the first polarizer to get the minimum transmission through all 3 polarizers?

QUESTIONS

1. What are the possible errors in the experiment?
2. What kind of approximations did you take into consideration while you were obtaining the physical quantities and how do they affect your results?
3. What discrepancies did you encounter between the calculated quantities and theoretical or literature values?
4. What is your overall conclusion?
5. Derive Eqn (2).

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NOTE for lab instructor:

At the end of lab, show students the Birefringence effect and stress distribution on transparent materials.