LU6: LAB 1-5C1: Polarization: Law of Malus (mal· loo·s)

REFERENCES:

- *Fundamentals of Light & Lasers* (OPTEC), 3rd edition
- Mod 5, Laboratory 1-5C.1, pages 55-56.
- http://optecvideo.opteccrm.org, Video 19: Read these instructions and watch the videos before doing the lab.
  - Course 1: Fundamentals of Light and Lasers
  - Lab Activity Video
  - Choose Video #

THEORY:

A special optical filter that is used to change randomly polarized light into linearly polarized light in a certain direction, is called a *polarizer* (polarizer 1). When the same optical filter is used to intercept incoming linearly polarized light and is used to yield information on the nature of that polarization, it is called an *analyzer* (polarizer 2). Randomly polarized light incident on a "polarizer" whose transmission axis (TA) is vertical allows only *vertically polarized* light to propagate from the polarizer. The vertically polarized light which is then incident on an "analyzer" whose transmission axis is horizontal, at 90° to the direction of the vertically polarized light. As a result, **no** light is transmitted. Study diagrams 1 & 2.

Law of Malus states that the *intensity* (*power* of beam area is unchanged) of light that is transmitted through both the polarizer (stationary) and the analyzer (rotated) is a *function of the angle between their axes of transmission*. Study diagram 3.

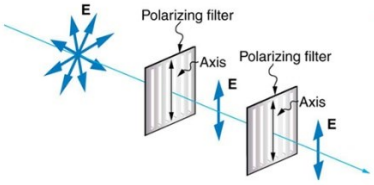


Diagram 1

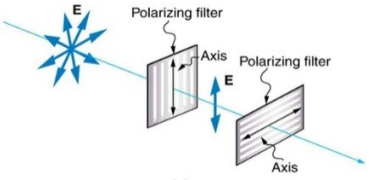


Diagram 2

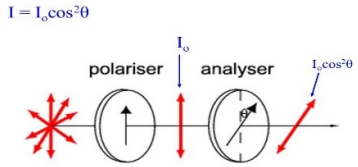


Diagram 3

OBJECTIVE:

Plot the power of a laser beam projected through a polarizer and an analyzer.
Plot the power at a series of angles between their axes of transmission to verify the Law of Malus.
To do a comprehensive and precise Lab Write-up.
Take appropriate pictures (5 or more) to prove/show lab work.

EQUATIONS:

$I = I_o\cos^2\theta$ (Law of Malus)

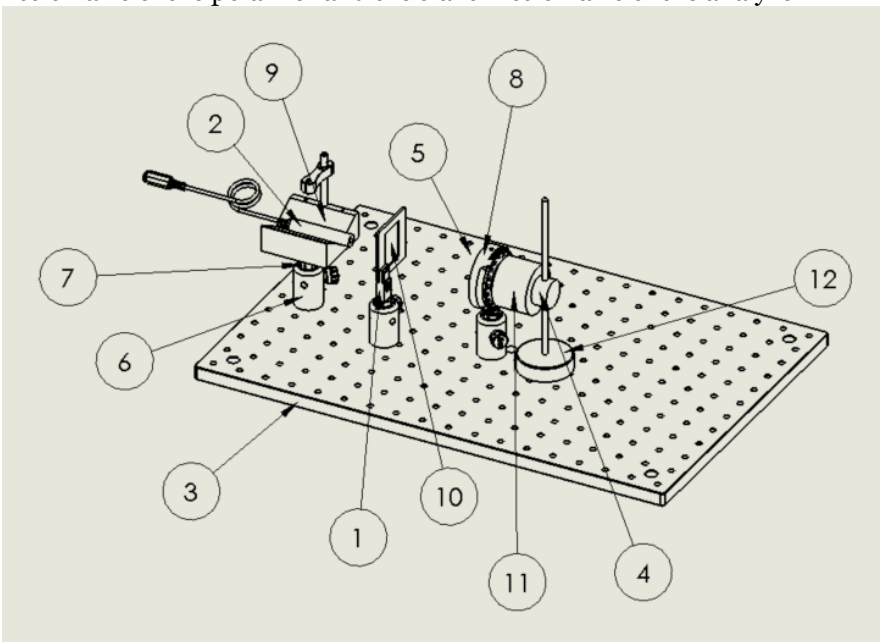
I = the *intensity* of the light transmitted by the **analyzer (measured & calculated)**
I_o = the *intensity* of the light that is incident on the analyzer at θ = 0°
θ = the angle between the transmission axis of the polarizer and the transmission axis of the analyzer

$P = P_o\cos^2\theta$ (Law of Malus when the beam area is unchanged; use in this equation)

P = the *power* of the light transmitted by the **analyzer (measured & calculated)**
P_o = the *power* of the light that is incident on the analyzer at θ = 0°
θ = the angle between the transmission axis of the polarizer and the transmission axis of the analyzer

EQUIPMENT:

Filter Holder (key 1)
Laser Diode Module (key 2)
Laser Diode Power Supply
Optical Breadboard (key 3)
Photometer, Detector (key 4)
Polarizer, Glass (key 5)
(3) Post Holder (key 6)
(3) Post (key 7))
Rotation Mount (key 8)
V-Clamp (key 9)
Polarizer, Slide Mounted (key 10)
Detector Shield (key 11)
Stand, Photometer Sensor (key 12)
Misc. Hardware



SET-UP: Read the entire SET-UP and PROCEDURE before starting the lab.

1. Mount a post holder near the midpoint of a short end of the breadboard.
2. Mount a post in the center hole on the bottom of the V-clamp and insert the assembly in the post holder.
3. Mount a second post holder in the same row of holes along the length of the board. Mount it near the center of the board.
4. Mount the glass polarizer in the rotation mount. Attach the mount to a post. Lay the assembly aside.
5. Mount the polarizer slide in the dual filter holder. Attach a post to the holder and lay the assembly aside.
6. Place a beam block at the end of the breadboard to contain the laser beam.
7. Mount the laser diode in the V-clamp. Adjust the position so the beam will be projected along the center of a row of holes the length of the board.
8. Assemble the photometer detector/sensor on its stand and place it on the breadboard beyond the empty post holder but close to it.
9. Place the polarizer slide assembly in a post holder & position the unit as close to the laser as reasonably possible, between the laser & the empty post holder.
10. Turn on the laser and adjust heights so that the laser beam passes through the polarizer and is centered on the photometer sensor. The detector face should encompass the entire beam.
11. Place the rotation mount assembly in the empty post holder and adjust its position so the laser beam is centered on the polarizer (analyzer).
    a. Reposition the photometer sensor if necessary to place it as near to the analyzer as practical to reduce interference from room lighting.
    b. If available, a sensor shield (short, thin cardboard tube) will also reduce interference from ambient light.

PROCEDURE: Read this complete procedure before following it.

1. Rotate the laser diode in the V-clamp to *maximize the beam power through* the polarizer slide (**measure 3 times** with the photometer) and clamp the diode in place. Laser beams are often partially polarized. The maximum power (P_{max}, **before analyzer**) will occur when the polarized axis of the laser beam is aligned with the axis of the polarizer slide. **Record**.
2. Rotate the analyzer with the rotation mount to **measure** the **maximum power** analyzer output power (*dim the room lights or shield the sensor to reduce interference from the room lights*). This is the power when the transmission axes are aligned (P_o, after analyzer). **Record** P_o in the Lab Write-Up per the table below (In the Measured Power, P, column and in the row where $\theta = 0$).
3. **Record** the starting angle in the table (indicated angle of the rotation mount at $\theta = 0°$, *it may not be zero*°).
4. Rotate the analyzer 10 degrees. **Record** the indicated angle and the transmitted power, $P_{\#}$, at that angle in the table below. Continue in 10 degree increments until the analyzer has been rotated 90 degrees.

Indicated Angle (deg) (Rotation Mount)	Δ Angle, θ (deg)	**Measured** Power, P (mW)	**Calculated** Power, P (mW) ($P = P_o \cos^2\theta$)	(%) Difference or Error
After polarizer; before analyzer		P_{max} =		
After analyzer = X° indicated on rotation mount.	0	P_o =		
	10	P_1 =		
	20	P_2 = and so on....		
	30			
	40			
	50			
	60			
	70			
	80			
	90			

CALCULATIONS:

1. Use $\mathbf{P = P_o \cos^2 \theta}$ to **calculate** the power, P, predicted by The Law of Malus for each θ. Use the **measured** power at $\theta = 0°$ for P_o.
2. **Calculate & record** the % difference/error between the calculated and measured powers at each θ to complete the table.
3. **Explain** discrepancies.

DISCUSSION:

- Malus, a French army engineer, discovered polarization by reflection accidently while looking at sunlight reflected off the windows of the Luxembourg Palace in Paris through a crystal.
- Squid and octopuses have the ability to see polarization. This helps to find and identify food sources such as plankton that are otherwise difficult to see.