EXPERIMENT 5: Experiment of Polarization

Part 1: Polarizer and Screen

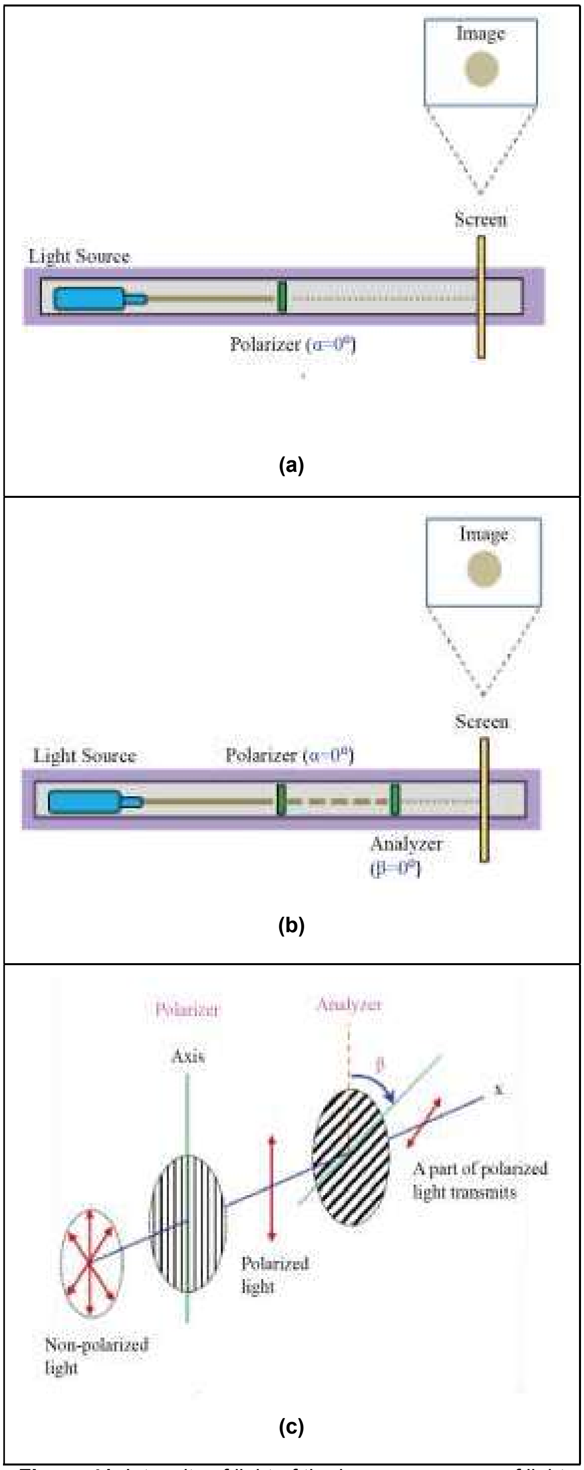

Figure 41: Intensity of light of the image on screen of light passing from polarizer **(a)**, intensity of light of the image on screen of light passing from analyzer **(b)**, and the angle of analyzer with respect to the axis of polarizer **(c)**.

1. Light source, polarizer and screen are placed on optics track.

   1.1. Distance between light source and polarizer is adjusted to;
   - $x_1 = 20\ cm.$

   Distance between screen and polarizer is adjusted to;
   - $x_2 = 30\ cm.$

   1.2. White pointer on polarizer is adjusted to;
   - $\alpha = 0°.$

   1.3. Light source is opened and image is formed on screen (Figure-41a).

   1.4. Polarizer is removed from optics track and whether intensity of illumination of the image changes or not is observed. If it changes, its reason is explained.

2. Now, second polarizer (analyzer) is placed behind polarizer (Figure-41b).

   2.1. Distance between analyzer and polarizer is adjusted to;
   - $x_3 = 15\ cm.$

   2.2. Firstly, white pointer on analyzer is adjusted to;
   - $\beta = 0°.$

   2.3. Next, the angle of analyzer is set as $\beta = 30°$ in condition that the angle of polarizer is kept unchanged $(\alpha = 0°)$ (Figure-41c).

   2.4. After this operation, the angle between axes of first polarizer and second polarizer (analyzer) will be;

   $$\Delta = \beta - \alpha = 30°.$$

   2.5. Change of intensity of illuminance of the image on screen is monitored.

3. Same steps are repeated, changing the angle of analyzer as increase of 30° between $\beta = 30°{\sim}180°.$

   3.1. According to each change of angle, how intensity of illuminance of the image on screen changes is observed.

3.2. When difference of angle between polarizer and analyzer is $\Delta = 90°$, whether image is formed on screen is determined. If there is no any image on screen, its reason is explained on experimental report.

Two polarizers are used in experimental set-up. Light passes from these polarizers through plane marked 0° and 180° on scale of polarizer. As a result of this, light passing from first polarizer is linearly polarized. If direction of second polarizer is same as direction of vibration of linearly polarized light, that light passes is observed. If the angle between these two directions is 90°, that light does not pass is seen.

4. What is polarization?

If components of an electromagnetic wave vibrate in different directions, phenomenon of reduction of this vibration to one direction is called "polarization".

5. What is direction of polarization?

Direction of vibration and direction of propagation of electric field component of an electromagnetic wave form plane of polarization, direction of vibration of this electric field component is called direction of polarization. Direction of vibration of electric field vector is chosen for direction of polarization of light wave.

6. The angle between axes of polarizer and analyzer is β. How does change intensity of light passing from analyzer with change of angle β?.

When the axes of polarizer and analyzer are parallel with each other ($\beta = 0°$ or $\beta = 180°$), intensity of light passing from analyzer becomes maximum, in the case of that the axes are perpendicular to each other ($\beta = 90°$ or $\beta = 270°$), intensity of light becomes minimum (zero).

6. Polarization

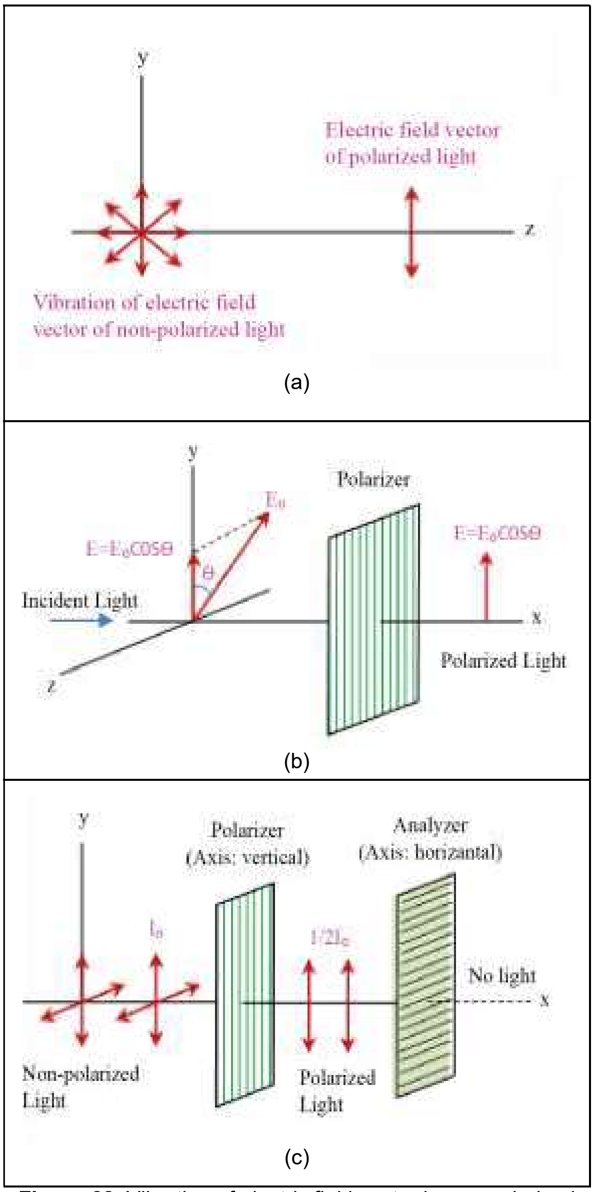

Figure-28: Vibration of electric field vector in non-polarized light and in polarized light **(a)**, polarized light that has angle θ between its axis and vertical axis is polarized after it passes from polarizer **(b)**, when axis of polarizer is perpendicular to axis of analyzer, analyzer does not pass light **(c).**

There are two types of waves, depending on direction of vibration (shape of propagation). They are transverse and longitudinal waves. Waves of which direction of propagation and direction of vibration are perpendicular to each other are transverse waves.

Electromagnetic waves are transverse waves. Waves of which direction of propagation and direction of vibration are parallel with each other are longitudinal waves. Sound waves are longitudinal waves.

Displacement per time of waves is velocity of waves. Velocity of a wave depends on frequency of wave and wavelength. It is given by the following relation:

$$v = \lambda f$$ (**Experimental**) (48)

Here,

$v(m/s)$: Velocity of wave.

$\lambda(m)$: Wavelength.

$f(Hz)$: Frequency.

In light waves, electric and magnetic field vector are perpendicular to each other and direction of propagation. Electric field (**E**) and magnetic field (**B**) of electromagnetic wave change as perpendicular to each other. In addition, electric and magnetic field vibrate in same phase. In other words, electric field and magnetic field increase or decrease together. Velocity of propagation of electromagnetic waves is perpendicular to these two fields.

Electromagnetic waves have a feature of polarization. If components of a wave vibrate in different directions, phenomenon of reduction to only one direction is called polarization. Direction of polarization of an electromagnetic wave is taken at direction of electric field. If electric field vibrates at only one direction, it is expressed as linearly polarized. Direction of vibration of electromagnetic wave's electric field is direction of polarization (**Figure-28a**).

If the angle between linearly polarized wave and polarizer is θ (**Figure-28b**), magnitude of electric field vector of wave is given below:

$$E = E_0 \cos\theta \tag{49}$$

If intensity of light of polarized light is I_0, intensity of light passing from polarizer will be as below:

$$I = I_0 \cos^2\theta \tag{50}$$

Here,

I_0 : Intensity of light.
θ : The angle between linearly polarized wave (incident light) and axis of filter.

When non-polarized light passing from a polarizer of which polarized axis is vertical, light becomes polarized as vertical. Therefore, polarizer allows passing only vertical component of incident light. In the case of use of analyzer, if polarized axis of this analyzer and axis of polarizer are perpendicular to each other, light do not pass (**Figure-28c**).

Two methods are used for polarization of visible light.

1. To pass light from polarizer,
2. Polarization by means of reflection.

6.1. Polarizer

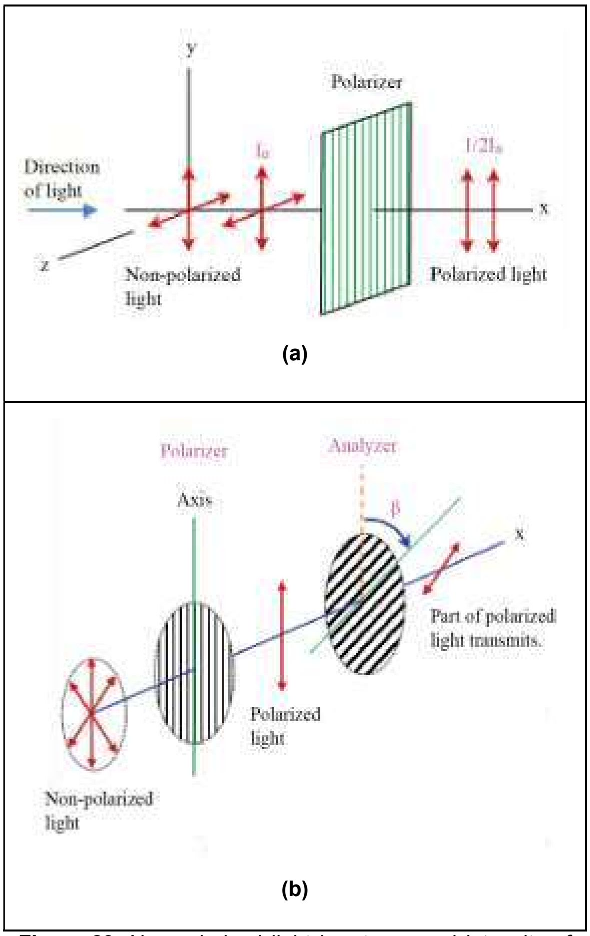

Figure-29: Non-polarized light has two equal intensity of light as horizontal and vertical components. Intensity of light reduces in half after passing from polarizer **(a)**. A part of polarized light passes from analyzer **(b)**.

Material which selects an electromagnetic wave vibrating only certain direction from non-polarized light and obtains polarized light is called polarizer. When polarizer is used for polarization of visible light, polarizer allows passing a major part of incident light in parallel with axis of polarization. In other words, it allows passing a part of light in direction of electric field. As a result of this, intensity of light reduces in half.

When non-polarized light is passed from polarizer, second polarize is needed to understand whether light beam is polarized.

When we turn second polarizer by a value between 0° and 180°, light is polarized if intensity of light changes between maximum and minimum (zero). Second polarizer used for this purpose is called analyzer. If intensity of light transmitted to analyzer is zero at certain position, light is polarized with %100. Moreover, if intensity of light reaches to minimum value, light is partially polarized.

As an example, in system of two polarizers, axis of the first polarizer is vertical and the angle between axis of the other polarizer and vertical line is 60°**.** To find intensity of light passing from analyzer, firstly it is needed to determine intensity of light passing from polarizer. Intensity of light passing from polarizer is a half of intensity of incident light. Therefore, after non-polarized pass from first polarizer, its intensity reduces to half (**Figure-29a**).

$$I_1 = \frac{1}{2} I_0$$

After light polarized as vertical pass from second polarizer (analyzer), its intensity decrease:

$$I_2 = I_1 (\cos 60^0)^2$$

$$I_2 = \frac{1}{4} I_1$$

As a result, it is found that;

$$I_2 = \frac{1}{8} I_0$$

As seen, intensity of light passing from analyzer (I_2) is equal to 1/8 of intensity of non-polarized light and polarization occurs at $\beta = 60°$ (**Figure-29b**).