2. Theory

2.1 Detection of Polarized Light

Light is a transverse electromagnetic wave that can be represented by two orthogonal oscillation vectors, both perpendicular to the propagation direction of light. These vectors are the electric field vector ***E*** and the magnetic field vector ***B***. By definition, the oscillation direction of the electric field vector ***E*** is called the polarization direction of light.

As light interacts with matter, various phenomena such as reflection, refraction, birefringence, or dichroism may occur. Correspondingly, the plane of oscillation of the electric field vector of light may be altered giving rise to various states of polarization of light. If the plane of polarization of light becomes fixed in a particular direction, then it is called linear polarization; if the plane of oscillation of the electric field vector of light rotates or otherwise varies in a uniform manner, then it is circular or elliptical polarization.

Polarized light can be described by the two orthogonal components of its electric field, E_y and E_z,

$$\begin{aligned} E_y &= E_{oy} \cos(\omega t - kx) \\ E_z &= E_{oz} \cos(\omega t - kx - \delta) \end{aligned} \tag{1}$$

Where E_{oy} and E_{oz} are the amplitudes of the electric field along y and z axes, respectively; and δ is the phase delay between these components. The value of the phase delay determines the type of the polarization of the light wave as

$\delta=0$, Linear
$\delta\neq0$, Elliptical
$\delta=\delta(t)$ Random, Unpolarized
$\delta=\pi/2$, $E_{oy}=E_{oz}$, Circular
$\delta=\pi/2$, $E_{oy}\neq E_{oz}$, Elliptical, major/minor axes aligned along y and z axes.

Under normal circumstances, human eyes are unable to recognize polarized light directly, but have to be aided with a polarizer that is often called an analyzer. A polarizer is a special device that selectively passes only the component of the electric field parallel to its optical axis. When unpolarized light passes through a polarizer, it is linearly polarized with plane of polarization parallel to the direction of the optical axis of the polarizer.

2.2 Malus's Law

As described above, if a ray of unpolarized light is incident on a polarizer, then only a portion of light with plane of oscillation of the electric field vector parallel to the axis of the polarizer can pass the polarizer. All the other component of light with plane of oscillation of the electric field vector perpendicular to the axis of the polarizer is absorbed by the polarizer. Similarly, if the transmitted light with linearly polarization is incident on a second polarizer (analyzer), then only a portion of the linearly polarized light with polarization parallel to the axis of the analyser can pass through.

Malus's law defines the transmitted intensity of light through two polarizers with an angle of θ between the transmission directions of the polarizers, as

$$I = I_{max} \cos^2 \theta \tag{2}$$

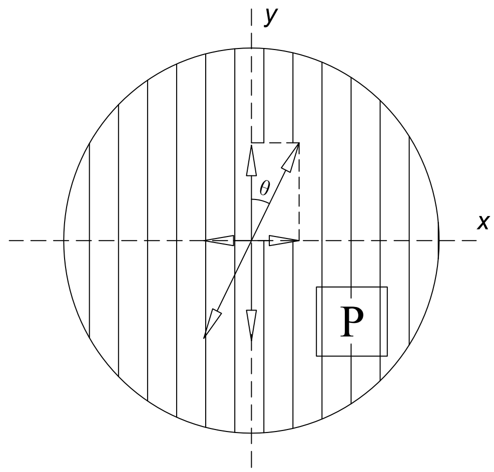

Figure 1 Schematic of Malus's Law

2.3 Effect of Optical Activity

When linearly polarized light passes through certain solid substances or solutions, the plane of polarization of the light rotates a certain angle. This phenomenon is called the effect of optical activity and the optical rotatory angle is called the specific rotation of the substance. The specific rotation of a solution depends on a number of parameters such as the substance in the solution, the concentration of solution, the sample path length, the temperature of solution, and the wavelength of light. If other parameters are fixed, then the specific rotation, θ, is linearly proportional to the concentration of solution, C, as

$$\theta = \beta C \tag{3}$$

where β depends on the substance in the solution, the sample path length, the temperature of solution, and the wavelength of light.

The polarization rotation ability of a substance can be further evaluated by its specific rotatory power, as described by

$$[a]_{\lambda}^{T} = \frac{\theta}{lC} \tag{4}$$

where T represents the temperature of the solution (°C), λ is the wavelength of monochromatic light (nm), θ is the specific rotation degree, l is the sample path length (dm), and C is the concentration of solution (g/100 mL).

It is apparent from equation (4) that **a)** the plane of polarization of light rotates gradually as light propagates in the solution so that the specific rotation is proportional to the length of the sample, **b)** the specific rotation is also proportional to the concentration of the solution.

If the concentration of the solution and the sample path length are known, the specific rotatory power of the solution can be calculated once the specific rotation is measured. This can be conducted by measuring the specific rotation while varying the solution concentration. From the slope of the obtained θ-C line, the specific rotatory power of the substance can be derived. Similarly, if the specific rotatory power of a substance is known, then its concentration in a solution under test can be determined once the specific rotation is measured.

The specific rotation of an optically active medium can be either left-handed or right-handed. When viewed against the propagation direction of light, if the specific rotation is clockwise, then the substance is called a right-handed substance; if the specific rotation is counter-clockwise, then the substance is called a left-handed substance.