

# Modulation of Visualized Electrical Field

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## ABSTRACT

Polarization is an important concept of electromagnetism, and polarizers were traditionally applied to demonstrate this concept in a laboratory. We set up an optical system with the optical component “axis finder” to visualize the polarization direction immediately. The light phenomena, such as birefringence, circular polarization, and Brewster’s angle, can be examined polarization visually. In addition, the principle of different waveplate and optical axis can be presented in a straightforward approach. By means of image analysis, the great precision of polarizing direction can be measured up to 0.01 degree.

Modulated polarized light is applied to a few optical devices, like Liquid-crystal display. It is marvelous to trace the light polarization between the backlight module, polarizer, and panel. As seeing is believing, the visualized electrical field allows educators to teach polarization in a smooth and strikingly manifest manner. Without any polarizer and analyzer, we examine the rotary power of different concentration syrup, presenting the relationship with polarization change. We also demonstrate the wide application of polarization light in modern life, and examine the principle through this visualized electrical field system.

**Keywords:** polarization, axis finder, birefringence, optical activity

## 1. INTRODUCTION

It is well established that light may be treated as a transverse electromagnetic wave. In that case, the direction of the electric field vibration is defined as polarization. Once the vibration lays on a fixed direction, it is described as a linear polarization light. Another case is that the electric field vibration is rotating as seen by an observer whom the wave is moving. Generally, the nature light source is un-polarized, but this anisotropic phenomena may be caused by light-material interaction, such as reflection, scattering, or refraction.

The electrical field vibration direction cannot be observed by human naked eye or optical sensor because of its rapid frequency. Instead of polarization, intensity is the observed quantity. By means of polarizer, the polarization direction of light can be filtered, and transformed to intensity according to the included angle. However, intensity on analyzer is not visualized distribution. In this paper, an optical component called “axis finder” will be introduced, which provides a direct way to observe polarization.



Figure 1. Axis finder is applied to observe the light polarization of lake surface reflection and blue sky from scattering.

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Axis finder provides visualized image which is the polarization direction directly. Figure 1 shows the light passing through axis finder. Because the light is partially polarized after reflection and scattering, a dark line indicates the polarization direction in the center of axis finder. Electrical field can be demonstrated in imaging way by this component. The principle of this key component, axis finder, will be described below.

## 2. POLARIZATION ANALYSIS

Polarization is an important concept of electromagnetism. Normally, a linear polarizer is applied to produce specific wave. The natural light, such as the sunshine or the lamp, do not has specific vibration direction. Once passing through the polarizer, one direction electrical field is absorbed. Thus the rest light has specific vibration in the perpendicular direction. We call this direction as the transmission axis of the polarizer. If another polarizer is placed to block the light again, the total penetrated power will depend on their included angle of their transmission axis. The second polarizer is called analyzer. In this paper, the axis finder is used to replace analyzer. The design of axis finder is showed in Figure 2.

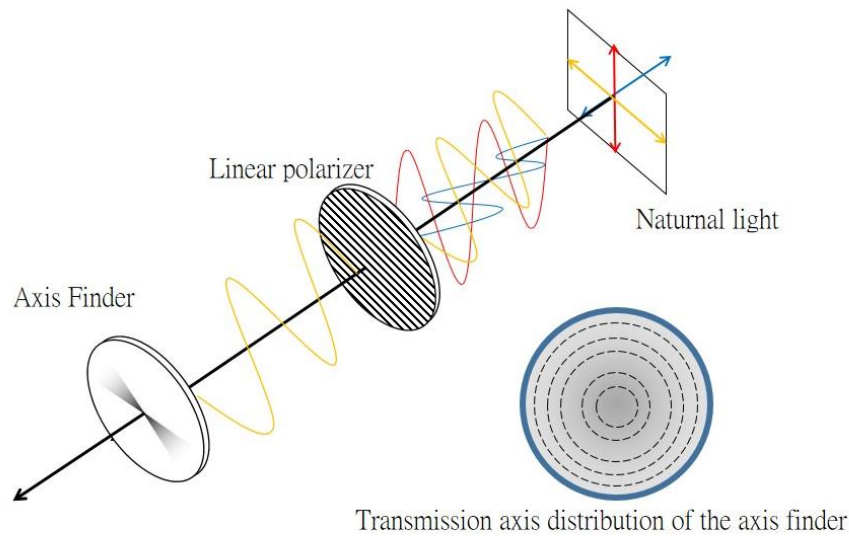


Figure 2. Structure of Axis finder and system set up

The transmission axis is designed as a concentric circles. Therefore radial electric field is blocked and shows the black line. As the transmission axis distribution, axis finder converts the linear polarization light as a black line intensity distribution. This black line indicates the polarization direction clearly, and provides a convenient approach to analyze polarization.

Optical activity is a suitable phenomenon to demonstrate polarization state changing, and it shows the power of material to rotate polarization. For an optically active substance, such as solution, the specific rotation is defined as:

$$[\alpha]_{\lambda}^T = \frac{\alpha}{l \times c}$$

In this equation,  $\alpha$  is the measured rotation in degrees,  $l$  is the path length in decimeters,  $c$  is the concentration in g/mL,  $T$  is the temperature at which the measurement was taken, and  $\lambda$  is the wavelength in nanometers<sup>1</sup>.

Although the formal unit for specific rotation values is  $\text{deg}\cdot\text{mL}\cdot\text{g}^{-1}\cdot\text{dm}^{-1}$ , values for specific rotation are typically reported in units of degrees<sup>2</sup>. These values should always be accompanied by information about the temperature, solvent, concentration, and wavelength of light used, as all of these variables can affect the observed rotation.

The following table lists specific rotation of different compound. The wavelength of the light used is 589 nanometers (the sodium D line), the symbol “D” is used, and the temperature is set at standard room temperature (20 °C).

Compound name	$[\alpha]_D^{20}$
Fructose	-92.0°
Sucrose	+66.5°
Glucose	+52.7°
L-ascorbic acid	+19.2°
Cholesterol	-31.5°
Progesterone	+172
Testosterone	+109°
All values are given in units of $\text{deg}\cdot\text{dm}^{-1}\cdot\text{cm}^3\cdot\text{g}^{-1}$	

Table 1. Optical activity of different compound<sup>2</sup>

Polarimeter is applied to measure specific rotation, and tell the difference between Dextro-rotatory and Levo-rotatory<sup>4</sup>. In the flowing section, a demo set up is established to observe the polarization rotation.

### 3. DATA ANALYSIS

First, the analyzer is replaced by axis finder in the conventional polarization system. Traditionally, the included angle between two polarizers causes the transmission with different power. It follows the Malus' law and proportion to the cosine angle square<sup>3</sup>. Instead of power measurement, axis finder is applied to observe the polarization directly. In the following case, the sample is inserted between the polarizer and axis finder. By analyzing the imaging on the axis finder, we can determine the polarization direction. If the wave plate inserted between them, the polarization direction will be modulated.

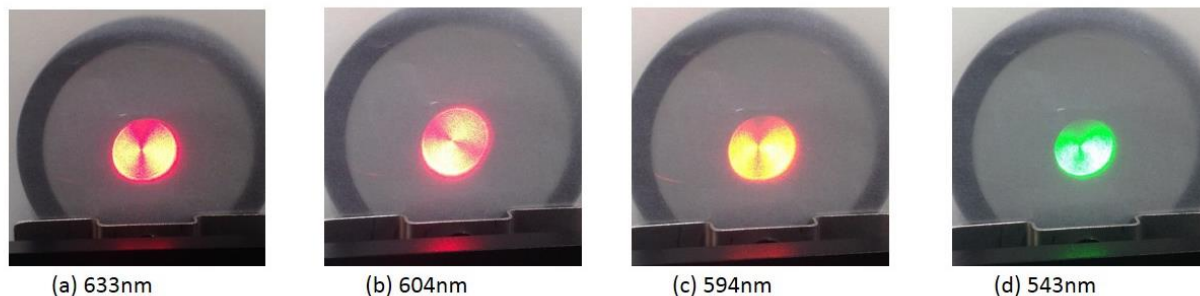


Figure 3. A half wave plate(632.8nm) is illuminated by different wavelength light.

A waveplate works by shifting the phase between two perpendicular polarization components of the light wave. A typical waveplate is simply a birefringent crystal with a carefully chosen orientation and thickness. For a half-wave plate, the optical path difference is half wavelength, and causes  $\pi$  phase difference. In the experience, a 633nm half wave-plate is used, and different wavelength light source is illuminated. Because of the dispersion, the rotating angle of different light is different<sup>5</sup>. It provides a simple approach to exam the polarization.

In another case, syrup solution is a good sample to test as well. Different solution with different concentration is made. Sucrose and fructose are measured, and the optical path is controlled at 20cm. Figure 4 shows the polarization rotation.

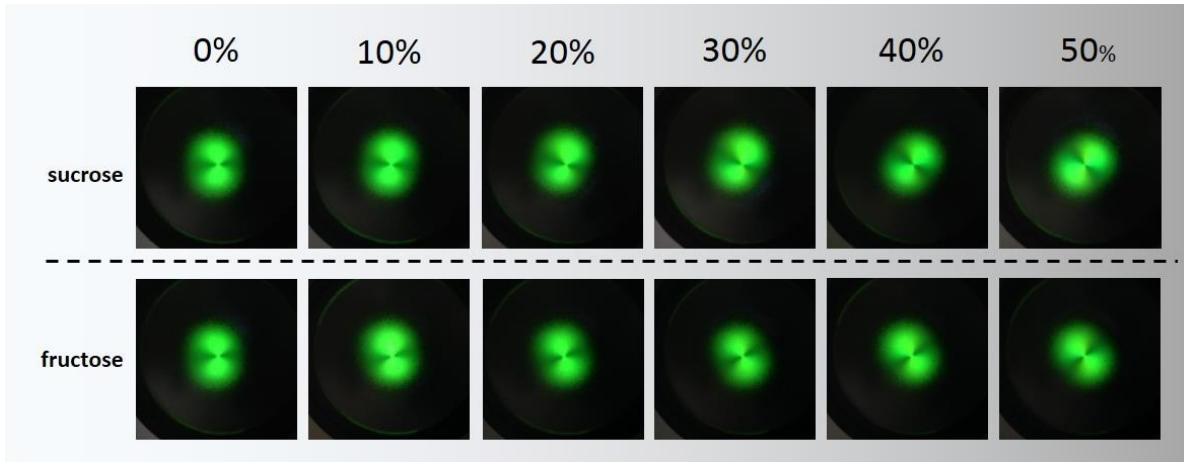


Figure 4. optical activity of different solution.

As shown in Figure 4, the polarization angle of sucrose solution rotates clockwise. While the fructose solution cause counterclockwise rotation. With the same concentration, the characters of Dextro-rotatory and Levo-rotatory can be demonstrated easily.

In the modern life, polarization is used frequently in many device. Liquid-crystal display is a good example. It is marvelous to trace the light polarization between the backlight module, polarizer, and panel. Figure 5 shows the R,G,B pixels of popular mobile phone display nowadays.

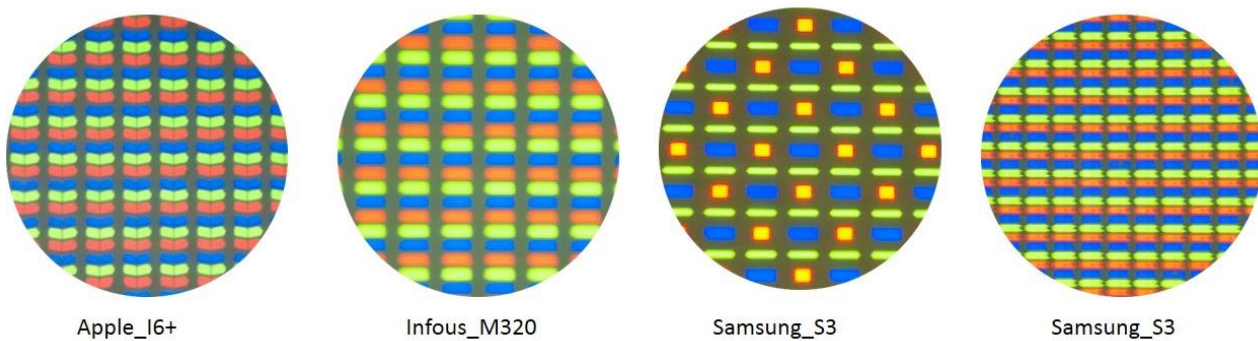


Figure 5. Macroscopic view of Display pixels.

#### 4. CONCLUSION

We examine the rotary power of different concentration syrup, presenting the relationship with polarization change. We also demonstrate the wide application of polarization light in modern life, and examine the principle through this visualized electrical field system. By means of axis finder, direct polarization imaging provides photonics educator a smart way to clarify relative issue.

## 5. REFERENCES

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