Linear Polarization, Graphical Representation

Kamal L. Rajpal

No light passes through two crossed polarizers. However, if a third polarizer is inserted, at let's say 45 degrees, in between the two crossed polarizers then, light does go through the three polarizers in series. This behavior can be explained with the help of a mathematical analysis. This article explains it using a simple graphical approach.

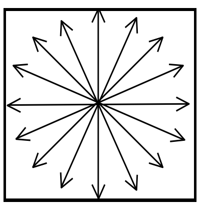

Figure 1

Figure 1 is a representation of un-polarized light. It can be viewed as eight photons traveling along a ray of light, perpendicular to the plane of this paper. Each double arrow represents the transverse vector direction of polarization of a photon.

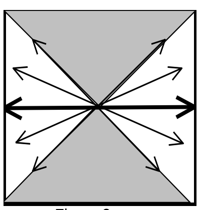

Figure 2

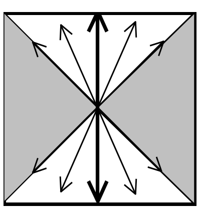

Figure 3

Figure 2 is a representation of linearly polarized light (H or horizontal). The four double arrows can be viewed as four photons traveling along a ray of linearly polarized light (H). The **bold** double arrow along the X-axis is the resultant direction obtained by the vector addition of the four double arrows.

Figure 3 represents linearly polarized light (V or vertical).

It is easy to visualize that a ray of un-polarized light consisting of eight photons (Fig.1) can be split up into two rays of linearly polarized light, horizontal (Fig.2) and vertical (Fig.3), each consisting of four photons.

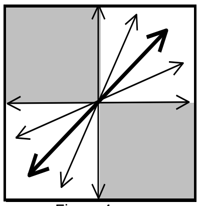

Figure 4

Figures 4 and 5 are the vector representation of linearly polarized light at (+45 degrees) and (+135 or minus 45 degrees) respectively. A ray of un-polarized light in Figure 1 can also be split up into two parts, each of one half intensity of the incident light, as in Figures 4 and 5.

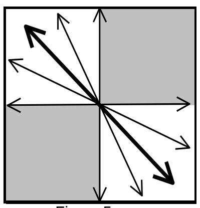

Figure 5

In fact, from a ray of un-polarized light, we can get an infinite pairs of two, equal intensity, orthogonal, linearly polarized light rays; say for example, at 30 degrees and 120 degrees.

The shaded areas in Figures 2, 3, 4 and 5 represent the non-transparent opaque region of a linear polarizer. No light can pass through this region. If Figures 2 and 3 are placed on top of each other, we get a pair of crossed polarizers. No light can pass through this pair since, the transparent region of each polarizer lies on the opaque region of the other. Similarly, no light goes through a pair of crossed polarizers represented by Figures 4 and 5.

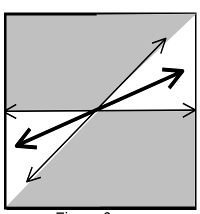

Figure 6

Next, let’s place Figures 2 and 4 on top of each other. Light will pass through the common transparent region as given by Figure 6. This is linearly polarized light at +22.5 degrees and consists of two photons only.

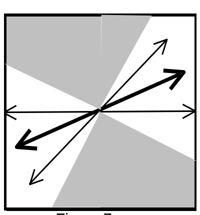

Figure 7

However, this light on coming out of the polarizer will spread out from minus 22.5 degrees to +67.5 degrees with the resultant vector remaining unchanged at +22.5 degrees (Figure 7).

CONJECTURE: **The transverse vector direction of polarization of photons, traveling along a ray of linearly polarized light, is not confined to a single plane of vibration, but has an angular spread of 90 degrees.**

Text books in physics, the graphical representation of linear polarization is shown by the resultant bold double arrow only. The angular spread is assumed to be zero degrees. This is an incomplete translation of the mathematical model of linear polarization into a corresponding physical model.

If we place polarizer 4 in between the two crossed polarizers 2 and 3, it is now simple to visualize, as to why light will go through (and how much light will go through) the three polarizers in series but, no light will be transmitted if polarizer 4 is removed. By using trigonometry we can prove that the intensity of the transmitted light (as given by the overlapping transparent non-opaque areas) is as per the cosine squared law of Malus.

This graphical approach also helps to visualize, why no interference is observed with two orthogonal, linearly polarized, coherent point sources represented by Figures 2 and 3 or, by Figures 4 and 5. Physics text books give a mathematical explanation of this experimentally observed Fresnel-Arago law on the interference of polarized light.

This graphical approach also helps to explain, the observations seen by Alain Aspect in his (Einstein-Podolsky-Rosen) EPR paradox experiment (1982), when the polarization measuring devices are oriented obliquely to each other.

30 November 2002. Revised: 07 March 2013.
Email your comments on this article to:
webmaster@physicsphotons.org