

Simulator to Demonstrate Three States of Polarized Light Wave in 3D Form

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ABSTRACT

This work is about designing and developing the python based 3D simulator or application which demonstrates the three states of polarized light wave – linearly polarized light, circularly polarized light and elliptically polarized light. There are so many ways to obtain the linearly polarized light, but circularly polarized light and elliptically polarized light can be obtained by superposition of two linearly polarized light waves, which are polarized in mutually perpendicular planes, travelling along same direction and having some phase difference between them. The same method can also be used to obtain linearly polarized light. So, here the simulator is so designed that, it will ask user to enter amplitudes of two linearly polarized light waves which are to be superimposed and phase difference between these two waves and depending on these values, simulator will simulate the resultant state of polarized light in 3D form.

Keywords : polarized light, python, 3D, linearly polarized light, circularly polarized light, elliptically polarized light

I. INTRODUCTION

The states of polarized light are –

- i. Linearly polarized light
- ii. Elliptically polarized light
- iii. Circularly polarized light

Apart from this, light can also be partially polarized light and unpolarized light.

In a plane polarized light, the oscillations of electric field vector are strictly confined to a single plane. In a circularly polarized light, in the course of wave propagation, the magnitude of the electric field vector

stays constant but it rotates at a constant rate about the direction of propagation and sweeps a circular helix in space. In an elliptically polarized light, in the course of wave propagation, the magnitude of the electric field vector changes and it rotates at a constant rate about the direction of propagation and sweeps an elliptical helix in space [1].

The theory behind generating the circularly polarized light and elliptically polarized light is to superimpose two linearly polarized light waves, which are polarized in mutually perpendicular planes and which are travelling along same direction and has some phase difference between them. The same method can

also be used to obtain linearly polarized light, though there are several methods that can be used to obtain linearly polarized light. The resultant of these two superimposing waves can either be linearly polarized light or circularly polarized light or elliptically polarized light, depending on phase difference between two superimposing waves [1].

Normally, while teaching this topic in a classroom, the derivation of ‘superposition of two linearly polarized light waves polarized in mutually perpendicular planes and travelling along same direction’ is derived, by explaining its theory. The resultant equation of superposition is obtained and by substituting various values of phase differences in the resultant equation, either the equation of straight line or ellipse or circle, is obtained. If the obtained equation is of straight line, the resultant of the two waves is linearly polarized light. If the obtained equation is of circle, the resultant of the two waves is circularly polarized light. If the obtained equation is of ellipse, the resultant of the two waves is elliptically polarized light. But, from student’s perspective, it is difficult to imagine this whole scenario from theory, equations and 2D diagrams. So, here an attempt has been made to develop the python based simulator which demonstrates three states of polarized light in 3D form. The purpose to design this simulator is - the students can visualize the three states of polarized light, i.e., linearly polarized light, circularly polarized light and elliptically polarized light in a better way and to reduce the time of classroom teaching [2, 3, 4].

Here, programming language which is used to write simulator program is Python [5]. Python is open source, object oriented, high level and interpreted language. It provides GUI programming support. Also, it has large standard library collection. Because of all these reasons, it is very much popular language for data analysis, machine learning, automation, simulators, web development, scripting, IoT based

applications, etc. Because of all these features, Python language is chosen to write simulator program.

Here, the simulator is designed to demonstrate three states of polarized light – linearly polarized light, circularly polarized light and elliptically polarized light in 3D form. Here, simulator is so designed that it accepts the amplitudes of two linearly polarized light waves which are to be superimposed and phase difference between these two waves and depending on these values, simulator will simulate resultant state of polarized light.

II. THEORY AND EXPERIMENTAL DETAILS

The equations for two linearly polarized light waves are represented by equation (1) and (2).

$$E_y = E_1 \cos(kx - \omega t) \dots\dots\dots(1)$$

$$E_z = E_2 \cos(kx - \omega t + \delta) \dots\dots\dots(2)$$

Where, E_y and E_z are instantaneous amplitudes of given two light waves, E_1 and E_2 are amplitudes of two waves. One wave is polarized in x-y plane and other wave is polarized in x-z plane and both waves are travelling along x direction. δ is the phase difference between these two waves.

After superposition of these two waves, their resultant is given by equation (3) which is the general equation of an ellipse. That means, their resultant is elliptically polarized.

$$\frac{E_y^2}{E_1^2} + \frac{E_z^2}{E_2^2} - 2 \frac{E_y E_z}{E_1 E_2} \cos \delta = \sin^2 \delta \dots\dots\dots(3)$$

Now, this ellipse will either degenerate into straight line (equation (4, 5)) or into circle (equation (6)) or remain ellipse (equation (7)), depending on phase difference between the two waves.

If $\delta = 0$ or $\pm 2m\pi$,
 Equation (3) will degenerate into, $E_z = \frac{E_2}{E_1} E_y \dots\dots\dots(4)$

If $\delta = \pi$ or $\pm (2m + 1)\pi$,
 Equation (3) will degenerate into, $E_z = -\frac{E_2}{E_1} E_y \dots\dots\dots(5)$

If $\delta = \frac{\pi}{2}$ or $\pm (2m + 1) \frac{\pi}{2}$ and $E_1 = E_2 = E_0$

Equation (3) will degenerate into, $E_y^2 + E_z^2 = E_0^2$ (6)

For remaining values of δ ,

$\frac{E_y^2}{E_1^2} + \frac{E_z^2}{E_2^2} = 1$(7)

Fig. (1) is the flowchart of simulator program. The python program for simulator is written according to this flowchart and according to theory and mathematical equations discussed above.

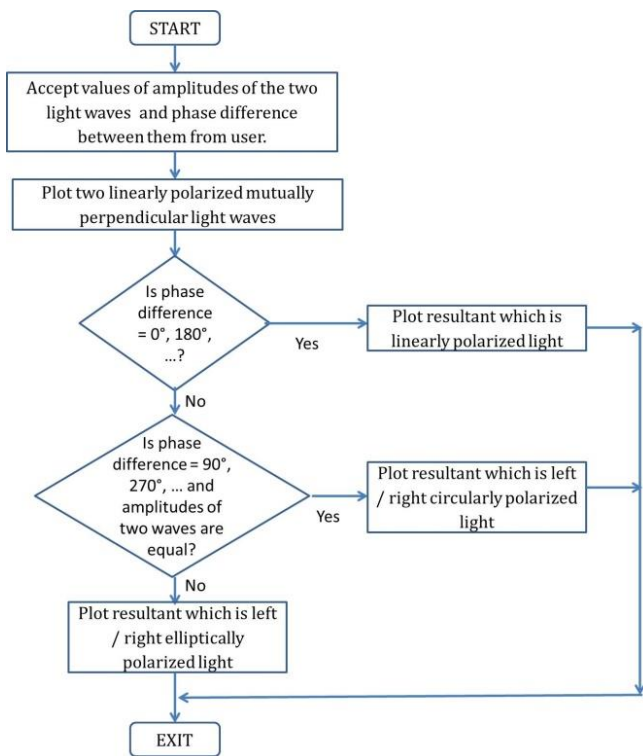


Fig. (1): Flowchart of simulator program

According to this flowchart, simulator program is so written that it accepts the amplitudes of two linearly polarized light waves which are to be superimposed and phase difference between these two waves from user and depending on these values, calculations will be done at the backend according to equations (3), (4), (5), (6), (7) and accordingly simulator will simulate resultant state of polarized light.

III.RESULT AND DISCUSSION

Fig. (2) is the screenshot of simulator window, where two linearly polarized superimposed light waves are shown by red and green colour. Both these waves are travelling along same direction and polarized in mutually perpendicular planes as shown in Fig. (2). Here, the phase difference between these two waves is so chosen that, their resultant is linearly polarized light wave which is shown by blue colour in Fig. (2) and this simulation is well in accordance with theoretical results.

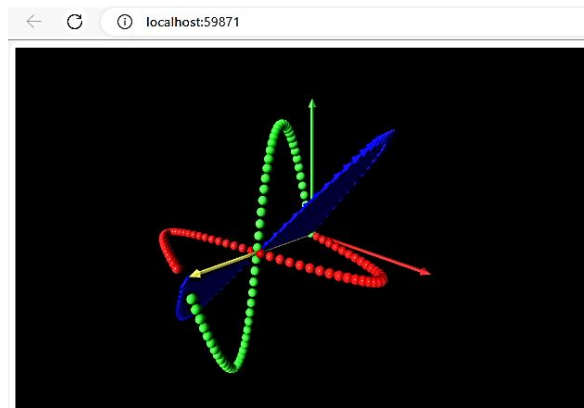


Fig. (2): Screenshot of simulator window

Fig. (3) is the screenshot of simulator window, where two linearly polarized superimposed light waves are shown by red and green colour. Both these waves are travelling along same direction and polarized in mutually perpendicular planes as shown in Fig. (3). Here, the phase difference between these two waves is so chosen that, their resultant is circularly polarized light wave which is shown by blue colour in Fig. (3) and this simulation is well in accordance with theoretical results.

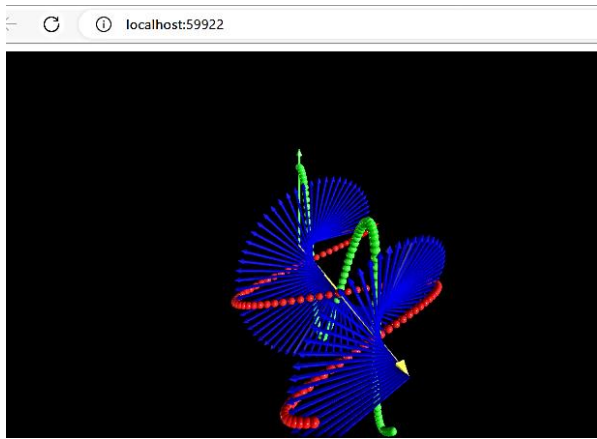


Fig. (3): Screenshot of simulator window

Fig. (4) is the screenshot of simulator window, where two linearly polarized superimposed light waves are shown by red and green colour. Both these waves are travelling along same direction and polarized in mutually perpendicular planes as shown in Fig. (4). Here, the phase difference between these two waves is so chosen that, their resultant is elliptically polarized light wave which is shown by blue colour in Fig. (4) and this simulation is well in accordance with theoretical results.

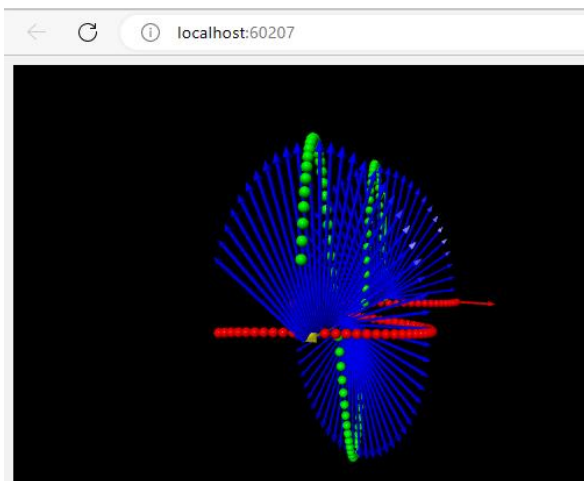


Fig. (4): Screenshot of simulator window

IV. CONCLUSION

The 'Simulator to Demonstrate Three States of Polarized Light in 3D Form' is designed, programmed, built and tested successfully. All the three states of

polarized light, i.e., linearly polarized light, circularly polarized light and elliptically polarized light, plotted by this simulator in 3D form are in accordance with theory.

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