A GEOMETRICAL MODEL FOR PHOTON

Jayesh Suresh

Abstract- This is a model based on assumption that light is a particle. Here it has been described that a particular pattern of motion of particle results in observing light as a wave. In this article, a new model of motion of photon has been described to link particle behaviour of light with wave. Till now our view is that quantum of energy or photon travel as waves. We know that an imaginary component has been introduced in the equation for such wave. Here a humble attempt has been made to explain the imaginary component in real terms. It seems that if we can explain the imaginary component we can explain true nature of photon.

Key words- photon; quantum; light; wave; particle; model
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INTRODUCTION

It is known that light and other electromagnetic waves travel as waves and they behave as particle also. The proof of light behaving as a particle is its effects like photoelectric effects. But the dual existence is an enigma till now. This is a new model for electromagnetic waves or this is an in detail explanation of old wave equation in terms of reality. Here the light is considered as particle. Let us go through the problem of current equation for wave and then the new model is explained.

A DIFFERENT INTERPRETATION OF THE WAVE EQUATION

The equation for electromagnetic wave is given as \( y = A \sin(Kx - wt) \). Let us see whether this is the actual equation for electromagnetic wave through this article.

When we consider the electromagnetic wave, according to current concept, we have to consider an imaginary part to explain the wave. We take the help of equation 1

\[
e^{i(kx-wt)} = \cos(kx-wt) + i \sin(kx - wt)
\]

\( e^{i(kx-wt)} \) can be written as

\[
e^{i(kx-wt)} = e^{i \pi \frac{2 \times \lambda - vT}{2}}
\]
$e^{\pi i} = -1$ according to Euler’s equation. ($e^{\pi i} + 1 = 0$)

Hence $e^{\pi i^2} = (-1)^2$

So the equation becomes $1^{(\frac{x^2}{T})}$

1 raised to any power is equal to 1. So $e^{i(kx-wt)} = 1$.

Hence $\cos(kx-wt) + i \sin(kx-wt) = 1$

Let us rewrite the equation as $\sin(kx-wt) = \{1 - \cos(kx-wt)\} / i$

$y = A \sin(kx-wt)$

So $y = A \{1 - \cos(kx-wt)\} / i$

After taking derivative it becomes

$C = 0 - Aw \sin(kx-wt) / i$. We know that $-1/i = i$

$C = Aw \sin(kx-wt)$

The formula we know for velocity, $C = -Aw \cos(kx-wt)$

So we can write $C = Aw \sin(kx-wt) = -Aw \cos(kx-wt)$

$-\cos(kx-wt) = i \sin(kx-wt)$

Let us take square and make it in real terms

$\cos^2(kx-wt) = -\sin^2(kx-wt)$
So the meaning of this may be the wave form given by $i \sin (kx - wt)$ can be an imaginary wave equal and opposite to a real $\cos (kx - wt)$ wave. That means imaginary propagation of the wave is opposite to the direction of Cos wave.

The sum of these wave forms may give a structure like standing wave and each unit will look like an ellipse like shape.

The below given model is made on this assumption. Each ellipse like shape may represent the packet of energy called quantum.

**EQUATION FOR THE MOTION OF LIGHT PARTICLE**

Let us find equation for this ellipse like quantum of light in X-Y Co-ordinates

Let us write the equation for energy assuming that there is a light particle and it revolves in addition to the linear motion just like an electron. In other words let us assume that light particle is an elementary particle.

We know that energy of a quantum is $E_q = h\nu$

So $h\nu = \text{Total kinetic energy} + \text{Potential energy}$

The potential energy of a light particle can be considered very small as it is almost mass less and it is chargeless.

So we can write

$$h\nu = \frac{1}{2} mv^2 + \frac{1}{2} Iw^2$$

Total energy of quantum $= \frac{1}{2} mv^2 + \frac{1}{2} mv rw$ is a constant
\[ E_T = \frac{1}{2} m x^2/t^2 + \frac{1}{2} mr x/t^2 2\pi, \]
where \(x\) is the linear displacement and \(r\) is the radius at each point of time.

\[ 2mE_T = x^2/t^2 + r x/t^2 2\pi \]

Applying derivative of the equation with respect to time, it becomes

\[ \frac{dr}{dt} = -\frac{x}{\pi}. \]

This means that the light particle travels in circles with changing radius at the rate of \(-\frac{x}{\pi}\). Let us plot graph on X-Y co-ordinates using this equation with \(x\) (position on X Co-ordinate) ranging from \(-\lambda/2\) to \(+\lambda/2\) and taking \(y = r_1 + dr\) (where \(r_1\) is the radius in the previous \(dt\) unit of time). The value of \(dr\) changes with each unit time \(dt\) at the rate of \(-\frac{x}{\pi}\). On plotting, we will get an ellipse.

Fig 1. The ellipse formed by light particle in one quantum
Till the point of maximum amplitude, the displacement \( x \) has a negative sign and \( \frac{dr}{dt} \) is positive. It means the light particle is accelerating. At the point of maximum amplitude, \( x \) is zero. When \( x \) become positive, \( \frac{dr}{dt} \) becomes negative. It means that the light particle starts decelerating.

Let us see whether our model has any relation to the original wave equation.

In our model, the average speed is \( C \). In effect it is like the light particle formed an ellipse of semi minor axis \( r \) and semi major axis \( \lambda/2 \) in time \( T \).

Let us consider for half time from \( T/2 \) to \( T \)

\[
\frac{dr}{dt} = \frac{0-r}{T}-\frac{T}{2} = \frac{2r}{T}
\]

\[x = \frac{\lambda}{2}\]

So \( \lambda = 4 \pi r \) in unit time \( T \)

If \( 4r = 1 \) unit, then \( \lambda \) is equal to \( \pi \) units. Let us draw a graph with positive values of \( 4r \) plotted against \( \lambda \) on X-Y co-ordinates starting from \(- \pi/2 \) as we have derived the equation for ellipse on X-Y Co-ordinates from \(- \lambda/2 \) to \(+ \lambda/2 \). The plot will be similar to Cos wave.
Fig 2. Cos wave representing the equation $y=\cos x$ where $4r = 1$ unit.

The negative part of cos wave also can be plotted similar to the positive part as when $x = \pi$, $4r$ become -1 and when $x = 3\pi/2$, $4r$ becomes 0. Beyond which we cannot trace using the equation of motion of particle. So it is like a snap shot for one wave length of a Cos wave, $y = \cos x$.

If we put the actual values, then the equation of Cos wave becomes

$y = 4r \cos kx$. Here $k$ is the period of the wave which is equal to

$k = 2\pi/\lambda$

It has to be noted that $\lambda = 2\lambda$ as per the elliptical model as part of two ellipses make one Cos wave.

We can write as $y = 2r \cos kx$.

Let us consider the wave we have written is due to superimposition of two Cos waves.
So $y = 2r (\cos kx + \cos kx)$

Let us assume the equation of two Cos waves super imposed

Earlier in this article, we have found out that

$\cos kx - wt = i \sin kx - wt$, but both in opposite direction

Hence $y = 2r (\cos kx - i \sin kx)$

But the superimposed Cos waves are in same direction. We know that the other Cos wave should be in the opposite direction to form the ellipse like structures or a standing wave like structure.

So for that we can write equation of ellipse as $y = 2r (\cos kx + i \sin kx)$.

We can write it as $y = 2r e^{ikx}$, $2r$ is the amplitude of the particle. This amplitude is double of individual wave amplitude.

So the equation can be re-written as

$y = Ae^{ikx}$. So we can derive an equation which is similar to Fourier transform of the original equation of wave function from the elliptical motion model of light particle. So it is like two waves, a real $y = r \cos kx - wt$ and an imaginary $y = r \sin kx - wt$ has superimposed. Doing so, it is like they combined their energy and amplitude. If we see the motion of light particles in this model, we can understand that whenever the light particle is making part of upper border of ellipse, its velocity is in positive X direction. Whenever it is making part of
lower border of ellipse, velocity is in the negative X direction. Suppose a person can see the ellipse from outside, it will seems like upper part is moving in positive X direction and lower part in negative X direction.

The equation of the ellipse in our model can be written as $4x^2/\lambda^2 + y^2/r^2 = 1$.

we can understand that this model is close to the equations used for wave function. So the light particle may have circular motion inside an ellipse.

**THE PROPOSED MODEL FOR MOTION OF PARTICLE OF LIGHT**

In order to have such a model, first we have to assume the light particle has very small mass and a magnetic moment like a neutrino. In this model it is assumed that light particle has forward movement along X axis, rotation about X axis (spin), revolution in XY plane and it has a rotation of axis about Z axis (precession). We already know that photon is a spin 1 particle. Here we assume that a light particle has a magnetic moment for itself due to rotation, which changes its direction due to its precession and it creates a magnetic field due to its revolution. This magnetic field is varying in magnitude. So it creates a varying orthogonal electric field. It is to be noted that the velocity of the particle (more than $3 \times 10^8$ m/s) reaches more than the velocity of the fields ($3 \times 10^8$ m/s). The light particle moves in enlarging circles. This magnetic field increases to the maximum value when the particle makes the largest circle. The velocity of the particle increases till its angular kinetic energy reaches the maximum attainable value ($mc^2$). Then the particle
starts decelerating. The magnetic field decreases in magnitude, when the
particle start decelerating to conserve energy. Let us assume that 180 degree
precession for the particle occurs during the displacement equalling the major
axis of ellipse. It means for each ellipse, there is a 180 degree spin about the z
axis if we consider the axis of propagation is X axis. The propagation is in the x
axis for the particle but magnetic field reverses its direction in Z axis for each
ellipse. This is due to the change of direction of rotation and revolution due to
180 degree spin about Z axis. The magnetic field changes in direction but
continues to increase and then decrease in a sinusoidal wave pattern. It means
the magnetic field and electric field propagates as sine waves.

The light particle accelerate and propagate helically with
increasing diameter. But it can accelerate only to the point that its angular
kinetic energy is equal to $E_A - mc^2$ as total energy of the particle has to be
conserved. Let us consider $B_1$ is the magnetic moment due to spin of light
particle and $B_2$ is the magnetic field due to revolution. The associated electric
field also increases as the equation for electric field is, $E = BC$. The vector sum
of $B_1$ and $B_2$ is dominated by the $B_2$ component. At the end of deceleration $B_2$
component becomes equal and opposite to $B_1$ for an infinitesimally small time
due to 180 degree precession during one quantum. Then the magnetic field also
reverses its direction as the magnetic moment of the particle is in the opposite
direction and the particle starts revolving in the opposite direction. So a change of direction of magnetic field occurs.

We have to consider light particle accelerating and decelerating in this model. But at the end, the velocity observed will only be $3 \times 10^8$ m/s. This is because we can observe only the quantum, not the light particle.

Fig. 3 is a representation of the ellipse which may be the single unit derived from the equation

$$e^{i (kx-wt)} = \cos(kx-wt) + i \sin(kx-wt).$$

So the wave is propagating as packets of energy of ellipses.

Fig 3. The accelerating and decelerating light particle forms an ellipse (one quantum)
Advantages of this model are that we eliminated imaginary terms in our model. This model can explain particle wave duality. It can explain the two slit experiment as well as the photoelectric effect. It explains the orthogonal electric and magnetic fields of electromagnetic waves. It explains the sine wave pattern of both the fields. This model is also based on the original wave function equation,

$$e^{i(kx-ft)} = \cos(kx-ft) + i \sin(kx-ft).$$

RELATION OF NEW MODEL WITH OTHER EQUATIONS IN PHYSICS

We can write for a light particle entering the phase of circular motion. For its initial circular motion, we can write

$$E_{\text{Total}} = \frac{1}{2} Iw^2 + \frac{1}{2} mv^2 + \text{Total potential energy}$$

Here we may consider total potential energy as a very small quantity

$$\frac{1}{2} Iw^2$$ is the angular kinetic energy. $$\frac{1}{2} mv^2$$ is the kinetic energy.

$$\frac{1}{2} Iw^2$$ is the angular kinetic energy which can be written as $$\frac{1}{2} mvrw$$ which is $$\frac{1}{2} mv^2$$ when the photon forms the first circle.

Hence Total energy = $$mv^2$$. It can be written as $$mc^2$$ as $$c$$ is the speed of light.

Let us denote angular kinetic energy as $$E_A$$ and linear kinetic energy is $$E_L$$. So the total energy
$mc^2 = E_A + E_L$. It means the value of each component increases to $mc^2$ and decreases to zero with time so that energy is conserved.

Total energy of a photon is $mc^2$

According to Planck, total energy of a quantum is

$E_{Total} = h\nu$, where $\nu$ is the frequency of quantum

We can write it as

$E_{Total} = h\nu = mc^2$

This expression is possible as we have proven that total energy is equal to $mc^2$ for a single quantum or a single ellipse of light energy.

$h = m\lambda c$

$\lambda = h/mc$, where $\lambda$ is the wave length of quantum or the long axis diameter of ellipse according to the new model, $m$ is the mass of the light particle and $h$ is the Planck constant.

Conclusion

This model is an attempt to unravel the meaning of imaginary part of wave equation using a geometrical model. An attempt has been made to explain the imaginary component and to find a real meaning for equation of wave. This model seems to explain the imaginary part and seems to be in conformity with the concept of quantum of electromagnetic wave. This is a model which may or
may not be true as it is made with assumptions. One can find what happened to cat inside the box only when you open the box and see. But this has been a humble attempt to explain the wave particle duality in real and simple terms and to give an alternate interpretation for Schrodinger wave equation

References


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