Mediation and Propagation of Electromagnetic Waves by Virtual Photons

Satvik Shukla

Student, 12th Grade, City Montessori School, Kanpur Road, Lucknow-226012, India, August 29, 2020

Abstract

Light has, since time immemorial, been remarkably fascinating to Physicists. Innumerable scientists have contributed their part to what constitutes today's 'Light'. Yet it is a topic still debatable among scientists and new theories are being put forward. One such theory is the CPH Theory (Creative Particles of Higgs Theory) [1], which introduces two new constituting particles of a Photon, called Virtual Photons. This paper poses a theoretical description of how Virtual Photons can be used to describe the mediation and propagation of Electromagnetic Waves [2].

Keywords: Photon, Virtual Photons, CPH Theory, Electromagnetic Wave.

Paper Type: Research Paper

1. Introduction

1.1. *Brief history of light*

The foundation of optics was laid in Ancient Greece, when three great philosophers, namely Socrates, Plato and Aristotle, established the foundations of various scientific disciplines [3].

The first scientist to provide extensive qualitative and quantitative theories on optics was Sir Isaac Newton. He proclaimed that light is a mixture of different colors having different refractivities. He proposed a theory which he named the 'Corpuscular Theory of Light' [4], in which he proposed that light is constituted of particles called 'corpuscles'.

In 1678 [5], a new theory of light was put forward by a remarkable young scientist. It was 'The Wave Theory of Light' proposed by Christiaan Huygens. It had to face stormy criticism for opposing Newton's Particle Theory, but it eventually became the mainstream theory for Light, when the 'wave nature' of Light was proved by Young's Double Slit Experiment [6] in 1801.

Thomas Young, by means of his experiment showed that Light, when made to pass through a double slit, undergoes 'Diffraction' [7] and manifest 'Interference Pattern' [8] on a screen, which are typical characteristics of a wave.

With the publication of 'A Dynamical Theory of the Electromagnetic Field' [9] in 1865, James Clerk Maxwell demonstrated that electric and magnetic fields travel through space traversing at the speed of light. He proved this by a set of equations which he gave, known as Maxwell's Equations [10].

A turning point in the field of Physics arrived, when Sir Albert Einstein proposed 'The Photoelectric Effect' [11] in 1905, which proved the 'Particle Nature of Light'. Einstein declared that Light was constituted of particles which he named 'Photons'.

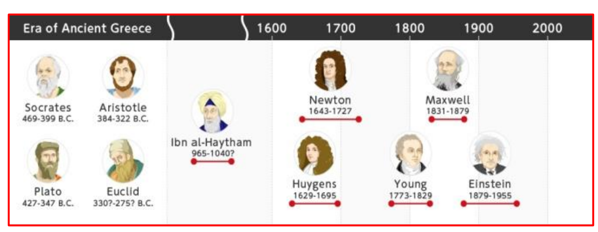

Fig.1. Timeline of advancements in the field of Optics.

Name	Equation	
	Integral form	Differential form
Faraday's law of induction	$\oint_c \vec{E} \cdot d\vec{l} = -\iint_S \frac{\partial \vec{B}}{\partial t} \cdot d\vec{S}$	$\nabla \times \vec{E} = -\frac{\partial \vec{B}}{\partial t}$
Ampère-Maxwell law	$\oint_c \vec{H} \cdot d\vec{l} = \iint_S \vec{J} \cdot d\vec{S} + \iint_S \frac{\partial \vec{D}}{\partial t} \cdot d\vec{S}$	$\nabla \times \vec{H} = \vec{J} + \frac{\partial \vec{D}}{\partial t}$
Gauss' electric law	$\oiint_S \vec{D} \cdot d\vec{S} = \iiint_V \rho\, dV$	$\nabla \cdot \vec{D} = \rho$
Gauss' magnetic law	$\oiint_S \vec{B} \cdot d\vec{S} = 0$	$\nabla \cdot \vec{B} = 0$

Fig.2. Maxwell equations in both Integral and Differential forms.

1.2. *Photons and their distribution in space*

A Photon is a quantum of Electromagnetic Radiation. It is a neutral elementary particle falling under the category of Gauge Bosons [12].

But wait! If it is neutral then how does it manifest electric and magnetic fields? This paper tries to resolve this conundrum with the help of the CPH Theory (Creative Particles of Higgs Theory) [1]

Now, Maxwell described how electric charges can create electric and magnetic fields, by means of his equations:

Using Maxwell's Equations, one can derive the complex Maxwell Wave Equation of a Photon, which is of the form:

$$i\frac{\partial \boldsymbol{\psi}(\boldsymbol{r},t)}{\partial t} = c\boldsymbol{\nabla} \times \boldsymbol{\psi}(\boldsymbol{r},t) \quad (1)$$

[13]

This equation can be used to find a Photon's quantum state, i.e. it's electric and magnetic field distributions in space and time, if a single-photon state of a field is created.

Here, the $\psi\,(\boldsymbol{r}\,,\,t)$ is the coordinate-space function of a single Photon.

Moving forward, the Dirac Equation:

$$\left(\beta mc^2 + \sum_{k=1}^{3} \alpha_k\, p_k c\right)\boldsymbol{\psi}(\boldsymbol{r},t) = i\hbar\frac{\partial\boldsymbol{\psi}(\boldsymbol{r},t)}{\partial t}$$

[14] (2)

for a mass less particle, such as a Photon gives us:

$$\left(\sum_{k=1}^{3} \alpha_k\, p_k c\right)\boldsymbol{\psi}(\boldsymbol{r},t) = i\hbar\frac{\partial\boldsymbol{\psi}(\boldsymbol{r},t)}{\partial t}$$

(3)

Where β and α_k are all 4x4 Hermitian and Involutory matrices, p_k are the components of momentum, and $\hbar$ is the reduced Planck's constant $h/2\pi$.

On solving equations (1) and (3), we get the solutions, i.e. information of the Photon, if the Pauli 4-component matrices of equation (2), corresponding to spin ½ electrons, are replaced by analogous 3-component matrices, corresponding to spin 1 Photons.

A Photon is ejected by following procedure:

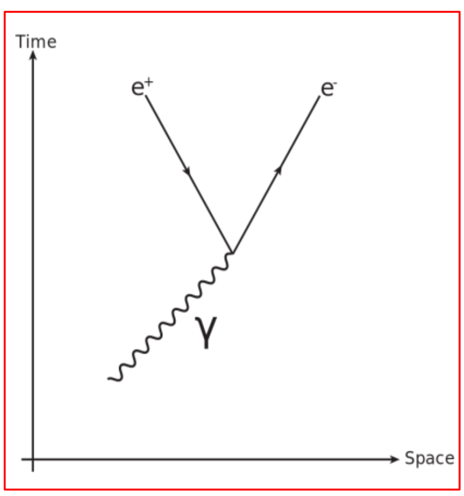

Fig.3. Schematic of how a Photon is ejected in a pair production.

The Photon propagates on a 1-D line in vacuum, if we are considering a single Photon ejection. Since photons are bosons, the function for their distribution in space is the Bose-Einstein Distribution:

$$f(E) = 1\Big/\left(Ae^{\frac{E}{kT}} - 1\right)$$

[15] (4)

Where the normalization constant A=1 for Photons.

We cannot determine the exact trajectory of a single Photon in space, but we can say with fair confidence, that in vacuum, a single Photon moves in a straight 1-D line.

2. Virtual Photons as Mediators and Propagators of Electromagnetic Radiation

2.1. *Postulate*

A single Photon being electrically neutral, the alternating and mutually perpendicular Electric and Magnetic Fields are the manifestations of the mutually revolving Virtual Photons, collectively constituting a Photon, and the frequencies of the Electric and Magnetic Fields depend on the Frequency of Revolution $\boldsymbol{\nu}$ *of the Virtual Photons.*

2.2. *Diagrammatic explanation*

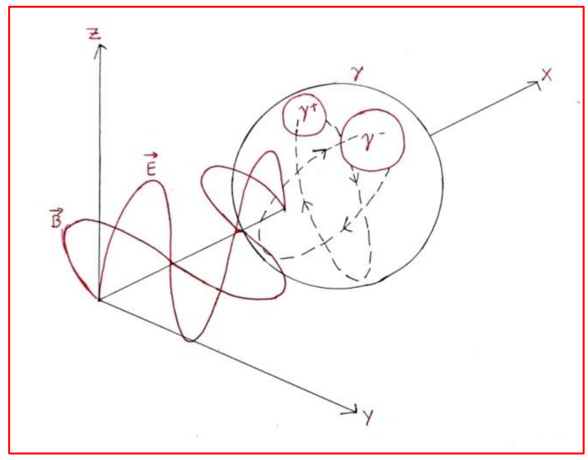

Fig.4. Illustration of how Virtual Photons can be thought to mediate Electromagnetic Waves.

If the motion of the Virtual Photons is of the form as depicted above, then the Electric and Magnetic Fields will be manifested as depicted above.

Here $\boldsymbol{\gamma}_+$ and $\boldsymbol{\gamma}_-$ are the Virtual Photons, collectively building up the Photon $\boldsymbol{\gamma}$. The $\boldsymbol{\gamma}_+$ has a net positive charge and the $\boldsymbol{\gamma}_-$ has a net negative charge which can be either integral or fractional. The components of the Virtual Photons in the Y-axis cancel out, their components in the X-axis add to give a net Electric and Magnetic Field in Z-axis and Y-axis respectively.

Of course, this is a theoretical model, as we can never exactly calculate the momentum and position of a quantum particle simultaneously with 100% accuracy, according to Heisenberg's Uncertainty Principle [16]:

$$\Delta\boldsymbol{x}\cdot\Delta\boldsymbol{p} \geq \frac{\hbar}{2}$$

(5)

Where $\hbar$ is the reduced Planck's constant $h/2\pi$.

The motion of the Virtual Photons along with the motion of the Photon in the X-axis will manifest Electric and Magnetic Fields as depicted.

Since the frequencies of the Electric and Magnetic Fields are dependent upon the frequency of revolution of the Virtual Photons, therefore the quantum energy and hence the energy of the Electromagnetic Wave is dependent upon the frequency of revolution of the Virtual Photons.

3. Future Scope

Although this a theoretical model and there is no proof of this phenomenon, hopefully in the future this phenomenon will be evinced, which could be used to expand the present Standard Model of Particles.

4. Conclusion

This paper is intended to better explain a Photon and it's distribution in space and consecutively pose a postulate to demonstrate that maybe the Photons are not elementary quantum particles and that they are constituted of even more elementary particles called Virtual Photons, which interestingly help to better understand the propagation of a Photon and the corresponding Electromagnetic Wave, and the simultaneous manifestation of the alternate and mutually perpendicular Electric and Magnetic Fields.

5. References

1. Javadi, Hossein; Forouzbakhsh, Farshid; Daei Kasmaei, Hamed, 'What is CPH Theory?' *The General Science Journal*, 2016, pp. 16, accessed August 2020, <https://core.ac.uk/reader/60672387>

2. 'Electromagnetic Radiation', *Wikipedia The Free Encyclopedia*, accessed August 2020, <https://en.wikipedia.org/wiki/Electromagnetic_radiation>

3. 'A Brief History of Light', *Photon* Terrace, accessed August 2020, <https://photonterrace.net/en/photon/history/>

4. 'Corpuscular Theory of Light', *Britannica* Publications, accessed August 2020, <https://www.britannica.com/science/corpuscular-theory-of-light>

5. 'Christiaan Huygens', *Wikipedia The Free* Encyclopedia, accessed August 2020, <https://en.wikipedia.org/wiki/Christiaan_Huygens>

6. 'Double Slit Experiment', *Wikipedia The Free Encyclopedia*, accessed August 2020, <https://en.wikipedia.org/wiki/Double-slit_experiment>

7. 'Diffraction', *Britannica Publications*, accessed August 2020, <https://www.britannica.com/science/diffraction>

8. 'Wave Interference', *Wikipedia The Free Encyclopedia*, accessed August 2020, <https://en.wikipedia.org/wiki/Wave_interference>

9. 'Electromagnetic Field', *Wikipedia The Free Encyclopedia*, accessed August 2020, <https://en.wikipedia.org/wiki/Electromagnetic_field>

10.'Maxwell Equations', *Wikipedia The Free Encyclopedia*, accessed August 2020, <https://en.wikipedia.org/wiki/Maxwell%27s_equations>

11. 'Photoelectric Effect', *Wikipedia The Free Encyclopedia*, accessed August 2020, https://en.wikipedia.org/wiki/Photoelectric_effect

12. 'Gauge Boson', *Wikipedia The Free Encyclopedia*, accessed August 2020, https://en.wikipedia.org/wiki/Gauge_boson

13. M. G. Raymer and Brian J. Smith Oregon Center for Optics and Department of Physics University of Oregon, Eugene, Oregon 97403, 2005, pp. 1-5, accessed August 2020, <https://arxiv.org/pdf/quant-ph/0604169>

14. 'Dirac Equation', *Wikipedia The Free Encyclopedia*, accessed August 2020, <https://en.wikipedia.org/wiki/Dirac_equation>

15. R Nave, 'Bose-Einstein Distribution', *Hyperphysics Publications, Wikipedia The Free Encyclopedia*, accessed August 2020, <http://hyperphysics.phy-astr.gsu.edu/hbase/quantum/disbe.html#c1>

16. 'Uncertainty Principle', *Wikipedia The Free Encyclopedia*, accessed August 2020, https://en.wikipedia.org/wiki/Uncertainty_principle