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Introducing a New Coefficient for the Phase of Electromagnetic Waves: A Further Symmetry and Possible Connection to Quantum Interpretation

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Abstract. A new parameter is introduced in the structure of the phase term of the plane wave solution. This new parameter is satisfying a further symmetry in regard to famous conjugates of Heisenberg's Uncertainty Principle, so the correlation between this parameter and angular momentum could provide new inspirations on the wave-particle duality, propagation dynamics of electromagnetic wave and possible connections between Quantum Mechanics and Electromagnetic Theory.

Keywords: Maxwell Equations; Quantum Mechanics; Uncertainty Principle, Phaseuanta *(this word is introduced by myself and used for the first time in the scope of this work)*

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1 Introduction

Maxwell Equations (ME) are describing the Electromagnetic (EM) waves and their propagation in a symmetrical and complete form, which is very well working from the wave point of view [1]. Quantum Mechanics (QM) is also another set of complete theory, whose explanations are based on quantization and several other postulates, which

are of critical importance in explaining most of the small scale events [2] and in explaining wave-particle duality in some extent [3]. Actually, the most important reinforcement lying under the concession of QM is may be its success in explaining the wave-particle duality. On the other hand, Heisenberg's Uncertainty Principle (UP) is a crucial restriction in QM and this principle is valid for some conjugate parameters [4]. Most famous conjugates and the interpretations of the principle are as followings;

$$\Delta P \Delta x \geq \bar{h}/2 \tag{1}$$

$$\Delta E \Delta t \geq \bar{h}/2 \tag{2}$$

$$\Delta L \Delta \theta \geq \bar{h}/2 \tag{3}$$

where P is the momentum, x is the position, E is the energy, t is the time, L is the angular momentum, θ is the angle and $\bar{h}$ is the Planck's constant over two.

One can solve the 2nd and 3rd MEs for Electric Field E via the well known procedure of taking curl from both sides, so that the so called Helmholtz equation, describing the propagation of EM waves, would be reached

$$\nabla E - \frac{1}{c^2}\frac{\partial^2}{\partial t^2} = 0 \tag{4}$$

Solution of this equation can be proposed in one dimension as,

$$E = E_0 e^{-i(kx+\omega t+\phi)} \tag{5}$$

I have interpreted this solution in one dimension for simplicity and E_0 is the amplitude term, k is the wave number, ω is the angular frequency and ϕ is the phase. In this point, I would like to point out the fact that; coefficients of the position and time namely k and ω are already associated with their conjugates in UP via the followings; $P = \bar{h}k$ and $E = \bar{h}\omega$ while there is no a similar term in front of the phase parameter ϕ , which is currently a dimensionless parameter.

2 Introducing the New Coefficient

Actually, Angular Momentum L is a famous parameter of QM and its explicit representation is missing in the proposed wave solution indeed (5). In fact, one can expect the explicit representation of an associated angular momentum during the propagation of an EM wave. At this point, I have introduced a new parameter in the structure of the phase term and I have denoted it by ξ, the *Phaseuanta*, which is introduced by myself and used for the first time in the scope of this work. This word is inspired from "phase" and "quanta". So ϕ should be made up of by two items as $\phi = \xi\varphi$ Having satisfied the symmetry of conjugates of UP and wave solution with this new parameter, the new form of the wave solution and dependencies of the considered coefficients would be as follows;

$$E = E_0 e^{-i(kx+\omega t+\phi)},\ P = \hbar k,\ E = \hbar\omega \text{ and } L = \hbar\xi \tag{6}$$

At this point, we can remember the explicit physical meanings of k and ω as;

$$k = \frac{2\pi}{\lambda};\ \omega = 2\pi\nu \tag{7}$$

λ and ν are the well known wavelength and frequency parameters respectively and the recently introduced Phaseuanta term would be supposed to be correlated to another critical parameter in the same fashion. I denote this parameter as η and the correlation should be;

$$\xi = 2\pi\eta \tag{8}$$

So, Phaseuanta is attributed to another parameter, which is expected to be famous and common known parameter in regard to established analogy. I claim, this parameter is connected to QM interpretation and it can be regarded as the quantum number. This juncture is inspired from Bohr's atomic model, where the principal quantum number was proposed for the first time on the quantization idea of the angular momentum [5]. Motion of electrons in the energy levels is standing waves and revealing wave peculiarity, radiations caused by the transitions between energy levels are also recognized waves and there seem implicit relations with the circular electron motion, which is a quantized angular momentum factor in the structure of this phase term.

3 Future Inspirations

This idea and alternative notation is subject for a thorough investigation, which could enable new developments. For example, the phase velocity defined by $V_p = \frac{\omega}{k}$ experiences some problem of being nonphysical under certain circumstances. New parameter can open windows to new ideas and models on the quantization of the propagation velocity of the EM waves, which was previously zoomed to mind by Quantum Electrodynamics via a set of different visual interpretation [6].

Acknowledgement

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