Four possible methods to extend Lehnert's screw-shaped photon: Towards Soliton Orbital Angular Momentum Radio (SOAmR)

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Abstract

This paper was at-least-partially inspired by the problem of relatively slow internet connection in our country. We believe that the same common problem has plagued other developing countries like ours, so it seems that we need a new technology to increase the internet capacity, especially the wireless network capacity. One way to do that is to look at the photon electrodynamics theory. In a series of papers, Bo Lehnert has suggested screw-shaped model of photon, inspired by his Revised Quantum Electrodynamics (RQED). Therefore in this paper we will review 4 possible methods to extend his screw-shaped photon model. In the mean time, there is recent debate concerning theoretical basis and utilization of photon orbital angular momentum (OAM), in particular as a means to increase wireless internet capacity. Promising results have been reported from laboratory experiments carried out by Bo Thide group and others too. But considering Vigier's proposal to consider photon as soliton, in this paper we will discuss not the usual photon OAM as suggested by Thide group, instead we will consider soliton orbital angular momentum. If the proposed concept holds true, then it is possible to develop soliton radio wave based on OAM, which we call here as SOAmR (Soliton Orbital Angular Momentum Radio).

Introduction

Light in helical modes has received much attention since its discovery because of the orbital angular momentum (OAM) that it carries. A single photon carries $\ell\hbar$ of OAM, with ℓ being its topological charge or the winding of the phase about the beam center in multiples of 2π .[13]

This paper was at-least-partially inspired by the problem of relatively slow internet connection in our country. We believe that the same common problem has plagued other developing countries like ours, so it seems that we need a new technology to increase the internet capacity, especially the wireless network capacity. One way to do that is to look at the photon electrodynamics theory.

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In the mean time, there is recent debate concerning theoretical basis[4] and utilization of photon orbital angular momentum (OAM), in particular as a means to increase wireless internet capacity.[10] Promising results have been reported from laboratory experiments carried out by Bo Thide group and others too [5][6][7][8][9]. But considering Vigier's proposal to consider photon as soliton, in this paper we will discuss not the usual photon OAM as suggested by Thide group, instead we will consider soliton orbital angular momentum. If the proposed concept holds true, then it is possible to develop soliton radio wave based on OAM, which we call here as SOAmR (Soliton Orbital Angular Momentum Radio).

Four possible methods to extend Lehnert's screw-shaped model of photon

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a. Esposito's superluminal photon [29]
   Salvatore Esposito has proposed a very simple but general method to construct solutions of Maxwell equations propagating with a group velocity not equal to speed of light ($v_{gr} \neq c$). This result is obviously unlike the standard STR that electromagnetic travels with speed of light. Although neutrino is considered massless, nonetheless it is quite surprising that experiment carried out some years ago indicate that some neutrino is also superluminal.
b. Tomilin's Potential-Vortex theory [30][31]
   A.K. Tomilin has derived an extended version of Maxwell's electromagnetic equations with a bottom-up strategy, as follows [30, p.349]:

$$\nabla \times H + \nabla H^* = j + \frac{\partial D}{\partial t}, \tag{1}$$

$$\nabla \cdot D = \rho + \varepsilon' \varepsilon_0 \frac{\partial B^*}{\partial t}, \tag{2}$$

$$B^* = \mu' \mu_0 H^*, \tag{3}$$

   And the last two equations are the same with Maxwell equations:

$$\nabla \times E = -\frac{\partial B}{\partial t}, \tag{4}$$

$$\nabla \cdot B = 0. \tag{5}$$

c. Hirsch's superconductor electromagnetic theory [32][33]

According to J.E. Hirsch, from the outset of superconductivity research it was assumed that no electrostatic fields could exist inside superconductors and this assumption was incorporated into conventional London electrodynamics. Then Hirsch discusses a revised version of London equations in order to explain electrodynamics of superconductors.[32] Hirsch proposes a new fundamental equation for electrodynamics for superconductors as follows: [32]

$$\Box^2(A-A_0)=\frac{1}{\lambda_L^2}(A-A_0), \tag{6}$$

where

- London penetration depth λ_L is defined as follows:[33]

$$\frac{1}{\lambda_L^2}=\frac{4\pi n_s e^2}{m_e c^2}, \tag{7}$$

- And d'Alembertian operator is defined as: [32]

$$\Box^2=\nabla^2-\frac{1}{c^2}\frac{\partial^2}{\partial_t^2}\ . \tag{8}$$

Then he proposes the following equations: [32]

$$\Box^2(F-F_0)=\frac{1}{\lambda_L^2}(F-F_0), \tag{9}$$

And

$$\Box^2(J-J_0)=\frac{1}{\lambda_L^2}(J-J_0), \tag{10}$$

where F is the usual electromagnetic field tensor and F_0 is the field tensor with entries $\vec{E}_0$ and 0 from $\vec{E}$ and $\vec{B}$ respectively when expressed in the reference frame at rest with respect to the ions.

Then in a recent paper I discuss a possible extension of Hirsch's equations by modifying Proca equations, as follows [3]:

$$(\Box^2-m_\gamma^2)(F-F_0)=\frac{1}{\lambda_L^2}(F-F_0), \tag{11}$$

And

$$(\Box^2 - m_\gamma^2)(J - J_0) = \frac{1}{\lambda_L^2}(J - J_0). \quad (12)$$

Assuming that photon can be considered as boson, then it seems possible to consider photon as superconductor too. If yes, then the above modified Proca equations may be worthy to discuss in the context of massive photon electrodynamics.

d. Photon-soliton model
Kamenov & Slavov and also Hunter et al. [18][19] have discussed possible soliton model of photon. They may be inspired by earlier photon-soliton model of Vigier. Eckholdt also discusses possible soliton model of electron [27].
In this context, it is interesting to note that Firth and Skryabin have discussed optical soliton which carries orbital angular momentum [21]. This concept is considered very important, so we discuss that concept of SOAM in the next section.

Soliton Orbital Angular Momentum (SOAM)

In the preceding section, we already reviewed 4 possible methods to extend Lehnert's screw-shaped photon model. However, we shall note that the screw-shaped model of photon is deeply related with its orbital angular momentum (OAM), and as Leader remarks in [4], photon orbital angular momentum has been plagued by controversy until now. There is also restriction of utilizing photon OAM for long-distance radio communication [11].

Moreover, it is known since Jefimenko that Maxwell's electromagnetic theory violates momentum conservation law.[3] Therefore, it seems that this is a second problem with Bo Thide's photon OAM radio proposal. So, we need an alternative route which obeys momentum conservation law. And photon-soliton model seems to work in this context.

In this regards, it seems worth to consider a paper by A.S. Desyatnikov & A.I. Maimistov (2000) which suggests that multidimensional optical soliton obeys momentum conservation law [22]. Therefore in this section we will focus on their treatment on soliton, by keeping in mind that it is possible to consider photon as solitary wave.

The propagation of a light wave in a medium with the focusing Kerr nonlinearity and defocusing fifth-order nonlinearity is described by a parabolic equation, which is a generalization of the NLSE [22]:

$$i\frac{\partial u}{\partial z} + \Delta u + |u|^2 u - |u|^4 u = 0, \quad (13)$$

[3] I have been told about Maxwell theory's violation of momentum conservation law through communication with Prof. Akira Kanda. See also: Kholmetskii *et al*. [12], Enders [14] and Lindberg [34].

Where u is the slowly varying normalized envelope of the light wave.

The conservation of the angular momentum is a consequence of the invariance of the parabolic equation (13) to the rotation transformation in the plane perpendicular to the propagation direction. The Lagrangian corresponding to this equation is also invariant to the rotation transformation. [22]

Using the Galilean invariance of the equations, it can be shown that the angular momentum of the soliton is the sum of its spin and angular momentum [22]:

$$M = \frac{E}{2}\left| r \times \frac{dr_0}{dz} \right| + sE. \tag{14}$$

This expression may be compared with expression of photon OAM, see for instance [9][15][16][34][35].

Possibility of Soliton Orbital Angular Momentum Radio (SOAmR)

To our best knowledge, Amiri group in Malaysia seems to work in novel radio wave communication based on soliton physics [23][24][25], but it appears that they do not consider yet soliton Orbital Angular Momentum as discussed in this paper. Therefore, this paper discusses the possible concept of SOAmR for the first time.

Various applications for Photon OAM seem to be working for soliton OAM too, at least in theory.[10][15][21][26]

Zhao Guan has discussed secure communication protocol for single photon, and it seems this concept may be applicable for photon-soliton too. [17].

Concluding Remarks

Light in helical modes has received much attention since its discovery because of the orbital angular momentum (OAM) that it carries. A single photon carries $\ell\hbar$ of OAM, with ℓ being its topological charge or the winding of the phase about the beam center in multiples of 2π .[13]

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