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SELF-INCONSISTENCIES OF THE U(1) THEORY OF ELECTRODYNAMICS: MICHELSON INTERFEROMETRY

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The Michelson interferogram from perfectly reflecting mirrors does not exist in the $U(1)$ gauge theory of electrodynamics, which is therefore seriously flawed. The adoption of an $O(3)$ internal gauge field symmetry allows these flaws to be remedied self-consistently and leads to several developments in electrodynamics, enriching the subject considerably.

Key words: gauge theory of electrodynamics, Michelson interferometry.

1. INTRODUCTION

In consequence of the adoption of a $U(1)$ gauge field symmetry for electrodynamics, the Michelson interferogram vanishes from perfectly reflecting mirrors. This severe self-inconsistency can be remedied by the adoption of a non-Abelian, $O(3)$ symmetry, for the internal gauge space of the gauge theory that leads to electrodynamics. This theory is more self-consistent and enriches the subject considerably. In view of the glaring inconsistencies introduced by a $U(1)$ internal gauge symmetry, unified field theory and quantum electrodynamics are more self-consistently developed with an $O(3)$ sector for electrodynamics. This presents a major challenge to modern physics, in particular, contemporary field/particle theory and optics.

2. MICHELSON INTERFEROMETRY

The additional phase introduced by Wu and Yang [1] is a non-Abelian construct which multiplies the usual electromagnetic phase. The introduction of this phase factor is related to the existence in Yang-Mills theory of the topological magnetic field [2-10]:

$$\mathbf{B}^{(3)} = -ig\mathbf{A}^{(1)} \times \mathbf{A}^{(2)}. \tag{1}$$

This link is developed in this section and applied to Michelson interfereometry from perfectly reflecting mirrors. Without loss of generality we can write Eq. (1) as

$$\pi R\kappa A^{(0)}\mathbf{k} \cdot R\mathbf{k} = \mathbf{B}^{(3)} \cdot Ar\mathbf{k}, \tag{2}$$

which can be integrated straightforwardly to give the non-Abelian Stokes theorem [11]

$$2\pi\kappa A^{(0)} \oint \mathbf{R} \cdot d\mathbf{R} = \iint \mathbf{B}^{(3)} \cdot d\mathbf{A}\mathbf{r}, \tag{3}$$

where R is given by

$$R = \frac{1}{\kappa} = \frac{\lambda}{2\pi}, \tag{4}$$

with λ denoting the wavelength. Multiplying both sides by $g = \kappa/A^{(0)}$ defines the required non-Abelian phase in terms of a non-Abelian Stokes theorem:

$$\phi = 2\pi \oint \boldsymbol{\kappa} \cdot d\mathbf{R} = \frac{\kappa}{A^{(0)}} \int\int \mathbf{B}^{(3)} \cdot d\mathbf{Ar}. \tag{5}$$

The line integrals must be evaluated along a closed curve [10] and are defined therefore by:

$$\phi = 2\pi \oint_{AO} \boldsymbol{\kappa} \cdot d\mathbf{R} = -2\pi \oint_{OA} \boldsymbol{\kappa} \cdot d\mathbf{R}. \tag{6}$$

There is a change of sign which is a basic mathematical property of line integrals. This is a property peculiar to non-Abelian (e.g., $O(3)$) electrodynamics, and is the reason for the existence of the Michelson interferogram from perfectly reflecting mirrors.

In the usual $U(1)$ theory, the path dependent part of the electromagnetic phase is the familiar $\boldsymbol{\kappa} \cdot \mathbf{R}$, and the complete electromagnetic phase is $\omega t - \boldsymbol{\kappa} \cdot \mathbf{R}$, a quantity invariant under motion reversal symmetry (T), and parity inversion symmetry (P). In $U(1)$, the phase arriving back at the beam splitter upon perfect nromal reflection from a mirror of the interferometer is therefore precisely the same as that originating at the beam splitter. The failure of $U(1)$ theory in the Sagnac effect is due to the T invariance of the $U(1)$ phase [10]. Using the non-Abelian phase (5) however, there is a change in sign in ϕ after reflection, because of the fact that we are using line integrals, and the phase arriving at the beam splitter is different, and depends on R, the distance from the beam splitter to the mirror. The Michelson interferogram is generated, as usual, by changing the length of one arm of the interferometer [11]. This is of course the basis of contemporary Fourier transform infrared spectroscopy.

The fundamental gauge field of the $U(1)$ theory uses a scalar internal gauge space and is the familiar four-curl:

$$F_{\mu\nu} = \partial_\mu A_\nu - \partial_\nu A_\mu, \tag{7}$$

where A_μ is the vector potential with no internal indices [2-10]. In other words, A_μ is a scalar in the internal gauge space. In $O(3)$

electrodynamics, the internal gauge space is a vector space ((1), (2), (3)) which is a physical space. The unit vectors of this space are

$$\mathbf{e}^{(1)} = \mathbf{e}^{(2)*} = \frac{1}{\sqrt{2}}(\mathbf{i} - i\mathbf{j}), \quad \mathbf{e}^{(3)} = \mathbf{k}, \tag{8}$$

and the 4-potential is a vector

$$\mathbf{A}_\mu = A_\mu^{(1)}\mathbf{e}^{(1)} + A_\mu^{(2)}\mathbf{e}^{(2)} + A_\mu^{(3)}\mathbf{e}^{(3)} \tag{9}$$

in the internal gauge space. The electromagnetic field tensor is also a vector,

$$\mathbf{G}_{\mu\nu} = G_{\mu\nu}^{(1)}\mathbf{e}^{(1)} + G_{\mu\nu}^{(2)}\mathbf{e}^{(2)} + G_{\mu\nu}^{(3)}\mathbf{e}^{(3)}, \tag{10}$$

and is defined by

$$\mathbf{G}_{\mu\nu} = \partial_\mu \mathbf{A}_\nu - \partial_\nu \mathbf{A}_\mu + g\mathbf{A}_\mu \times \mathbf{A}_\nu. \tag{11}$$

The basic $U(1)$ *ansatz* reduces this to Eq. (7), so the commutator $\mathbf{A}_\mu \times \mathbf{A}_\nu$ in Eq. (11) vanishes. This means that $B^{(3)}$ in Eq. (1) vanishes. It is interesting to note that the commutator $\mathbf{A}^{(1)} \times \mathbf{A}^{(2)}$ is an imaginary quantity directly proportional to the third Stokes parameter [12], which is the real and physical quantity

$$S_3 = -i\omega^2 |\mathbf{A}^{(1)} \times \mathbf{A}^{(2)}|. \tag{12}$$

Therefore, in $U(1)$ theory, the third Stokes parameter vanishes because $U(1)$ gauge theory implies

$$\mathbf{A}^{(1)} \times \mathbf{A}^{(2)} = \mathbf{0} \quad (U(1)). \tag{13}$$

We therefore find another major inconsistency of the $U(1)$ gauge theory applied to electrodynamics.

3. DISCUSSION

The general adoption of a theory of electrodynamics based on an internal $O(3)$ gauge symmetry leads to field equations [7] which are isomorphic with those derived by Barrett [8] using an $SU(2)$ internal gauge symmetry, and are closely similar to those developed by Lehnert and Roy [5], indicating the presence of photon mass. The main advantages of $O(3)$ electrodynamics are described in a collection of fifty papers [10] and are summarized here. The new field equations allow a precise description of the Sagnac effect, both with platform at rest and in motion, using a round-trip in spacetime with $O(3)$ covariant derivatives. The Sagnac effect is described as a gauge transformation in the internal gauge space. The $U(1)$ Yang-Mills theory (Maxwell-Heaviside theory) of electrodynamics is unable to describe the Sagnac effect because it is invariant under motion reversal symmetry. This is conculsive evidence for the $O(3)$ electrodynamics which is also successful in describing Michelson interferometry as described above. The $O(3)$ field equations produce a novel fundamental field $B^{(3)}$, known as the Evans-Vigier field, which is the fundamental spin of electromagnetic radiation, and directed along the axis of propagation. The $O(3)$ electrodynamics lead to a new type of electroweak theory based on $SU(2) \times SU(2)$ symmetry, and to the emergence of a massive boson which will be searched for on the heavy hadron collider at CERN. If found, this would lead to a description of all field theory in terms of Montonen-Olive duality, a major step forward.

$O(3)$ electrodynamics is able to describe the inverse Faraday effect without phenomenology, and, when extended to quantum electrodynamics, produces self-consistent and novel results, for example very tiny but measurable corrections to the electron g factor and Lamb shift. It is renormalizable at all orders in quantum electrodynamics, and does not suffer from any problem of intractable divergences in the infrared or ultra-violet. All this is discussed intensively in Ref. [10]. The $O(3)$ electrodynamics is able to provide a self-consistent description of simple normal reflection, which follows from the discussion in Sec. 2. The Maxwell-Heaviside theory violates parity on the classical level when dealing with normal reflection - a surprising but rigorously correct result as follows from Sec. 2. The $O(3)$ electrodynamics is a gauge theory and therefore Lorentz covariant and gauge invariant. The potential differences in the theory take on a physical ontology as discussed by Barrett [8], who gives several experimental sources for this conclusion. Gauge transformations therefore become physically meaningful as in the Sagnac effect, and the basic structure of the Maxwell-Heaviside theory has been refuted [10] in several ways described in [10]. The field equations of $O(3)$ electrodynamics produce physical solitons and instantons which are observable in principle in phase shifts, which are reorientations in the internal gauge space. From Sec. 2, it follows that interferometry, and more generally optics, are described by an $O(3)$ electrodynamics where, in the plane wave approximation, its field equations reduce to Maxwell-Heaviside structures for the transverse components, and to novel equations for the $B^{(3)}$ field. The latter is an observable of interferometry, as demonstrated in this paper. The field equations of $O(3)$ electrodynamics produce the phenomenon of radiatively induced fermion resonance [7,10], which has many potential advantages over ESR and NMR. In general, the theory has a profound impact across a range of physical phenomena.

$O(3)$ electrodynamics allows for the possible existence of a magnetic monopole of topological origin, but in the plane wave approximation, this monopole vanishes [7,10]. Barrett [8] has presented six experiments in which a magnetic monopole of this type has been observed, experiments by Mikhailov which are reviewed in [8]. The $O(3)$ electrodynamics allows for a non-zero photon mass and vacuum current and in general is a major development in contemporary physics. Further information on these developments can be found on the U.S. Department of Energy restricted website *http://www.ott.doe.gov/electromagnetic/*

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