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Maxwell to Photonics

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1. Abstract

The main topic to be addressed is the search for a new source of energy: light. Electromagnetism has been the energy that has most changed civilization in the last two centuries. The emergence of photonics instead of electronics is a new challenge. Photonics is the clean energy to look for.

The 20th century was that of electrons. Several innovations took place through electronics. However, despite these numerous innovations due to the electromagnetic properties of the electron, the 21st century will be that of the photon. The advent of a new generation of innovations arising from the electromagnetic properties of the photon is expected. There is a primordial photon from the light invariance still to be revealed, and a growing photonic market awaiting new properties of the photon. The new perspective lies in discovering electromagnetism, where the photon is the own source of electromagnetic fields and self-interacting photons at the tree level are generated.

Our proposal is the four bosons electromagnetism [1]. A model based on charge transfer. An enlargement of Maxwell supported upon a general electric charge triad $\{+, 0, -\}$ and an extension to gauge symmetry for a nonlinear abelian gauge theory [2]. Elementary particle physics shows several reactions interchanging positive, negative and zero charges. It yields a physicality considering the charges set $\{+, 0, -\}$ mediated by four gauge bosons. A quadruplet physics manifested by photon, massive photon and charged photons. A new EM energy is to be explored. Introducing new electromagnetic sectors beyond Maxwell as nonlinear EM, neutral EM, spintronics, weak interaction, and photonics. The basis for photonic engineering.

2. Introduction

Maxwell studied EM without the knowledge of electrical charge. He only worked with the macroscopic electrical fluid. His physicality was restricted to charges and currents generating electric and magnetic fields [3]. Consider the EM under charges distributions. However, although EM has been successful in the last 150 years, it contains limitations. It is linear, polarization and magnetization vectors are introduced by hand, passive light, and others. More than that, it is under a limited nature of the electrical charge.

3. Microscopic Electromagnetism

There is microscopic electromagnetism beyond Maxwell to be investigated. Understand its electric charge physics. Post-Maxwell concerns the microscopic understanding of electrical charge. In 1874, Stoney proposed the atom of electricity and magnetism and coined the terminology electron [4]. In 1894, he launched the idea of a charged atom and stipulated the charge of $10^{-20}C$. Pierre Curie discusses the matter [5]. And, in 1897, with the discovery of the electron by Thompson, the era of electric charge seen by elementary particles begins [6]. In 1913, Millikan measures its value equal to $1.6 \cdot 10^{-19}C$ [7]. In 1919, Rutherford discovered the proton with the same opposite sign to electron charge [8]. In 1925, through the Stern-Gerlach experiment and the proposal by Uhlenbeck and Goldsmith, electromagnetism becomes the theory of electric charge and spin [9].

The microscopic manifestation of electrical charge became the investigation to be considered. The development of elementary particle physics in the 20th century introduced seven physicalities to electric charge. Quantization, spin magnet, carried by particles with different flavours and spins, charge exchange $\Delta Q = 0, \pm 1$, charge transmission made by messengers vector bosons, Gell-Mann–Nishijima charge expression by quantum numbers, modulation of its value by the renormalization group, fractional charges of quarks. They brought a new configuration to electromagnetism. So, the new question is, by preserving Maxwell's two postulates, which are light invariance and electric charge conservation, incorporate the microscopic physicalities of electric charge. To develop electromagnetism with the microscopic properties that Maxwell's macroscopic epoch did not record.

3. EM Lost History

Historically, in 1923, three particles with different charges were known. The electron, proton, and photon (e, p, γ). What made it possible to understand the electromagnetic meaning through the exchange of charges? Consider the interchangeable three under charges $\{+, 0, -\}$. The emergence of field theory in the 1930s reinforced this assumption with the notion of creation and destruction.

The microscopic charge comprehension opened the possibility for EM to go beyond the 19th century. Include that, although zero charges do not affect Coulomb's balance, its participation is signalized as the carrier of electromagnetic energy. The photon is a neutral particle carrying electromagnetic energy and momentum. Maxwell equations without sources also prescribe a neutral EM. Neutrino spin interaction also provided the neutral EM interaction. Three results include zero charge as participating in the EM phenomena

There was a generic electric charge to be defined in the early days of quantum field theory. Consider the EM based on three charges. A triad formed by $\{+, 0, -\}$. A relationship that should be understood. While macroscopically the presence of zero charge is not detected, microscopically it is observed. In this way, we would observe that the inclusion of neutral electromagnetism carrying zero charge was possible since the 1930s decade. And so, instead of Maxwell's discovery of electromagnetism being conclusive, it should be understood as a part of an enlarged EM.

The theme in the 1930s would be the possibility of an EM coming out beyond two charges. Surpass the two attractive and repulsive charges detected since antiquity and categorized in 1600 with the book Magnet by William Gilbert[10]. The novelty would be the introduction of an EM governed by three charges united between themselves. In 1938, at the Warsaw conference, 14 particles were already included in the particle table $(e^-, \rho, \rho, \gamma, e^+, n, n, v, n, \pi^+, \pi^-, \pi^\circ, \mu^-, \mu^+)$. The next study should be on the transmission of charges. A visible physics at the time.

Maxwell symmetries should work as a framework to discover a new $\{+, 0, -\}$ electric charge physics. Excavate new EM sectors. There, would be other EM regions driven by invariance of light and electrical charge conservation. A subject that was necessary at the time, when, there were criticisms of Maxwell's limitations, such as the London equation introduced by hand [11].

Nevertheless, this path was not taken. Oscar Klein opted for the 'Theory of Everything' [12]. His proposal did not pay attention to charge transfer. It only stated the formulation of the QED established between 1927-1934 by Dirac, P. Jordan, O. Klein, E. Wigner, W. Pauli, W. Heisenberg, V. Fock, E. Fermi, B. Podolsky, V. Weisskopf, where only the photon was the sole protagonist of electromagnetism. Two fundamental consequences followed. The first, in the 1940s, was QED. Feynman (1948-1951), Tomonoga (1946-1949), Schwinger (1948-1954), and Dyson (1949) developed the second phase of QED. They constructed the EM energy conducted by the $\Delta Q = 0$ channel, that of the photon transmission [13]. Another theme was the unification of the forces of nature. The perspective of seeking to unite the led four fundamental forces to the Standard Model and String Theory.

Thus, the 1940s decade consecrated the Maxwell extension to QED. In 1947 the highly precise measurement of the electron anomalous magnetic moment was definitive [14]. A physics based on the linear photon formulation took place. Interestingly is that in 1940 Schwinger proposed the mesotrons spin-1 charged particles [15]. A perspective continued by Lee-Yang in the 1960s [16]. However, without enlarging the EM or including a massive photon. The microscopic EM proposal of the three interchangeable charges was omitted. The exchange of three charges would appear later in the 1950s, but, not as a generalization to QED. The presence of four vector bosons was included within the context of another interaction, weak interaction.

Since then, the view of generalizing electromagnetism was lost. It remains the question of how far is QED a final theory. The corresponding divergences are indicating an incompleteness. In this essence, preserving the two electromagnetic postulates, we arrive at the so-called four bosons electromagnetism. A possibility of introducing new EM sectors based on electric charge transfer phenomenology.

3. Proposal

The proposal is to lead Maxwell to Photonics. The historical moment turns into the search for electromagnetism based on light. Several experiments are being built about the collision of photons, either by particle accelerators or lasers[17]. A time similar to Compton's 1923. The difference is that the scattering is photon-photon.

The perspective of EM until the 19th century was macroscopic electrical currents. A new process followed in the 20th century. The development of elementary particle physics brought knowledge of electric charge and spin. What led physics to go beyond Maxwell's macroscopic perspective? Arriving at QED, scalar QED and vector QED.

Nevertheless, there is a scenario still to be explored by physics, which is the charge transfer view. Electromagnetism based on the generic electric triad $\{+, 0, -\}$ has not been developed. A physics to be considered. A room for understanding the meaning of electrical charge more deeply. Consider its symmetry as the original physical meaning for EM fields.

Thus, a four bosons electromagnetism is proposed. An extension to Maxwell by including the exchanging of three charges between themselves $\{+, 0, -\}$. Requires the electromagnetic energy to be transported by four interconnected bosons. In addition to the usual photon, introduce the photon with mass and two massive charged photons. Fields are connected under the electric charge symmetry. As a consequence, granular and collective EM fields and coupling constants beyond electric charge are introduced. New EM sectors are divided. They are non-linear EM, neutral EM, spin EM, electroweak, and photonics.

Thus, to introduce photonics a new EM extension is necessary. By preserving the Maxwell essence, which is its abelian gauge symmetry, expand on the electromagnetic energy. Keeping the basic symmetries, there is another EM manifestation to be envisaged. Include photonics with self-interacting photons.

4. Photonics

The 20th century was for electron, the 21st century will be the photon. The question is how to go beyond Maxwell. The development of elementary particle physics opened three microscopic perspectives to the electromagnetic phenomenon. The electric charge is carried by particles with different flavours and spins, transmitted through charge exchanges $\Delta Q = 0, \pm, 1$ and the spin acts as a magnet. Three elements to go beyond Maxwell. Make the trip from Maxwell to photonics.

Electromagnetism is the theory of electric charge and spin. It is not the theory of light. Light is a consequence. In Maxwell, its meaning is ambiguous. It appears as a foundation through the invariance of light; on the other hand, a consequence of oscillating electrical charges. We are in the age to identify the Physics of Light. Discover new photon properties beyond Maxwell, Planck-Einstein, Quantum Mechanics. The work proposal is to introduce light as the origin. Consider on primordial photon. Containing own charge as the source and producing self-interacting photons at tree level.

The epoch is looking for a Photonics Engineering. This century predicts a replacement of electronics by photonics. Fundamental challenges such as applications of lasers in medicine and biology depend on scientific advances in basic science. A new electromagnetic challenge is to be taken. Then, from a microscope EM, Maxwell's trip to photonics turns to a nonlinear abelian EM. Promote theoretical, phenomenological, experimental, and innovative features from an original non-linear photon. Is a time of lasers offer new experimental measurements of light properties and a promising market for photonic innovations: Consider the theoretical and experimental study with non-linear photons interactions not depending on electric charge.

Given the need for new energy sources and the growing photonic market, the question turns to how to find out this photonic world. Several theoretical attempts exist in the literature, mainly based on the Schrödinger equation. However, we are looking for a fundamental nonlinear EM beyond Maxwell. Our fundament is based on a generic electric charge $\{+, 0, -\}$. It introduces an EM with explicit potential fields in the equations of motion and so introduces self-interacting photons. A study to be verified phenomenologically with photonic experiments.

Theoretical models proposing light-light scattering have been around for a long time. In 1933 Halpern and 1934 Heisenberg showed that quantum effects induce photon-photon scattering. This result was first calculated at the low-frequency limit by Euler and Kockel in 1935. Subsequently, Heisenberg and Euler derived in 1936 a more general expression for quantum non-linearities beyond QED and in 1951 Karplus and Neuman performed the photon-photon scattering calculation.

Recently, the LHC measured the direct photon-photon interaction [17]. This result brings a new understanding of Delbruck scattering, the Breit-Wheeler effect, and photon decay. Nevertheless, this result is based on the loop process as figure 1 A is showing. Physics is missing $\gamma - \gamma$ interaction at tree level as figure 1 B.

The 21st century is looking for a light-based EM[18]. In addition to the LHC, several experiments are being built regarding the collision of photons through lasers. 'Extreme Light and Short-Pulse Super-Powers Lasers' are being developed in several laboratories (SULF, XCELS, OPAL, LCLS, others)[19]. Study on Maxwell extension has non-linear

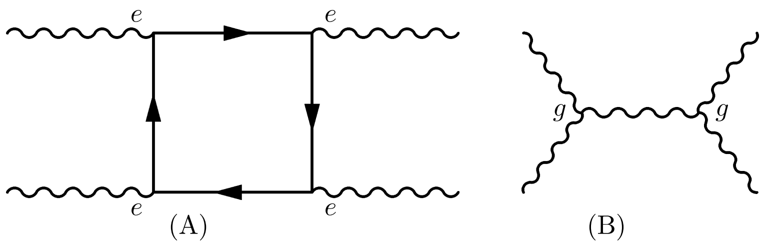

Figure 1: $\gamma - \gamma$ interaction.
LHC proposes Fig 1 (A) experiment. Four bosons EM Fig 1 (B), The difference is that four bosons does not depend necessarily on electric charges as coupling constant.

effective models [20], brirefringence [21]

QED is expected to be replaced by an electromagnetic model that describes $\gamma - \gamma$ at tree-level scattering. In this defy, as an alternative to the electroweak unification SU(2)XU(1) and non-linear effective extensions such as Euler-Heisenberg and Born-Infeld, an abelian non-linear extension through the so-called four bosons electromagnetism is proposed. The photon appears as the universal connector. The model is challenged to rewrite QED experimental results[22]. It introduces three differences from the Standard Model. First, tree-level self-interacting photons. Second, the origin of the mass lies in the energy of the field itself, and not in the spontaneous breaking of symmetry performed by a scalar field. Third, the photon-Z^{o} and photon-neutrino interactions take place at the tree level.

Thus, the Physics of Light project via four bosons EM exposes a new perspective to electromagnetic theory based on an extension to the meaning of electric charge. Preserving Maxwell's two postulates and based on the three premises of microscopic EM, it produces a nonlinear abelian EM. It studies the transport of electric charge $\Delta Q = 0, \pm 1$ and develops new behaviours for the electric charge on conservation, interaction, conduction, and transmission. The result is electromagnetism associated with the set of charges$\{+, 0, -\}$, mediated by four vector bosons $\{A_\mu, U_\mu, V_\mu^{\pm}\}$. The corresponding gauge theory is constituted through the symmetry U(1) X SO(2). A renormalizable, unitary tree-level model. An EM beyond effective theories.

New EM prospects. Based on the charge transfer phenomenology, the four bosons model reinterprets the EM under a general electric charge $\{+, 0, -\}$. It provides new EM fields (granular and collective), surpasses Maxwell's limitations, introduces a new electric charge physics, and produces EM interactions beyond the electric charge coupling. Monopoles are introduced[23]. Move EM from Maxwell to photonics.

5. Conclusion

A new EM model is proposed. The literature contains 57 models beyond Maxwell [24]. The four bosons EM model proposes news EM fields strengths, EM Lagrangian, fields charges, three Noether equations, and interactions (electric, modulate, neutral). A new EM energy. New EM sectors are developed. The model introduces a non-linear EM, neutral EM, spintronics, weak interaction, and photonics. Its objective is to construct a Photonic Engineering.

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