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EXPERIMENTAL OBSERVATION OF THE $B^{(3)}$ FIELD: A REPLY TO RAJA ET ALIA

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The recent claims by Raja *et al.* [1,2] are corrected in this reply. It is shown that there is no Faraday induction due to $\mathbf{B}^{(3)}$ in vacuo, as observed by these authors. The observation of the inverse Faraday effect by these authors is an observation of the $\mathbf{B}^{(3)}$ field at second order. Their data, correctly interpreted, constitute strong support for the existence and predicted properties of the $\mathbf{B}^{(3)}$ field.

Key words: experimental observation of $\mathbf{B}^{(3)}$, Faraday induction, inverse Faraday effect.

1. INTRODUCTION

Recently, Raja *et al.* [1,2] claimed to have observed the inverse Faraday effect and to have demonstrated that there is no Faraday induction due to $\mathbf{B}^{(3)}$ in vacuo, as predicted theoretically [3–8]. They have therefore observed the $\mathbf{B}^{(3)}$ field at second order in the non-relativistic limit with visible frequency radiation. Their data interpretation is corrected in this reply, which identifies several elementary errors of logic and procedure in the authors' original work.

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2. FARADAY INDUCTION IN VACUO AND INVERSE FARADAY EFFECT

The authors claim to have observed no Faraday induction in vacuo due to the $\mathbf{B}^{(3)}$ field. If we accept this claim uncritically, a well known prediction of the $\mathbf{B}^{(3)}$ theory [3–8] would have been verified experimentally with considerable precision. The $\mathbf{B}^{(3)}$ field signals the existence of a vacuum electrodynamics in which the equations for $\mathbf{B}^{(3)}$ are as follows [3–8]:

$$\nabla \times \mathbf{B}^{(3)} = 0, \tag{1}$$

$$\frac{\partial \mathbf{B}^{(3)}}{\partial t} = 0, \tag{2}$$

$$\nabla \cdot \mathbf{B}^{(3)} = 0, \tag{3}$$

$$\mathbf{B}^{(3)} := ig\mathbf{A}^{(1)} \times \mathbf{A}^{(2)}, \tag{4}$$

where g is a constant and where $\mathbf{A}^{(1)} \times \mathbf{A}^{(2)}$ is the cross product of complex vector potentials such as plane waves in vacuo [9]. Therefore $\mathbf{B}^{(3)}$, as postulated [3–8], is irrotational and divergenceless in vacuo, and does not induce an electric field under *any* circumstances. This is due fundamentally to the underlying O(3) gauge structure of the theory a structure which can be found in any good elementary text [9] on non-Abelian gauge theories. Evidently, the authors are entirely unfamiliar with the basics of such theories and are still thinking in terms of an Abelian, or U(1), gauge theory of electrodynamics in vacuo. For example, we find $\nabla \times \mathbf{B}^{(3)} = \mathbf{0}$ in Eq. (29b), p. 261, of Ref. 3, quoted, but evidently not studied, by the authors themselves. Raja *et al.* [1,2] choose not to refer to recent books on the subject, volumes which develop $\mathbf{B}^{(3)}$ in several fundamental directions. Their data are claimed to be repeatable and reproducible, but their interpretation is pure dogmatism, with no element of scholarship. The paper contains self-evident misconceptions on an elementary level. For example: "If a circularly polarized beam possesses an axial magnetostatic field, it must induce a voltage signal in an inductive coil as the beam traverses through it." The $\mathbf{B}^{(3)}$ field, however, is not a magnetostatic field by hypothesis [3–8], i.e., is *not* the curl of a vector potential. It is the cross product (Eq. (4)) of complex vector potential plane waves in vacuo, something quite new to the authors. The O(3) electrodynamics signaled by $\mathbf{B}^{(3)}$ [3–8] are as self consistent as the U(1) electrodynamics in everyday use, but one must be careful not to mix up the theories as these authors do. The $\mathbf{B}^{(3)}$ field is *not* a field of U(1) (Maxwellian) electrodynamics in vacuo.

The authors' observation [1,2] of the inverse Faraday effect, the empirical basis of $\mathbf{B}^{(3)}$ theory [3–8], is a belated and unoriginal confirmation of the existence of a well-known phenomenon, first observed in the early sixties [10]. For example, Eq. (416) of the first volume of Ref. 4 shows that at visible frequencies the effect is proportional to $B^{(0)}\mathbf{B}^{(3)}$, where $B^{(0)}$ is the scalar magnitude of $\mathbf{B}^{(3)}$, and is thus proportional to the beam intensity I as observed [1,2,10]. Since $\mathbf{B}^{(3)}$ theory is built on the empirical inverse Faraday effect [3–8], it takes complete subjective bias to claim [1,2] that the inverse Faraday effect disproves $\mathbf{B}^{(3)}$ theory. This is a blank denial of the scholarly process and an admission of complete ignorance as to the basics of the theory that the authors are attempting to criticize. Indeed, Eq. (9) of the authors' Ref. 1 has the same structure, exactly as Eq. (416) mentioned already. This is using cookies for biscuits. In other words, data originally used as the empirical basis [3–8] of $\mathbf{B}^{(3)}$ theory are claimed to constitute a refutation of the same theory. The magnetic field induced in a sample through the $\mathbf{B}^{(3)}$ description of the visible frequency inverse Faraday effect is given in Eq. (F5) of the 3rd volume of Ref. 4 and is shown there to *reproduce* the Pershan result [10], the Eq. (9) of Raja *et al.* [1]. For a pulse power density of the order of a million million watts per square meter, the induced magnetic field within the sample is of the order of one nanotesla [4]. This is the same result as that of van der Ziel *et al.* [10], a result obtained using $\mathbf{B}^{(3)}$ theory. The result cannot therefore be a refutation of $\mathbf{B}^{(3)}$ theory, as claimed by Raja *et al.* [1,2]. This claim is 100% biased against the hypothesis, and is therefore entirely dogmatic and on this basis entirely unscientific.

As shown in Sec. (12.4) of Vol. 1 of Ref. 4 and in Appendix F of Vol. 3 [4], the conditions under which $\mathbf{B}^{(3)}$ induces magnetization at first order require the use of microwave or radio frequency radiation, *not* visible frequencies as used by the authors [1,2]. Reference 4 evidently has *not* been read by the authors prior to their claimed experimentation. They therefore have no scientific basis whatsoever for their activity. They prefer [1,2] to use a phenomenological description developed [3–8] five years ago. Furthermore, this equation is used with *no* given parameters to synthesize a curve which is superimposed arbitrarily on their claimed empirical results. This exercise is then used as a *"refutation"* of $\mathbf{B}^{(3)}$ theory, which is what the authors wish to conclude subjectively. It is not what nature shows nor what the true $\mathbf{B}^{(3)}$ theory [3–8] shows either. The curved line is a refutation of $\mathbf{B}^{(3)}$ theory as distorted by the authors with some ingenuity. The *actual* $\mathbf{B}^{(3)}$ theory [3–8] as developed in the literature produces a straight line.

3. RADIATION INDUCED FERMION RESONANCE

It is now known that the interaction of $B^{(3)}$ with one fermion is determined from first principles by the standard Dirac equation and standard minimal prescription [11]. In the non-relativistic limit the interaction is proportional to beam intensity; in the relativistic limit it starts to become proportional to the square root of beam intensity [4]. An earlier version of this theory is available in Ref. 4, Vol. 3, Chaps. 1 and 2, but this earlier version uses a slightly non-standard Dirac equation. Hugely misguided preconceptions and complete ignorance of the exact one-fermion theory led these authors [1,2] into a bizarre refutation of nature. There are some very shaky theoretical pronouncements, for example "Evans proposed that $B^{(3)}$ field (sic) vanishes in a transformation from the photon's reference frame to the laboratory frame as the photon moves with the speed of light." Unfortunately for Raja *et al.* [1,2], Evans did no such thing. The sentence is an admission that the authors know nothing about elementary relativity theory, nothing of the fact that the photon moving at c has no rest frame, and in consequence cannot be transformed from one frame to another: It has no non-relativistic meaning. The authors [1,2] fortuitously appear to understand, however, that $B^{(3)}$ is invariant in vacuo under the Lorentz transformation [12]. This and several other things show that these authors do not grasp the nettle; they do not understand, for example, that lack of Faraday induction is due to the gauge structure of a *novel* O(3) electrodynamics, a different thing from the U(1) electrodynamics which they orbit without escape: "La belle dame sans merci / Hath thee enthral."

The optical NMR data of Warren *et al.* [13], gathered over a period of three or more years, are cooly dismissed as artifact [1,2], probably without reading Goswami's thesis [14] on the subject. The work in Ref. 4 matching $B^{(3)}$ theory against these pioneering experiments is sublimely likewise ignored. This much we have come to expect, and the fact that Ref. 4 tends to confirm Ref. 13, and vice versa, is not dogma, and so means nothing to Raja *et al.* [1,2]. Instead we are told to accept a "refutation" of these data, a "refutation" based on one failed experiment at UNCC carried out on an ancient home-made NMR spectrometer under conditions so casually designed that failure became inevitable: as required by the dogma. The present author observed some of this process with resignation. In contrast, Goswami [14] argues that some of the Princeton data appear to be reproducible and repeatable. Finally, Ref. 11 now defines with precision the conditions under which radiation induced resonance due to $B^{(3)}$ should be observable from the Dirac equation.

4. THE OPTICAL FARADAY EFFECT

The expected optically induced Faraday rotation (optical Faraday effect [15]), using the Verdet constant of the crystal employed in the experiment [1,2], is of the order of one nanoradian if we use the fact that the magnetic field induced in the sample is of the order of a nanotesla, as inferred already. This conclusion is obtained through use of the usual empirical result that the rotation is the Verdet constant multiplied by the sample length and magnetic field within the sample. In this case, there is no external static magnetic field, so the induced magnetic field within the sample, one induced by the laser's $\mathbf{B}^{(3)}$, is the only one present within the sample. The authors [1,2] do not understand that the free-space value of $\mathbf{B}^{(3)}$ is orders of magnitude bigger than the induced magnetic field within the sample, because the way $\mathbf{B}^{(3)}$ interacts with matter is through its definition, i.e., through the conjugate product $\mathbf{A}^{(1)} \times \mathbf{A}^{(2)}$ and the latter's interaction with matter [3-8]. The present author was not clear on this point five years ago, when the first tentative steps towards $\mathbf{B}^{(3)}$ were taken, but recent literature [3-8] develops the point conclusively. A static magnetic field, in contrast, will interact with the sample through the first-order minimal prescription [11]. The $\mathbf{B}^{(3)}$ field always has to interact through the *second*-order object $\mathbf{A}^{(1)} \times \mathbf{A}^{(2)}$, because it is always defined by this object. Accordingly, the second-order (or optical) Faraday effect is much smaller than the first-order (or ordinary) Faraday effect. The thumbnail calculation leading to nanoradians means that the optically induced rotation is *orders of magnitude below the detection threshold* [1,2], as for the earlier Rikken experiment [16]. Characteristically, my reply to Rikken [17], making all this clear two years ago, is also ignored by these dogmatists: What else can dogma do? If a more accurate evaluation of the optical Faraday effect is needed, one need go no further than the work of Kielich *et al.* [15], available for about thirty five years. In other words, the standard, highly developed, theory of semi-classical nonlinear optics suffices perfectly well, because it already describes the interaction of $\mathbf{A}^{(1)} \times \mathbf{A}^{(2)}$ with matter. Express $\mathbf{A}^{(1)} \times \mathbf{A}^{(2)}$ as $\mathbf{E}^{(1)} \times \mathbf{E}^{(2)}$ and we have Pershan's phenomenological theory of 1963 [18], a theory which produces the inverse Faraday effect. The $\mathbf{B}^{(3)}$ theory infers an O(3) electrodynamics on this basis: on the basis that there exists *empirically* the object $\mathbf{A}^{(1)} \times \mathbf{A}^{(2)}$ in vacuo. This object is proportional to $\mathbf{B}^{(3)}$ by definition [3–8], and so $\mathbf{B}^{(3)}$ interacts with matter through this object's interaction with matter, as observed empirically. Thus, $\mathbf{B}^{(3)}$ is observed empirically in the inverse Faraday effect. A simple chain of reasoning. It is going to be a lot more difficult to refute $\mathbf{B}^{(3)}$ theory than these authors think, because the whole of magneto-optics already supports $\mathbf{B}^{(3)}$, a covariant and $\hat{C}\hat{P}\hat{T}$-conserving field, theory. It is concluded that O(3) electrodynamics is a self-consistent field theory which extends the validity of the linear U(1) theory to nonlinear optics [15] without the need for phenomenology. It can be argued that this appears to be a major advance in scientific field theory, but to dogma it means nothing.

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