Paper 4

Note on Radio Frequency Induced N.M.R.

The existence of radio frequency induced nuclear magnetic resonance (*RF-NMR*) is indicated by the Dirac equation. The recent theory of Harris and Tinoco [1] will not produce the main proton resonance because it has missed the key term.

4.1 Note

Recently, Harris and Tinoco [1] have used a perturbation theory to assert that the experimental data by Warren *et al.* [2,3] on optical *NMR* (*ONMR*) are inconsistent with the received view. It is asserted that light intensity produces negligible shifts in *NMR* spectra. This theory fails to reproduce the data reported by Warren *et al.* [2,3]. However, the Harris and Tinoco theory [1] is incomplete: the interaction Hamiltonian in their Eq. (4) contains no first order interaction between the nuclear spin from the Dirac equation and the radiation's conjugate product. For this reason the theory falls short of the data by seven or eight orders of magnitude. Using the first order spin term the eigenvalue of the interaction energy between the electromagnetic field and fermion (e.g. a proton) becomes [4] in Dirac's approximation [7],

$$W \sim \frac{e^2}{2m}\left(\boldsymbol{A}\cdot\boldsymbol{A}^* + i\sigma\cdot\boldsymbol{A}\times\boldsymbol{A}^* + \ldots\right), \qquad (2.4.1)$$

where e/m is the charge to mass ratio of the fermion. Here $\boldsymbol{A}\times\boldsymbol{A}^*$ is the conjugate product of complex vector potentials [4—6] observed empirically in the inverse Faraday effect. The Pauli matrix σ forms an interaction energy with $\boldsymbol{A}\times\boldsymbol{A}^*$ from the Dirac equation [4] and this term is missed by Harris and Tinoco [1]. Resonance occurs between the two topological states of the spinor as in ordinary *NMR*. A simple calculation [4] shows that the probe resonance angular frequency for a proton is

$$\omega_{res}\left({}^1H\right) = 1.532\times 10^{25}\frac{I}{\omega^2}, \qquad (2.4.2)$$

where ω is the pump angular frequency and I its intensity (watts per unit area). Superimposed on this main resonance (that of the bare proton unshielded by electrons) is the most useful feature of *RF-NMR*, the chemical shift spectrum [8]. The first term of our Eq. (2.4.1) is, within a factor $1/c^2$, the first term of Eq. (4) of Ref. 1. The second, spinor, term of our Eq. (2.4.1) is missing from Eq. (4) of Ref. 1 because Harris and Tinoco did not consider the direct interaction between the conjugate product [4—6] $\boldsymbol{A}\times\boldsymbol{A}^*$ and σ. The I/ω^2 coefficient of our Eq. (2.4.2) also appears in the top line, second column, page 9291, of Ref. 1, premultipied by a factor $2\pi c\epsilon\epsilon^*$. Thus Harris and Tinoco confirm our result [4—6] that $A^2\propto I/\omega^2$, the key to *RF-NMR*.

The Ar^+ laser frequencies reported by Goswami [3] are 528.7, 488 and 476.5 *nm*. Taking I to be 10 watts per square centimeter we find probe resonance frequencies from Eq. (2.4.2) of 0.12, 0.10 and 0.09(8) *Hz* respectively. These are the main unshielded proton resonances and are of the same order of magnitude as the experimental data [2,3], obtained at the extreme edge of what is possible with contemporary laser technology. If the pump frequency is reduced however to the radio frequency range the main probe resonance frequency should appear from Eq. (2.4.2) in the infra red to visible region [4] for constant I of 10 watts per square centimeter. *This is an indication of the Dirac equation itself.* Harris and Tinoco [1] calculated minute second order chemical shift changes using a perturbation theory applied to the shielding constant, missing the main mechanism of resonance. Clearly, Eq. (2.4.2) indicates a major advance in *NMR* technology if implemented in the laboratory, removing the need for super-conducting magnets and producing very high resolution *NMR* in the infra-red and visible regions of the spectrum. If these features are not observed experimentally the Dirac equation would have failed. This hypothetical (and improbable) failure would have nothing to do with $\boldsymbol{B}^{(3)}$ theory [4—6] however, because Eq. (2.4.1) uses only $\boldsymbol{A}\times\boldsymbol{A}^*$, a property which has been verified empirically in the inverse Faraday effect [4—6], and which also used by Harris and Tinoco to calculate light induced shifts in chemical shifts [1].

It is of the utmost practical importance to realize that even if we accept uncritically the small, second order, light shift of 10^{-7} *Hz* estimated in Ref. 1, this is increased to *no less than 10 MHz* if the light frequency is reduced from visible (order of 10^{15} *Hz*) to radio frequency (order of 10^8 *Hz*) for the same intensity. This alone, if realized empirically, would change all *NMR* and associated technology out of recognition: the resolution of the chemical shift would be enhanced enormously. It cannot be gainsaid, however, that Harris and Tinoco [1] have missed the main first order mechanism, one which if realized empirically will allow nuclear magnetic resonance spectra to be obtained routinely *in the visible range of frequencies without the use of magnets*. This would be of immense potential benefit to science and medicine.

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Paper 5

Fundamental Definitions for the Vacuum $\boldsymbol{B}^{(3)}$ Field

The fundamental definitions of the vacuum $\boldsymbol{B}^{(3)}$ field are developed in terms of the universal constants and radiation properties. The vacuum $\boldsymbol{B}^{(3)}$ field is the expectation value of the photomagneton operator $\hat{\boldsymbol{B}}^{(3)}$, an irremovable and fundamental property of the vacuum electromagnetic field.

5.1 Introduction

In the received view of electromagnetism in vacuo [1—3], the fields are transverse to the direction of propagation, and the photon is massless. Recently, this view has been challenged at the fundamental level by the proposal of the $\boldsymbol{B}^{(3)}$ (longitudinal) component, generated by the conjugate product of the transverse fields, a component which is phase free [4—10]. The existence of $\boldsymbol{B}^{(3)}$ is shown by the class of inverse Faraday induction phenomena [11—16], typified by the inverse Faraday effect, magnetization by radiation. Further experimental support for its existence would become