The Status of the Experimental Evidence for the $B^{(3)}$ Field

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The current status of the experimental evidence for the existence of the proposed longitudinal component of classical electromagnetic fields is reviewed. Experiments are outlined which might provide more convincing evidence for the existence of this field.

Introduction

Evans (1992)[1] and others (1997)[2] have suggested that the description of the classical electromagnetic field may be incomplete and that the usual Maxwellian transverse wave components may be accompanied by a phase free longitudinal component, the so-called $\mathbf{B}^{(3)}$ field. The original suggestion was that the conjugate product of the transverse field components yields a phase free, longitudinal, real magnetic field. The predicted properties of this field have been the subject of many publications (see vols 1-3 Enigmatic Photon[3] and references therein and this Special Issue). This inference has been criticised by Barron (1993)[4] as violating CPT symmetry and also more recently by Comay (1996)[5] as actually violating Maxwell s equations themselves. Comay (1996)[5] claims that the inclusion of a $\mathbf{B}^{(3)}$ component to the field of a rotating dipole leads to a violation of one of Maxwell s equations. Evans and Jeffers (1996)[6] have shown that this argument is incorrect since the curl of the $\mathbf{B}^{(3)}$ was incorrectly evaluated by Comay. Evans (1992)[1] offered as experimental support for this novel field component the Inverse Faraday Effect and, in particular, the experiment conducted by Deschamps (1970)[7]. Other empirical evidence cited includes the work of Warren *et al* (1993)[8] who have looked for shifts in NMR spectra that might be attributable to this field component. Recent attempts to provide other experimental evidence for this proposed field component include the work of Rikken (1995)[9]. It is now clear that the experimental parameters used by Rikken were incorrect by orders of magnitude (see Appendix F of Vol. 3).

The Magnetizing Properties of $B^{(3)}$

Evans (1994)[10] has discussed the motion of electrons interacting with a circularly polarized electromagnetic wave and concluded that the magnetization by the electromagnetic field depends on $\mathbf{B}^{(3)}$ and ω , the angular frequency of the field in the following way:

$$\mathbf{M}^{(3)} = \frac{N}{2}\left(a\chi' + bB^{(0)}\beta''\right)\mathbf{B}^{(3)} \qquad (1)$$

where $\chi' = -e^2c^2/2m_0\omega^2$, $\beta'' = -e^3c^2/2m_0\omega^3$ and $\mathbf{B}^{(3)} = B^{(0)}\mathbf{k}$, $\mathbf{k}$ being a unit vector in the direction of propagation of the radiation and $B^{(0)}$ is the scalar amplitude of $\mathbf{B}^{(3)}$.

The dependence of the magnetization on the strength of the $\mathbf{B}^{(3)}$ field thus depends on how the angular frequency compares to $(e/m)B^{(0)}$. Therefore, when $\omega \le (e/m)B^{(0)}$ the magnetization scales directly as $\mathbf{B}^{(3)}$, and thus to the square root of the beam intensity. However when $\omega \ge (e/m)B^{(0)}$ the second term dominates and the magnetization scales as $B^{(0)}\mathbf{B}^{(3)}$, *i.e.* as the inten-

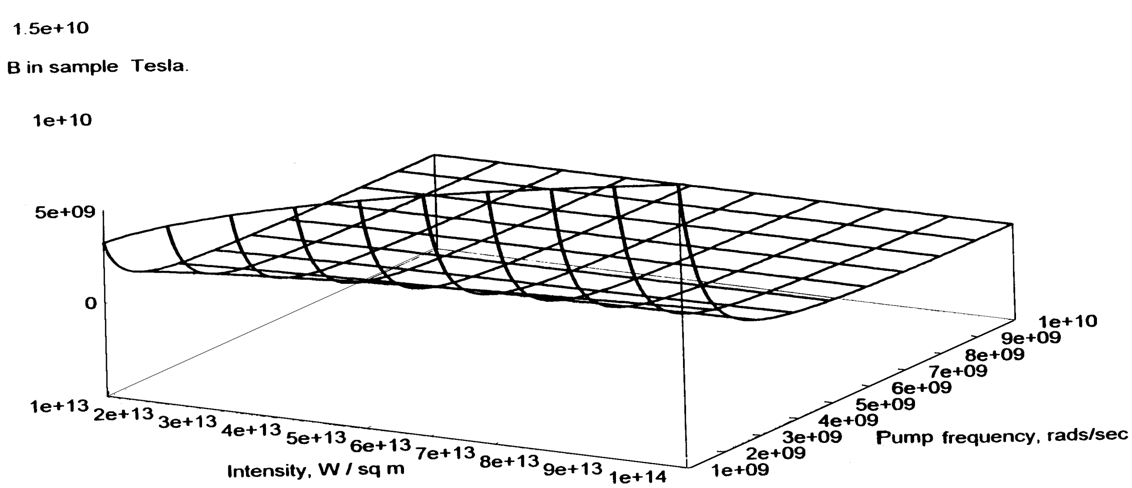

Fig 1. $\mathbf{B}^{(3)}$ in Tesla for a range of pump frequencies from 10^9 to 10^{10} rads/sec and beam intensities from 10^{13} to 10^{14} Watts/m^2.

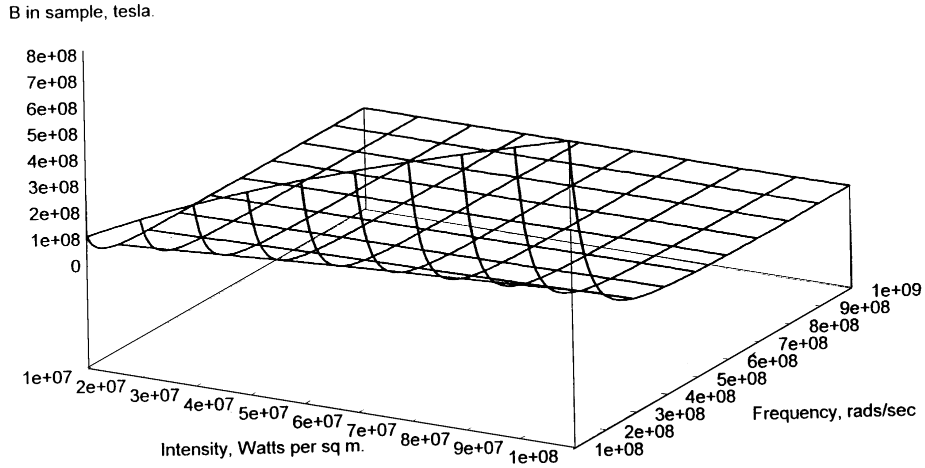

Fig 2. $\mathbf{B}^{(3)}$ in Tesla for a range of pump frequencies from 10^8 to 10^9 rads/sec and beam intensities from 10^7 to 10^8 Watts/m^2.

sity of the beam. Effects which scale with the beam intensity (*e.g.* the Inverse Faraday Effect) have been experimentally observed, but the predicted and novel dependence on the square root of the beam intensity has not yet been observed, as experiments specifically designed to observe this dependency have not yet been undertaken.

Deschamps Experiment

The experiment of Deschamps *et al* (1970)[7] used very high power circularly polarized microwave pulses to irradiate a low pressure helium gas. The gas became partially ionized and the electrons produced were driven into circular orbits by the rotating electric field of the microwave pulses producing an axial magnetic field. Under the circumstances of this experiment we have calculated the dependence of the magnetization produced using equation (1).

Under these conditions the relation between magnetization and beam intensity is predicted to be linear and that is exactly what the experimental data showed. Deschamps (1970)[7] gave a simple treatment of the interaction between the radiation and the electrons (with zero longitudinal field component) which predicts this linear relationship. The theory of Buckingham and Parlett (1994)[10] also predicts that the Inverse Faraday Effect should scale to first order with the beam intensity. Consequently existing data on the Inverse Faraday Effect cannot be interpreted as conclusive evidence for the $\mathbf{B}^{(3)}$ field. In order to conclusively reveal the effects of including the $\mathbf{B}^{(3)}$ field the experiment would have to be conducted under appropriate conditions, which would entail either going to unrealistically high beam powers if the experiment were repeated at the frequency used by Deschamp (3 GHz), or reducing the frequency of the circularly polarized radiation. We have proposed (Jeffers *et al* 1996)[11] an experiment which we believe should reveal the presence of the $\mathbf{B}^{(3)}$ field component. Jeffers *et al* (1996)[11] show that the power required under the conditions of the Deschamp experiment to ensure that the first

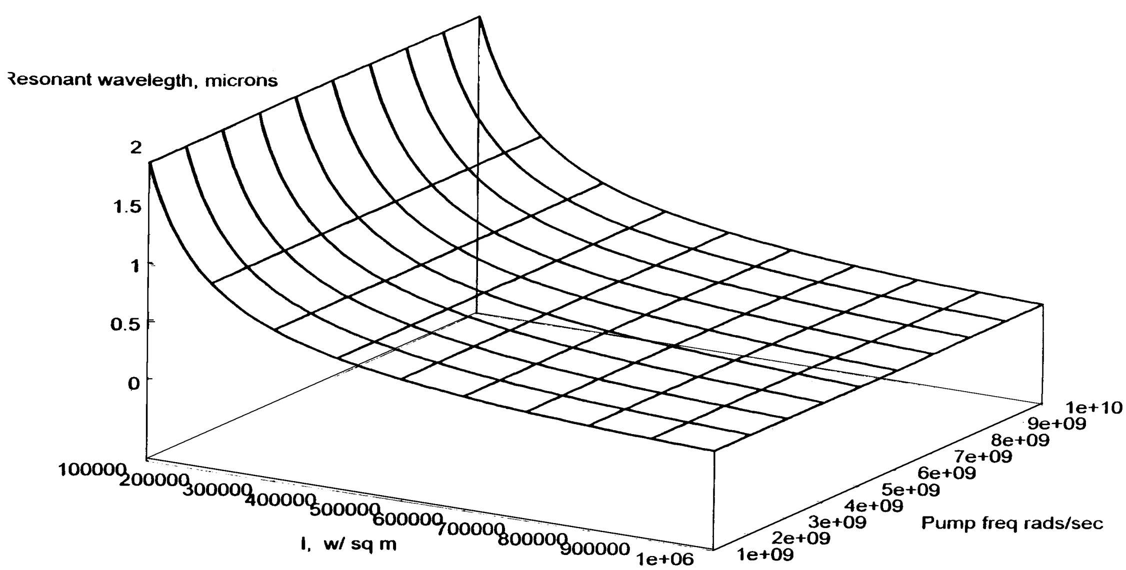

Fig 3. Resonant wavelength (microns) for a range of pump frequency from 10^9 to 10^{10}s/sec and a range of beam intensity from 10^5 to 10^6 Watts/m^2.

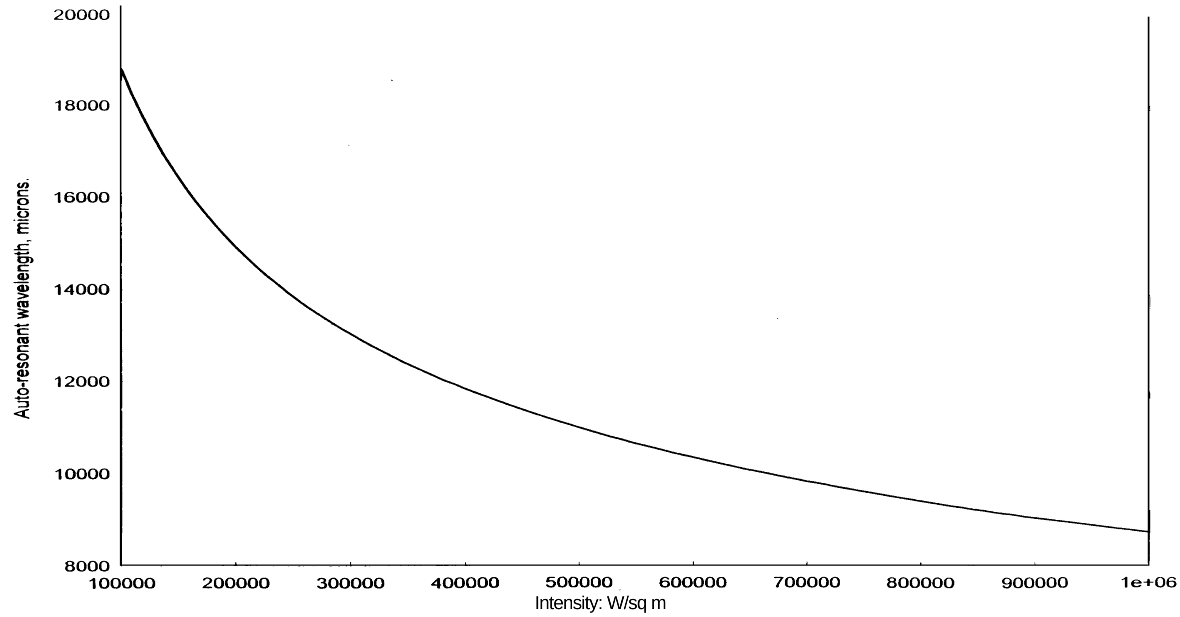

Fig 4. Auto-resonant wavelength (microns) as a function of beam intensity, Watts/m^2.

term in equation (1) predominates is of the order of $2.5.10^{14}$ W/m^2. This is illustrated in Fig 1 which shows the predicted $\mathbf{B}^{(3)}$ for a range of pump frequencies including that used by Deschamps and a much higher range of beam intensities. At these power levels the apparatus would probably vaporize!

Deschamps used the ionizing effects of the incident radiation to produce the free electrons. It would be better to arrange for the radiation to interact with an electron beam directly, since the magnetization scales as the electron density. Furthermore, as pointed out in Jeffers *et al* (1996)[11], positive ions would also be produced in the Deschamps experiment. These rotate in the opposite sense to the electrons, producing an axial field which opposes and reduces the field to be detected. This disadvantage is obviated by the use of an electron beam. Our proposed experiment would employ an electron gun, the beam from which would be irradiated head-on by circularly polarized microwaves generated by a helical antenna mounted in the same vacuum enclosure. A cone shaped baffle would be mounted concentric with the electron beam with its apex facing the antenna to reflect the incident microwaves at an angle to the axis of the apparatus. In this way standing microwaves would be prevented from arising. A pick-up coil would be mounted in the region where the beams overlap. Fig 2 shows the relation between the magnetization and intensity for a frequency of 0.3 MHz and a range of intensities from 1.10^7 to 1.10^8 W/m^2 clearly revealing the anticipated non-linear relationship. The electron density is taken to be 10^{25}/m^3.

Resonance and Auto-resonance Experiments

Evans, Roy and Jeffers (1995)[12] have discussed fermion spin resonance that arises in a microwave or radio frequency beam. Electrons in the presence of a magnetic field (the $\mathbf{B}^{(3)}$ field in this case) have two energy levels due to their interaction with the field. The angular frequency corresponding to resonance between these two levels is given by

$$\omega_{res} = \frac{e^2 \mu_0 c I_0}{\hbar m_0 \omega^2} .$$

Fig 3 shows the resonance wavelength in microns for GHz beam frequencies and a range of relatively modest beam intensities (10^5 to 10^6 Watts/sq m) .

The resonances could be detected in an experiment which used the apparatus described above with the addition of a crossed infra-red probe beam and Fourier Transform Spectrometer. An even simpler experiment would be to try to detect auto-resonance between the pump beam and the electrons. This arises when $_{res}$= . In the case of autoresonance, the angular frequency of the beam at resonance scales as the cube root of the beam intensity. This relationship is shown in Fig 4 where the autoresonant wavelength (in microns) has been plotted against beam intensity. This experiment would thus consist of monitoring the beam intensity after it has interacted with the electron beam and detecting minima by scanning the angular frequency of the radiation through the predicted resonant frequency.

Conclusions

Current claims for the existence of the $\mathbf{B}^{(3)}$ field are reviewed. These do not provide conclusive evidence for the existence of this novel field component. However some experiments are suggested which could, in principle, lead to such conclusive evidence.

Acknowledgment.

It is a pleasure to acknowledge the interest shown in this work by Professor M.W. Evans.

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The Jeffers Experiment and its History

The history of the Jeffers experiment (relativistic inverse Faraday effect) goes back to the work of Pershan, Piekara and Kielich in the early sixties, and to the spectacular demonstration by van der Ziel and co-workers in 1965 that circularly polarized laser radiation can magnetize glasses and liquids. This result was soon followed by the impressive demonstration by Deschamps *et alia* of magnetization of a plasma by a micowave beam at 3.0 GHz. Three years later Barrett and co-workers demonstrated the effect in a *Nature* paper. These demonstrations were followed soon by others in independent laboratories. My former colleague Peter Atkins made some Q.E.D. calculations of the effect with Miller in the mid sixties. This is before Atkins became a millionaire from royalties. Also, some very fine work on the inverse Faraday effect was being done in Russia at the same time by colleagues such as Mikhail Novikov, whom I met at *Vigier One*. The Poznan School under Kielich developed the effect in a typically splendid way throughout these years, and I had the great pleasure of working with Stanislaw Wozniak and Georges Wagniere on its development at Zurich University in between trips to the Bernese Oberland. To me it has always been an ultra fascinating phenomenon of nature that light can actually act as a magnet was almost beyond belief when I first came across it in Peter Atkins book while working for Enrico Clementi at I.B.M. Kingston, New York.

I first came across Stanley Jeffers work in the de Broglie centennial conference volume, and wrote to him from UNCC in the autumn of 1993. After some dialogue it was soon decided to organize *Vigier One* around mutual interests at the time, and I was invited to lecture at York University on the then mysterious $\mathbf{B}^{(3)}$. Unfortunately, a few days before this lecture I was accused suddenly of neglect of duty and misconduct by the equally mysterious Schley R. Lyons and Silveiro P. Almeida at UNCC and carpeted. I decided to go ahead with the Toronto trip and met Stanley with my wife Laura at the gleaming and impressive Toronto International Airport, a big grinning fellow with an Australian hat who explained that the first Chancellor of his University was Oscar Peterson, the great jazz pianist. No snobbery here, I thought.

The lecture was quite a showdown, but although outnumbered by three fearsome Canadian theoreticians, I held my ground, explaining that there were no rugby fields in North Carolina so I had to think of one.

The visit was interrupted occasionally by telephone calls from UNCC demanding instant resignation, but apart from that kind of minor nuisance plans for the experiment materialized well. I had the pleasure of meeting the Hathaway Brothers, and talking over the meticulous design of the microwave guides needed for circular polarization. The original concept was greatly improved by Jeffers who suggested the use of an electron beam to get rid of ionic interference. Later the calculations were clarified and the design optimized by Internet discussions.

Greatly to our disappointment, repeated approaches to NSERC in Canada have not secured funding for this key experiment, which looks for the tell-tale effects of $\mathbf{B}^{(3)}$ acting at first order through its intensity dependence. In the meantime the splendid organization of *Vigier One* went ahead, and we had the pleasure of seeing the great Jean-Pierre Vigier awarded his degree, *honoris causa*. The conference banquet speech was given by Prof. E. J. Sternglass, who worked with Einstein for a while we made many new friends and no new enemies.

The point here, to be serious for a minute, is a very simple one that science is blocked if the key experimental data are not made available. This is true irrespective of the ins and outs of the complicated theoretical world. If scholarship cannot be pursued at a bright and liberal place like York, it can t be pursued anywhere.

Myron Evans (April, 1997)