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In search of photon's elementary axial magnetostatic field

M. Yasin Akhtar Raja[1], **Wade N. Sisk**[2], **Mohammad Yousaf**[1,*], **David Allen**[1]

[1] Optoelectronics & Quantum-Optics Group, Department of Physics, University of North Carolina at Charlotte, 9201 University City Blvd., Charlotte, NC 28223-0001, USA
E-mail: raja@uncc.edu
[2] Optoelectronics & Quantum-Optics Group, Department of Chemistry, University of North Carolina at Charlotte, 9201 University City Blvd., Charlotte NC 28223-0001

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Abstract. Experimental investigations of the photon's $B^{(3)}$-field (third longitudinal polarization) are reported. The existence of an "axial magnetostatic field of photon" has been predicted in B_π or $B^{(3)}$-theory as the fundamental property of the circularly polarized light, and reported in numerous papers and monographs. High-sensitivity detection has been employed in photomagnetic induction, Faraday, and inverse Faraday effects (IFE) originating from such a field. The results of all three experiments clearly disprove the claims of B_π-theory. Putting together these results and theoretical calculations in perspective, it is concluded that such fields are non-existent.

Elliptically polarized intense optical beams can produce dc magnetic fields in axial direction upon interaction with various materials. The light-induced magnetization [1–4] in certain non-absorbing media arises from the optical Stark effect which removes the degeneracy of ground states manifold. Such interaction results in population redistribution in paramagnetic materials, while in diamagnetic materials, wave-function mixing contributes to light-induced magnetization. This phenomenon is known as Inverse Faraday Effect (IFE) [1–3]. On other hand, in absorbing media, magnetization occurs due to resonant excitation via optical pumping from ground states to magnetic levels [5] which is a different mechanism than that of the IFE.

Based on the IFE concept, recently Evans [6–10] has proposed a theory which predicts the existence of "photon's fundamental axial static magnetic field" in circularly (and elliptically) polarized optical beams. According to the theory the axial dc magnetic field of a photon arises from its angular momentum. Further, the magnetostatic field B_π or $B^{(3)}$ (as Evans calls it) is the fundamental property of the photon which circularly polarized beams possess even in vacuum. Evans defines a conjugate product $\bar{B}_\pi = (\mathrm{i}\bar{E} \times \bar{E}^*)/2cE_0$ of circularly polarized fields in analogy with the Poynting vector, and derives an expression for the dc axial magnetic field [6–10]. The magnitude of $B^{(3)}$ is proportional to the intensity of the optical beam while its direction is parallel or antiparallel to the propagation direction for right- and left-circularly polarized beams, respectively. A dc-axial electric field $E^{(3)}$, oppositely directed to $B^{(3)}$, has also been proposed in an effort to satisfy the energy-conservation requirements [8].

There are scores of papers, books and monograph's predicting photon's axial magnetic flux density B_π or $B^{(3)}$ [6–10] and its impact on nonlinear optics [9–10]. However, there is a lot of controversy in the literature [11, 12] about the "ghostly $B^{(3)}$-fields" and inconsistency in Evans' own papers as well. Our research group has been investigating over the past three years to establish the validity of the $B^{(3)}$-theory. The experimental studies conducted by our group and others [13] have not confirmed the existence of B_π or $B^{(3)}$ and its possible impact on laser-induced shifts in optical NMR [10]. In fact, an experimental report on laser-enhanced NMR spectroscopy [14] has explained results without resorting to the $B^{(3)}$-theory.

For experimental verification of $B^{(3)}$ or B_π-theory, we have conducted several magneto-optic experiments. Here, we report the results of those experiments which include photomagnetic induction, optical Faraday effect, and new results on IFE. The first two experiments, i.e. photomagnetic induction and optical Faraday effect, clearly refute Evans' theory because the predicted effects of B_π were not observed with high-sensitivity detection. We also investigated the room-temperature IFE in Terbium Gallium Garnet (TGG) crystals [4] and studied the IFE signal behavior as a function of optical power of the circularly polarized beam. These results do not support $B^{(3)}$ or B_π-theory as well, but are in agreement with those by Van der Ziel et al. [1, 2].

This paper is organized in four sections. Theoretical predictions and calculations based on [6–10] are

* *Present address*: SIA Technology, 337 Turnpike Road Southboro, MA 01772, USA

summarized in Sect. 1. Various experimental techniques of magneto-optics are discussed in Sect. 2. Section 3 deals with the experimental details, results and physical mechanism involved in each experiment. Finally, the main results with the concluding remarks are summarized in Sect. 4.

1 Photon's static magnetic field

1.1 Theoretical background

Evans first proposed the existence of B_π field in 1991 [15] by considering the vector product of circularly polarized light with its electric vector $\bar{E} = (1/\sqrt{2})\ E_0\,(x \pm \mathrm{i}y)\,\mathrm{e}^{\mathrm{i}\phi}$ and its conjugate $\bar{E}^*$. Later, he generalized his theory and gave new solutions of Maxwell's equations which included an axial dc E-field and an axial B-field and called them $E^{(3)}$ and $B^{(3)}$, respectively [8]. In various papers it was claimed that photons have three polarizations, and the third polarization comprised of static fields. The expressions for B_π were derived using quantum field theory [9] and classical electrodynamics [7]. In quantum theory, "a fundamental magnetostatic flux operator" attributed to a photon [6, 9] is defined in (1). Elsewhere [10] a term "photomagneton" was introduced:

$$\bar{B}_\pi = B_0\,\frac{\bar{J}}{\hbar}, \tag{1}$$

where B_0 is the scalar magnetic flux density amplitude of a beam of N photons (polarized circularly and $\bar{J}$ is photon's angular momentum operator with eigenvalues $\mp M\hbar$. On the other hand, the classical version of B_π is given by the following relation:

$$\bar{B}_\pi = \frac{\mathrm{i}\bar{E}\times\bar{E}^*}{2cE_0} \tag{2}$$

where E is the electric field vector of the circularly polarized beam and E^* is its conjugate. The $B^{(3)}$-theory (photon's elementary magnetostatic field) is claimed to be more general and fundamental [7], and IFE [1–3] is treated as a special case. According to [7–10] of the proponents of the theory, the magnetization $\mathbf{M}$ induced during the light–matter interaction (e.g. IFE) can be approximated as

$$\mathbf{M} = \frac{N}{kT}\,\langle m_z^{(0)2}\rangle_0\,B_{\pi z} + \frac{Nc^2}{3}\,({}^m\Upsilon^{ee}_{123} + {}^m\Upsilon^{ee}_{231} + {}^m\Upsilon^{ee}_{312})\,B^2_{\pi z} + \frac{N}{kT}\,\frac{\langle\xi^2_{zz}\rangle_0}{4\mu_0^2}\,B^3_{\pi z}\,, \tag{3}$$

where N is the number density, $\langle m_z\rangle$ the mean value of the dipole moment, $B_{\pi z}$ the longitudinal z-directed static field of photon, k the Boltzmann constant and T the absolute temperature. Likewise other symbols in the equation ${}^m\Upsilon^{ee}_{ijk}$, $\langle\xi^2_{zz}\rangle$, c, and μ_0 stand for molecular hyperpolarizability, magnetizability, speed of light and permittivity of free space, respectively. An interested reader should consult [10] which is one of Evans' books titled "The Photon's Magnetic Field". Using $E_0 = c|B_\pi|$ and $I = \frac{1}{2}\,\varepsilon_0\,cE_0^2$, (3) can be expressed in the following simple form:

$$\mathbf{M} = \alpha I^{1/2} + \beta I + \Upsilon I^{3/2}, \tag{4}$$

where the first and third terms are additional contributions from B_π, and the second term is related to the well-known IFE which has been established experimentally [1], theoretically [2, 3] and repeated recently [4]. The coefficients in (4) are related to the material response and have measurable values for high Verdet constant materials. The contribution of each term has been estimated in one of Evans' book [10]. First and third coefficients (α and γ) are temperature-dependent while the second coefficient β does not have temperature dependence. For a diamagnetic material the contribution due to each term under room temperature and irradiation ($I = 300\ \mathrm{GW\,cm^{-2}}$) was estimated to be 2.5, 30, and 2.0 ($\mathrm{A\,m^{-1}}$), respectively. Thus, a major contribution to magnetization comes from the second term at room temperature while other two terms contribute 15% of the signal. According to [10] this would result in a strength of magnetic field $B_\pi \sim 1$ T. Scaling down the optical intensity to $I \sim 300\ \mathrm{MW\,cm^{-2}}$ which is quite typical in Q-switched Nd:YAG lasers, a field strength of 1×10^{-3} T is expected. Thus, the calculated B_π-field is a factor of 10 greater than the Earth's magnetic field at its surface.

1.2 Estimate of magnitude of photomagnetic induction

The order of magnitude given in the preceding Sect. 1.1 comes from the Evans' generalized IFE theory which involves the interaction of high Verdet constant material and the circularly polarized light. For the sake of completeness, we can also use the estimated value of B_π in vacuum. From both (1) and (2) the value of B_π or $B^{(3)}$ can be calculated as [7–10]

$$\bar{B}_\pi = \left[\frac{I_0}{2\varepsilon_0\,c^3}\right]^{1/2}\bar{k}, \tag{5}$$

and its magnitude can be expressed as

$$B_0 = 10^{-7}\sqrt{I_0}\,, \tag{6}$$

where I_0 is the intensity of the circularly polarized optical beam in units of watts per square meter and B_0 is the magnitude of B_π in Tesla. The remaining symbols k, ε_0, and c designate an axial unit vector, permittivity of free space, and speed of light, respectively. Equation (6) provides an estimated value of the B_π or $B^{(3)}$-field. Since optical intensities in the range of $\mathrm{MW\,cm^{-2}}$ to $\mathrm{GW\,cm^{-2}}$ are easily accessible in cw and pulsed lasers beams, the resulting B_π-field should be in the range of 10^{-4}–10^{-2} T, which can be readily measured. This calculated value of B_π is of the same order of magnitude as estimated in the preceding subsection. This apparent repetition of approximate calculations might seem redundant but it should be noted that the first involves "generalized IFE" while the second based on (5) and (6) originates from the B_π-theory of the photon.

2 Method

The existence of the photon's axial magnetostatic field can be tested directly by various magnetooptic effects, e.g. photomagnetic induction, Faraday effect, Inverse Faraday Effect (IFE), and photo-Stern–Gerlach experiment to name a few. We have investigated the first three methods to search for the "enigmatic photon's ghostly fields."

The existence test of B_π based on Faraday's law of electromagnetic induction is quite straightforward. If a circularly polarized optical beam possesses an axial magnetostatic field, it must induce a voltage signal in an inductive coil as the beam traverses through it. A chopped cw optical beam or short pulse laser beam can be used. An optical pulse with a sharp rise and fall would produce higher-voltage spikes of opposite polarity with a resulting change in the flux rate, in accordance with Faraday's law as $\mathscr{E} = -(\mathrm{d}\Phi_B/\mathrm{d}t)$.

In the presence of dc magnetic fields when a linearly polarized light passes through certain transparent media, its plane of polarization is rotated. This phenomena is known as the Faraday effect [3], and can be employed to detect "dc magnetic fields associated with the photons" by using an optical pump–probe method. This procedure is inherently immune to electrical noise. In our laboratory a linearly polarized weak probe (632 nm, He–Ne) was passed through a TGG crystal alongwith a colinear strong circularly polarized pump beam (intensity $I_0 \sim 400\,\mathrm{MW\,cm^{-2}}$). A cross polarizer setup with a wavelength filter and photodetector was used for sensitive detection.

As discussed in Sect. 1, B_π-theory predicts a "generalized IFE", which can also be used to detect the alleged "$B^{(3)}$-field". IFE is a very weak effect which was first detected at low temperatures, 1.27–4.2 K, in $Eu^{2+}:CaF_2$ (3.1%) crystals [1] using a circularly polarized Ruby laser ($\lambda = 694$ nm) with intensity $I = 10\,\mathrm{MW\,cm^{-2}}$. Recently, room-temperature IFE in TGG crystals [4] has been reported using a circularly polarized frequency-doubled Nd:YAG laser ($\lambda = 532$ nm) at intensities exceeding $100\,\mathrm{MW\,cm^{-2}}$. A linear dependence of optically induced magnetization (IFE) was reported in the original experiment by Van der Ziel et al. [1, 2] and theoretically investigated by Shen [3]. Now B_π-theory predicts (e.g. (4)) that the magnetization due to IFE involves terms proportional to $I^{1/2}$ and $I^{3/2}$ in addition to well-known direct proportionality to I the incident optical intensity. Thus, induced voltage signal in the detection coil (with a high Verdet constant material in place) would involve contribution from all three terms in (4). Therefore, it would be a superlinear function of the circularly polarized pump beam intensity because all coefficients are positive. It can provide direct evidence of the validity of (4) and hence should furnish a convincing proof of $B^{(3)}$-theory.

3 Experimental details and results

The experimental arrangement used to investigate room-temperature IFE in TGG was similar to that of Van der Ziel et al. [1, 2] and has been reported elsewhere [4]. In order to determine the sensitivity of the detection system, another coil of a smaller diameter coaxial to the detection coil was used as a source of a pulsed B-field. The source coil had a diameter $\phi = 6.5$ mm, length $l = 5.1$ mm, number of turns $N = 10$, and used a copper wire of AWG # 30 gauge. The coil was wound on a wooden rod (6.5 mm diameter) fitted into a BNC-connector and a 10 kΩ current-limiting resistor in series with the coil and center pin of the BNC-connector. A pulsed-magnetic field was produced by providing voltage pulses to the source coil from a high-speed digital pulse generator. Such pulsed magnetic field simulates the effect of optical pulses which supposedly carry a magnetostatic $B^{(3)}$-field.

3.1 Simulation of pulsed B-field

Figure 1 shows an experimental setup for "optical pulse simulation" using high-speed electronic pulses. In simulation experiments, a source coil was inserted coaxially inside the detection-coil assembly. The source coil was connected to a digital-pulse synthesizer (Stanford Research Systems DG 550). Voltage pulses of 7 ns duration and variable amplitude ($V_0 = 80$–250 mV) are applied to generate pulsed B-field. The rise and fall of the electrical pulse is ~ 1.2 ns and current amplitude i_0 through the coil (with a 10 kΩ series resistor and 700 Ω inductive impedance) is 10 μA with an applied voltage amplitude of ~ 100 mV. The resulting magnetic field can be estimated using $B = \mu_0 N i_0 / 2R$ which comes out to be $\sim 9.8 \times 10^{-9}$ T. According to Faraday's law of electromagnetic induction the changing current in source coil would induce a voltage in the detection coil as

$$\mathscr{E} = \frac{\Delta\phi_B}{\Delta t} = \frac{\mathrm{NBA}}{\Delta t} \tag{7}$$

where $A \sim 3.32 \times 10^{-5}\,\mathrm{m}^2$ is the cross-sectional area of the source coil and Δt is the rise or fall time of the electrical pulse. Using appropriate numerical values, the induced voltage in the detection coil is estimated $\mathscr{E} = 1.36$ mV.

Figure 2 is typical data for pulsed B-field generated by the current source (8–25 μA and 7 ns) as discussed above.

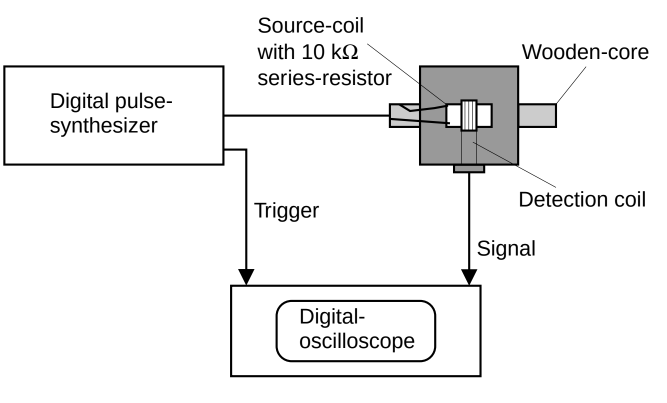

Fig. 1. Apparatus for generation of pulsed magnetic fields using high-speed electronic pulses for simulation of "optical pulses with $B^{(3)}$-fields"

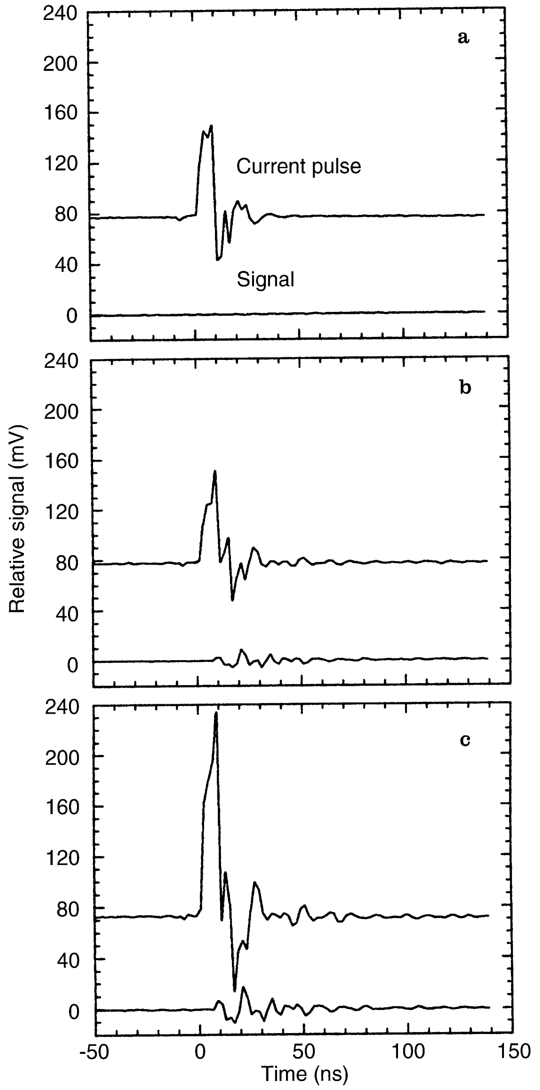

Fig. 2a–c. High-speed electromagnetic induction data from electronic simulations of "pulsed magnetic fields generated by circularly polarized optical beams". Upper and lower traces correspond to an applied voltage pulse in the source coil (with $\sim 10\,k\Omega$ series resistance) and resulting signal in the detection coil, respectively. **a** $\sim 8\,\mu A$ current pulse caused by a 80 mV voltage pulse in the source coil without coupling to the detection coil. **b** same as in **a** but with source coil inserted inside the detection coil. An induced voltage signal is clearly observable. **c** Same as **b** but with an applied voltage pulse ~ 160 mV

Multiple reflections due to impedance mismatch distort the source-coil voltage waveform as well as the induced voltage pulses in the detection coil. The sequence of data in Fig. 2 represents different current levels in source coil for coupling of source coil with the detection coil. For high-frequency pulses, $50\,\Omega$ input channel termination was used. The detection of $\sim 1 \times 10^{-8}$ T pulsed *B*-field due to 10 μA current was accomplished without any preamplifier, where the induced signal was ~ 1.1 mV. With an amplifier and improved signal processing the detection limit can be extended to subnano-Tesla.

3.2 Photomagnetic induction

Having established the sensitivity of detection, the photomagnetic induction experiments were carried out using the setup of [4]. The circularly polarized beam from the frequency-doubled Nd:YAG laser at $\lambda = 532$ nm was passed through the detection coil. No crystal or any other sample was placed inside the detection coil. The laser pulse duration τ was 7 ns with a rise time $\Delta t_r \sim 2.5$ ns and fall time $\Delta t_f \sim 4$ ns. The peak optical intensity used in the experiment ranges from 10 to 400 MW cm^{-2}. This according to (6) would result in $B^{(3)}$-fields $\sim 10^{-5}$–10^{-2} T, respectively. Consequently, induced voltage across the detection coil was expected to be of several volts but no signal was detected. Laser beams [16] with different wavelengths, ellipticity, pulsewidth and intensity were used but the results remained negative. Null results in our current experiments as well as earlier experiments [17] suggest that "ghostly $B^{(3)}$-fields" [6–10] are non-existent! Unpublished results by Compton and Armstrong [13] also corroborate our findings.

In an effort to explain the negative results of the photomagnetic induction experiment, Evans [18] proposed that "$B^{(3)}$-field vanishes in a transformation from the photon's reference frame to the laboratory frame as the photons move with the speed of light. Therefore, Faraday's electromagnetic induction will not be observed." But in the Lorentz transformation the axial fields (in the direction of propagation) do not change [19]; therefore the above explanation is not valid.

3.3 Optical Faraday effect

Failure of photomagnetic induction experiments to detect the $B^{(3)}$-field led to additional experiments for further verification. Optical Faraday Effect (FE) was our second choice. As is well-known, the plane of polarization of a linearly polarized light undergoes a rotation when it passes through certain materials (crystals, glasses, and liquids) in the presence of an external dc magnetic field along the axis of propagation [3]. The angle of rotation can be expressed by the relation

$$\theta = VlB, \tag{8}$$

where V, l and B are the Verdet constant of material, its length and external magnetic field, respectively. Figure 3 shows the experimental arrangement for optical FE experiments. A weak probe, linearly polarized He–Ne laser, and a strong circularly polarized pump beam were passed together through a TGG crystal which is a high Verdet constant material. Its Verdet constant at He–Ne laser wavelength $\lambda = 632$ nm is -134 rad T^{-1} m^{-1}. A pump beam from Nd:YAG or Alexandrite laser operating, respectively, at $\lambda = 1064$ and 755 nm (or their second harmonics) was circularly polarized with appropriate quarter-wave plate or a quartz Fresnel Rhomb. A cross-polarizer arrangement and a photodetector with a band-pass filter were used for detection. It was expected that the probe beam will undergo a rotation due to $B^{(3)}$-field of the circularly polarized pump beam. Based on the estimated

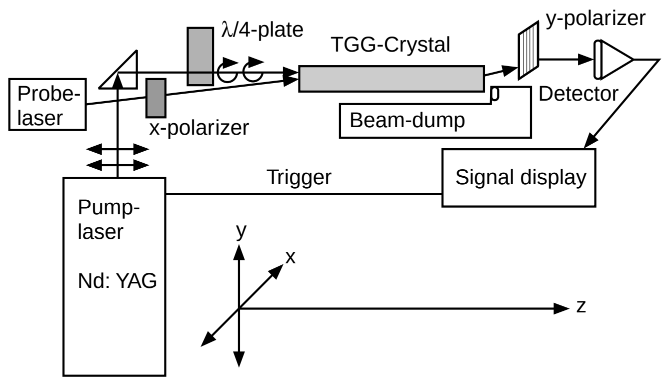

Fig. 3. Experimental arrangement for the optical Faraday effect

value of $B^{(3)}$ (10^{-5}–10^{-2} T), crystal length (30 mm) and the Verdet constant at 632 nm, a rotation ~ 0.023–$2.3°$ was expected which should be readily detectable. Again, no rotation of the probe laser was found which rejects the existence of B_π beyond any reasonable doubts. At extremely high optical intensities, magnetization due to well-accepted IFE [1–4] might produce orders of magnitude small rotation ($\sim 10^{-6}$ degrees) which would be beyond the detection sensitivity of the present apparatus, and obviously would not support the predictions of $B^{(3)}$-theory.

3.4 Inverse Faraday effect

The original IFE experiment by Van der Ziel et al. [1, 2] showed a linear dependence of induced magnetization on the laser intensity. The data in [1] were taken at low-temperature (1.27 and 4.2 K), and the optical intensity range of 1–40 MW/cm^2 was explored. Indeed, the experiment of [1] is the only one reported in literature which describes IFE in detail. Apparently, it has not been repeated using other materials under similar conditions. Although IFE experiment and its theoretical foundation [1–3] is well-understood and accepted in literature, Evans in his publications claims a more generalized IFE theory. Such generalized theory predicts a nonlinear intensity dependence of IFE magnetization. Thus, an implication of B_π-theory [7, 10] is that magnetization in well-known IFE [1–3] is a just second term, in (4). The contributions of additional terms should provide a steeper slope in the induced magnetization (IFE signal) vs optical intensity graph. Consequently, the signal in the induction coil should produce a superlinear response for optical power of the circularly polarized beam. The experimental setup of [4] was used to investigate the dependence of IFE signal on the incident optical power in a TGG crystal at room temperature. TGG and Tb-doped glasses have a high Verdet constant in the visible and near-infrared spectral region. The Verdet constant of TGG crystals at $\lambda = 1064$, 750, and 532 nm is -40, -80, and -190 rad m^{-1} T^{-1}, respectively. In a typical IFE measurement, a circularly polarized laser beam is passed through the crystal or any other sample placed inside the detection coil. The induced magnetization changes the magnetic flux density through the coaxial sample and produces a voltage signal proportional to time rate of change of magnetic flux.

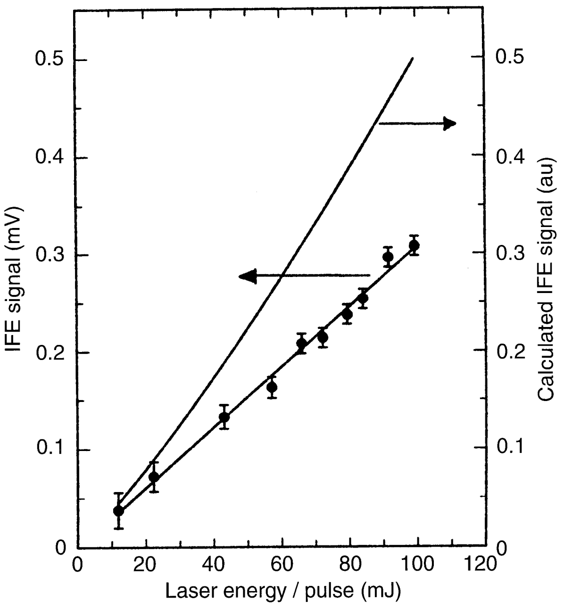

Fig. 4. Comparison of experimental data and theoretical calculations based on B_π-theory. *The line* with symbols and error bars represents room-temperature IFE signal in TGG as a function of laser pulse energy of the circularly polarized beam at $\lambda = 532$ nm. It shows a linear behavior even up to the damage threshold. The *solid curve* shows the calculated IFE signal (in arbitrary units), obviously theoretical predictions and experimental data do not match

The experimental details and the results of room-temperature IFE in TGG can be found elsewhere [4]. A collimated beam from a frequency-doubled Nd:YAG laser ($\lambda = 532$ nm) with a 4 mm diameter traversed a 7 mm diameter TGG crystal placed in the detection coil encapsulated in an aluminum box for shielding. Laser pulses with 7 ns pulsewidth (FWHM) and energies exceeding 100 mJ were used. The dependence of IFE signal on laser pulse energy was investigated over a wide range from 10 to 100 mJ. As the intensity distribution in the laser beam is Gaussian, peak intensities in the center of the beam readily approach the TGG crystal damage threshold for pulse energies in excess of 100 mJ. Therefore, proper care must be taken to preclude exceeding the damage threshold of TGG crystal which is ~ 500 MW cm^{-2}.

In Fig. 4 the experimental data and theoretical calculations (based on B_π-theory) are displayed for comparison. The curve with symbols and error bars represents room-temperature IFE signal as a function of optical energy of the circularly polarized beam, whereas the solid curve shows the corresponding calculations (using (4)) in arbitrary units. A linear dependence of IFE signal on the laser-pulse energy is evident from the graph. The behavior of the experimental curve does not match with the calculated results based on Evans' B_π-theory. First, the IFE signal is orders of magnitude smaller than predicted from (4) and, secondly, the IFE signal (resulting from induced **M**) is not a superlinear function of circularly polarized light.

In the original IFE experiment [1, 2] it was found that induced magnetization depends linearly on the optical intensity of circularly polarized light. These earlier experiments were carried out at low temperature and moderate intensity (1–40 MW cm^{-2}). Since the induced voltage signal in the detection coil depends on the magnetic flux, therefore it ultimately depends on the optical power. The IFE signal in TGG exhibits a linear dependence on optical energy (or power) over a wide range including energies near the TGG damage threshold.

The phenomenological model, first proposed by Pershan et al. [1, 2], predicts the correct behavior and signal strength with an acceptable accuracy (5% or better). A relationship between magnetization per unit volume $\mathbf{M}$ ($J\,T^{-1}\,m^{-3}$) and optical intensity I_0 ($W\,m^{-2}$) can be expressed with slight modifications using SI units as

$$\mathbf{M} = \xi \frac{V}{2\pi^2 c} \left[\frac{\lambda_0}{n_0}\right] I_0, \tag{9}$$

where V, λ_0, and n_0 are Verdet constant (in rad $T^{-1}\,m^{-1}$), wavelength (in m) and refractive index of the material, respetively. Among remaining symbols, c stands for the speed of light and ξ is the ellipticity parameter. For right-circular, linear and left-circular polarizations the value of ξ is $+1$, 0, and -1, respectively, whereas other values in the range $+1$ and -1 correspond to elliptical polarizations. The results given in [4] and the calculated values from (9) are consistent with the experimental findings. But they do not support (4). There seems to be no correlation with the $B^{(3)}$-theory predicitions and the experimental data illustrated in Fig. 4. Therefore, there was no manifestation of $B^{(3)}$-field in IFE experiments.

4 Concluding remarks

In summary, we have conducted a systematic investigation of magneto-optic effects in an effort to provide direct experimental evidence for the theoretically predicted $B^{(3)}$ (or B_π) fields of photons. All the reported experiments, i.e. photomagnetic induction, optical Faraday effect, and inverse Faraday effect yielded negative results for the existence of $B^{(3)}$ fields, the magnetostatic axial fields of photons. Simulations were also carried out in order to obtain the estimate of detection sensitivity which extends to the nano-Tesla regime. The inverse Faraday effect in TGG is novel but does not support the predictions of $B^{(3)}$-theory. On the other hand, the room-temperature IFE results in TGG are consistent with the original reports of Van der Ziel et al. [1, 2] over a wide range of optical intensity [20] of the circularly polarized laser beams. Based on these experimental studies we conclude, beyond any reasonable doubt, that "axial magnetostatic fields of photons" simply do not exist. Our conclusion is also supported by the theoretical findings of recent reports [11, 12] in the literature as well as linear dependence of IFE signal [1–4] on the optical energy of the circularly polarized laser beams.

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