EXISTENCE OF RADIATIVELY INDUCED FERMION RESONANCE (RFR) FROM THE STOKES PARAMETERS

M. W. Evans[1,2]

[1]Alpha Foundation and Laboratories
Institute of Physics
11 Rutafa Street
Budapest, Hungary

[2]J.R.F., 1975
Wolfson College
Oxford, Great Britain

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The classical polarization tensor of light is shown to contain a term proportional to the vector product of the Pauli matrix σ_3 with the conjugate product $A \times A^*$ of complex magnetic vector potentials. This simple analysis confirms the existence of a first order interaction energy,

$$E_n := -\frac{e^2}{2m}\sigma_3 \cdot A \times A^*;$$

between classical, circularly polarized radiation and a fermion or classical charged particle.

Key words: Radiatively induced fermion resonance, Stokes parameters, $B^{(3)}$ field.

1. INTRODUCTION

The classical polarization tensor of light [1] contains a term that shows the ability of circularly or elliptically polarized radiation to induce fermion resonance, a phenomenon which we have named radiatively induced fermion resonance (RFR) [2–5]. The resonance frequency induced in this way is proportional to I/ω^2 where ω is the angular frequency and I the intensity of the radiation, in units of radians per second and watts per square metre respectively. The theory produces [2–5] electron and proton spin resonance at frequencies approaching the visible range under accessible conditions, thus greatly increasing the instrumental resolution of current magnet based instruments of any kind. The RFR phenomenon can also be used to supplement the permanent magnet [6], producing in principle a greater instrumental resolution and site specific effects by second order perturbation theory [5].

2. THE STOKES PARAMETERS

Define the four Stokes parameters [6,7] in terms of the components of the magnetic vector potential

$$\begin{aligned} S_0 &:= A_x A_x^* + A_y A_y^*; \\ S_1 &:= A_x A_x^* - A_y A_y^*; \\ S_2 &:= A_x A_y^* + A_y A_x^*; \\ S_3 &:= -i(A_x A_y^* - A_y A_x^*). \end{aligned} \tag{1}$$

In circularly polarized radiation

$$S_1 = S_2 = 0 \tag{2}$$

and the general relation,

$$S_0^2 = S_1^2 + S_2^2 + S_3^2; \tag{3}$$

reduces to

$$S_0 = \pm S_3. \tag{4}$$

Therefore the existence of

$$S_0 := |\mathbf{A} \cdot \mathbf{A}^*|; \tag{5}$$

implies that of

$$S_3 := \mp i|A \times A^*| \tag{6}$$

in circularly polarized radiation. The two signs in Eq. (6) denote left and right handed circular polarization respectively.

3. THE CLASSICAL LIGHT INTENSITY TENSOR

We can choose to describe the light intensity tensor [6–10] in terms of a complex, rank two, tensor with a symmetric real and antisymmetric imaginary part,

$$I_{ij1} \propto \begin{pmatrix} A_x A_x^* & A_x A_y^* \\ A_y A_x^* & A_y A_y^* \end{pmatrix} ; \tag{7}$$

or as a real Stokes matrix,

$$I_{ij2} \propto \begin{pmatrix} A_x A_x^* & -iA_x A_y^* \\ -iA_y A_x^* & A_y A_y^* \end{pmatrix} : \tag{8}$$

In both cases, the tensor can be expressed in terms of the Stokes parameters, respectively,

$$I_{ij1} \propto \frac{1}{2} \begin{pmatrix} S_0 + S_1 & S_2 + iS_3 \\ S_2 - iS_3 & S_0 - S_1 \end{pmatrix} ; \tag{9}$$

and

$$I_{ij2} \propto \frac{1}{2} \begin{pmatrix} S_0 + S_1 & S_3 - iS_2 \\ -S_3 - iS_2 & S_0 - S_1 \end{pmatrix} : \tag{10}$$

These matrices can be expressed as combinations of Pauli matrices as follows. Resonance can be induced between the states of the appropriate Pauli matrix as usual.

4. THE PAULI MATRICES

There are several representations possible for the Pauli matrices, as discussed for example by Sakurai [11], they are defined by the $SU(2)$ group symmetry in any situation in dynamics and electrodynamics. Therefore we express the real and physical Stokes matrix (10) as a linear combination of the Pauli matrices

$$\sigma_0 = \begin{pmatrix} 1 & 0 \\ 0 & 1 \end{pmatrix} \qquad \sigma_1 = \begin{pmatrix} 1 & 0 \\ 0 & -1 \end{pmatrix}$$

$$\sigma_3 = \begin{pmatrix} 0 & 1 \\ 1 & 0 \end{pmatrix} \qquad \sigma_3 = \begin{pmatrix} 0 & i \\ -i & 0 \end{pmatrix} \tag{11}$$

which form the $SU(2)$ relation,

$$\left[\frac{\sigma_1}{2}, \frac{\sigma_2}{2}\right] = -i\frac{\sigma_3}{2} \text{ et cyclicum.} \tag{12}$$

For circularly polarized radiation the Stokes matrix is the real valued sum of two Pauli matrices,

$$I_{ij2} \propto \frac{1}{2}\begin{pmatrix} S_0 & S_3 \\ -S_3 & S_0 \end{pmatrix} = \frac{1}{2}(S_0\sigma_0 - iS_3\sigma_3), \tag{13}$$

and it is clear that resonance can be induced between the states of the real valued matrix,

$$-i\sigma_3 = \begin{pmatrix} 0 & 1 \\ -1 & 0 \end{pmatrix}.$$

DISCUSSION

The energy of interaction between a classical charged particle and the classical Stokes matrix (13) is dimensionally proportional to,

$$En \propto \frac{e^2}{2m} A^{(0)2}(\sigma_0 - i\sigma_3); \tag{14}$$

where e/m is the charge to mass ratio of the particle. Assuming that the constant of proportionality is unity we arrive at the same result as derived in a number of different ways in Ref. 3 from the minimal prescription. For an electron, and in SI units, the expected resonance frequency is [3,4],

$$\omega_{res} = 1.007 \times 10^{28} \frac{I}{\omega^2}; \tag{15}$$

and appears in the far infra red to visible region under accessible conditions [3,4].

In summary we have derived the phenomenon of radiatively induced fermion resonance in the simplest possible way, by re-expressing the Stokes matrix in terms of a sum of two Pauli matrices. Other derivations of the same result are given in Ref. 3.

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