«Using visual classical models is a usual method with the help of which one searches ways to obviate difficulties and which is used to find new representations in the field of microphysics»

V. L. Ginzburg

SPIN LIGHT IDENTIFICATION IN CLASSICAL AND QUANTUM THEORY OF SYNCHROTRON RADIATION

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Abstract. It is known, that the radiation of intrinsic magnetic moment of an electron (magneton-radiation, or spin light) is decomposed into two basically different mL-radiation and mTh-radiation types. The mL-radiation is conditioned by Larmor precession of the magnetic moment, while mTh-radiation is related to Thomas precession of the spin and has purely kinematic origin. In the relativistic quantum theory, based on Dirac equation, mL- and mTh- types radiation are not separated from each other and from the rest quantum effects of the electron radiation. A separate consideration is it possible only within the framework of the relativistic semi-classical radiation theory. Here it is shown, that the exactly analogy of spin light with all properties of this phenomenon in the first approximation over the Plank's constant   exists also in classical radiation theory. The conditions is established when the corresponding principle for spin light will be hold true in this work also.

1 Introduction

After the rehabilitation of relativistic classical spin theory on the basis of Bargmann- Michel-Telegdi theory [1] and successful approbation of this equation in precisional experiments to measure anomalous magnetic moment of an electron [2] there arose a question about the possibility of constructing classical theory of intrinsic magnetic moment of an electron which is adequate to a more rigorous quantum theory. This research resulted in the discovery of a new physical phenomenon, spin light [3-8], which is embracing new fields of relativistic radiation theory including its astrophysical aspects (see [9, 10] et al).

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2 Semiclassical interpretation of spin light

3. V. A. Bordovitsyn, I. M. Ternov, V. G. Bagrov. – Sov. Phys. Usp. 165 (1995) 1083.

8. V. A. Bordovitsyn. Spin light. In: Synchrotron Radiation Theory and its Development. World Scientific, Singapore, 1999. See also: Radiation Theory of Relativistic Particles. – Moscow: Fizmatlit, 2002 (in Russian).

$$W^{tot} = \left\{ 1 - \frac{55\sqrt{3}}{24}\xi + \frac{1+\varsigma\varsigma'}{2}\left(-1+\frac{a}{3}\right)\varsigma\xi \right\} W_{SR}, \quad \text{where} \quad W_{SR} = \frac{2}{3}\frac{e^2a^2}{c^3}\gamma^4$$

16. V. A. Bordovitsyn, V.V.Telushkin. – Izv. Vuz., Fiz. 49, № (2006).

$$\xi = 3\frac{\mu_0 H}{m_0 c^2}\gamma = \frac{3}{2}\frac{\hbar\gamma^2}{m_0 c\rho} = \frac{3}{2}\frac{H}{H^*}\gamma,$$

$\mu_0 = e\hbar / 2m_0 c$ - magnetic moment of an electron (Bohr magneton),

ρ - the radius of trajectory curvature,

$H^* = 4.413 * 10^{13}$ Oe – Schwinger critical magnetic field,

$\varsigma, \varsigma' = \pm 1$ for $\mathrm{H} = (0, 0, H)$, and $a = (g-2)/2$ with $g = 2(1 + \alpha / 2\pi)$

besides $\mu_a = a\mu_0$, where $\alpha = e^2 / \hbar c$.

$$W_{\sigma}^{tot} = \left\{ \frac{7}{8} - \frac{35\sqrt{3}}{12}\xi + \frac{1+\varsigma\varsigma'}{2}\left(-1+\frac{a}{6}\right)\varsigma\xi \right\} W_{SR},$$

$$W_{\pi}^{tot} = \left\{ \frac{1}{8} - \frac{5\sqrt{3}}{24}\xi + \frac{1+\varsigma\varsigma'}{2}\frac{a}{6}\varsigma\xi \right\} W_{SR}.$$

7. I.M.Ternov .- Introduction to Spin Physics of Relativistic Particles.- MSU Press (1997) 240 p.
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16. V. A. Bordovitsyn, V.V.Telushkin. – Izv. Vuz., Fiz. 49,№ (2006).

$$W^{em} = \left\{ \frac{1+\varsigma\varsigma'}{2}\left(\frac{g}{2}-4\right)\frac{1}{3}\varsigma\xi \right\} W_{SR},$$

$$W_{\sigma}^{em} = \left\{ \frac{1+\varsigma\varsigma'}{2}\left(\frac{g}{2}-7\right)\frac{1}{6}\varsigma\xi \right\} W_{SR},$$

$$W_{\pi}^{em} = \left\{ \frac{1+\varsigma\varsigma'}{2}\left(\frac{g}{2}-1\right)\frac{1}{6}\varsigma\xi \right\} W_{SR}.$$

3 Spin light in the classical theory of radiation

17. V. A. Bordovitsyn et al.. - Izv. Vuz, Fiz.21, №5 (1978) 12; №10 (1980) 33.

Here
$$A^{\alpha} = -\frac{1}{c}\frac{ev^{\alpha}}{R_{\rho}v^{\rho}}, \quad Q^{\alpha\beta} = -\frac{c\mu}{R_{\rho}v^{\rho}}\Pi^{\alpha\beta}.$$

v^{α} - four-dimensional vector velocity of charge with magnetic moment, R^{ρ}- a four-vector, conducting from charge to observer, $\Pi^{\alpha\beta}$ - dimensionless tensor of a spin.

$$\mathrm{H}^{\mu\nu} = \frac{1}{c}\frac{d}{d\tilde{t}}\mathrm{A}^{[\mu}n^{\nu]} - \frac{1}{c^2}\frac{d^2}{d\tilde{t}^2}Q^{[\mu\sigma}n_{\sigma}n^{\nu]}$$

with $\tilde{t} = t - R/c$ - retarded time of radiation.

$$\frac{dW_n^{eL}}{d\Omega} = \frac{3}{4\pi}\frac{n^2}{\gamma^4}\left\{\frac{\cos^2\theta}{\beta^2\sin^2\theta}J_n^{\;2} + J_n^{'\,2} + 4\varsigma\frac{\mu_0\omega}{e_0 c}\frac{\cos^2\theta}{\beta\sin\theta}nJ_nJ_n^{'}\right\}W_{SR}.$$

This formula is generalization of Shott formula for spectral-angular distribution of synchrotron radiation with radiation of intrinsic magnetic moment of an electron.

Here n - number of radiation harmonics, $J_n\left(n\beta\sin\theta\right)$ - Bessel`s functions,

θ - polar angle in the azimuthally symmetric system relatively of magnetic field,

$\omega = e_0H/m_0c\gamma$ - cyclotron frequency corresponding at g = 2.

18. I. M.Ternov, V. A. Bordovitsyn.- MSU, Department of Physics, Preprint №2, 1981.

For $\frac{\mu_0\omega}{e_0 c}=\frac{\mu_0}{e_0\rho}=\frac{1}{2}\frac{\hbar\omega}{m_0 c^2}=\frac{1}{2\gamma}\frac{H}{H^*}=\frac{1}{3\gamma^2}\xi$ we have

$W^{eL}=\left(1+\frac{1}{3}\varsigma\xi\right)W_{SR}$, and $W_\sigma^{eL}=\left(\frac{7}{8}+\frac{1}{6}\varsigma\xi\right)W_{SR}, W_\pi^{eL}=\left(\frac{1}{8}+\frac{1}{6}\varsigma\xi\right)W_{SR}.$

The formula for spectral-angular distribution of mixed radiation is

$$\frac{dW^{eL}}{dxdy}=\frac{27}{16\pi^2}y^2\left(1+x^2\right)^2\left\{K^2{}_{2/3}+\frac{x^2}{1+x^2}K^2{}_{1/3}+6\frac{\mu_0}{e_0\rho}\varsigma\frac{\gamma^2 yx^2}{\left(1+x^2\right)^{1/2}}K_{1/3}K_{2/3}\right\}W_{SR}$$

$x=\gamma\cos\theta=\gamma\psi,\ \ y=2/3\left(m_0/\gamma^3\right),$ $K_{1/3}, K_{2/3}$ - Macdonald’s functions, $z=\left(1+x^2\right)^{3/2}y$

$$\frac{dW^{eL}}{dx}=\left\{\frac{3}{32}\left[\frac{7}{\left(1+x^2\right)^{5/2}}+\frac{5x^2}{\left(1+x^2\right)^{7/2}}\right]+\frac{35}{16}\varsigma\xi\frac{x^2}{\left(1+x^2\right)^{9/2}}\right\}W_{SR},$$

$$\frac{dW^{eL}}{dy}=\frac{9\sqrt{3}}{8\pi}y\left\{\int_y^\infty K_{5/3}(x)\,dx+\frac{2}{3}\varsigma\xi\int_y^\infty K_{1/3}(x)\,dx\right\}W_{SR}.$$

19. V. A. Bordovitsyn, G. K. Razina, N. N. Byzov – Izv. Vuz, Fiz. 23, №10 (1980) 33. (formula (6.17)).

$\Pi^{\alpha\beta}$- dimensionless classical tensor of spin , P^α - four-dimension impulse of radiation.

$W^{eL}=\frac{c}{\gamma}\frac{dP^0}{d\tau}.$ From this it follows that $W^{eL}=\left(1+\frac{1}{3}\xi\frac{\Pi_z}{\gamma}\right)W_{SR},\ \ \Pi_z=\gamma\varsigma.$ See above.

20. I. M.Ternov, V. A. Bordovitsyn. – Vestn. Mosk. Univ. Ser. Fiz., Astron., 24, №5 (1983) 71.

4 Conclusion

Thus we have shown that at removal only quantum effects classical and quantum theory of spin light find with its full consent with each other in the first approximation by $\hbar$.

21. I. M Ternov, V.G.Bagrov, A. M. Khapaev. – Zh. Exp. Teor. Fiz.48 919650 921 (in Russian), Sov. Phys. JETP 21 (1965) 613.

22. V. A. Bordovitsyn, R. Torres. - Izv. Vuz, Fiz. 29, №5 (1986) 38.

Moreover, we have ascertain that in the mixed synchrotron radiation terms with anomalous magnetic moment in the power of radiation proportional $\hbar$ find in the full consent with classical theory. If in the semi-classical theory spin-light radiation connecting with Larmor precession pick out that for transition without spin-flip terms in the power of radiation including polarization components completely coincide therewith that give only classical theory developing above.

8. V. A. Bordovitsyn. Spin light. In: Synchrotron Radiation Theory and its Development. World Scientific, Singapore, 1999. See also: Radiation Theory of Relativistic Particles. – Moscow: Fizmatlit, 2002 (in Russian).

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