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Thomas precession and the electromagnetic angular momentum radiation from the relativistic charged particles with spin

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The problem of the relativistic theory of the electromagnetic orbital and spin angular momenta of the charge radiation is considered. It is obtained that the total power of the field spin angular momentum radiation is proportional to the Thomas precession and corresponds to the force field momentum of radiation.

Keywords: *electromagnetic field, spin, angular momentum, radiation, torque.*

1 Introduction

The hypothesis that electromagnetic waves have proper angular momentum was put forward by A. I. Sadowsky as long ago as 1897 [1]. He proposed the method of measurement for angular momentum of light based on light transmission through anisotropic crystalline plate: "... any apparatus processing linearly polarized light into circularly polarized must rotate... ".

In 1935-1936, B. A. Beth in USA [2] and A. N. S. Holborn in England [3] experimentally proved that circularly polarized light has angular momentum. Observation of considerably greater torque became possible with the emergence of lasers (see, for example, [4]). The existence of angular momentum of circularly polarized electromagnetic waves in the present time has no doubt about. However the general definition of angular momentum of the electromagnetic field (AMEF) is argued over among physicists to this day. Contentious debates about the adequacy of the theory of angular momentum and its radiation arise from time to time [5-9].

The base of the stated here the radiation theory of AMEF is exact methods of the relativistic radiation theory of the arbitrarily moving charge [10]. As an attachment there are considered properties of the orbital and spin moments of the synchrotron radiation with the specific source of this radiation such as an electron.

2 Relativistic theory of the orbital and spin angular momentum radiation

It may be distinguished two alternative ways of the relativistically covariant methods for the description of AMEF originated by D. D. Ivanenko and A. A. Sokolov [11] as well as by C. Teitelboim et al. [12-15].

Using the Teitelboim's method we can receive [16]

$$\frac{d\tilde{L}^{\mu\nu}}{d\tau} = \frac{2}{3}\frac{e^2}{c^5}\omega_\rho\omega^\rho(r^\mu v^\nu - r^\nu v^\mu), \tag{1}$$

$$\frac{d\tilde{\Pi}^{\mu\nu}}{d\tau} = \frac{2}{3}\frac{e^2}{c^3}(v^\mu\omega^\nu - v^\nu\omega^\mu) \tag{2}$$

where $v^\mu = dr^\mu/d\tau$ and $\omega^\mu = dv^\mu/d\tau$ are the four-vectors of velocity and acceleration correspondingly, e is the charge of an arbitrary moving relativistic particle.

It's interesting that on the method of D. D. Ivanenko and A. A. Sokolov yields the same results!

The received formulas have clear-cut physical interpretation. If we put into operation the well-known four-dimensional vector of the radiation momentum change [10] $d\tilde{P}^\mu/d\tau = (2e^2/3c^5)\omega_\rho\omega^\rho v^\mu$, then we can get the expression for the orbital momentum of radiation

$$\frac{d\tilde{L}^{\mu\nu}}{d\tau} = r^\mu\frac{d\tilde{P}^\nu}{d\tau} - r^\nu\frac{d\tilde{P}^\mu}{d\tau} = \frac{d}{d\tau}(r^\mu\tilde{P}^\nu - r^\nu\tilde{P}^\mu),$$

which is precisely the same relation between moments of the force tensor and of the angular momentum tensor derivative like relativistic mechanics $\tilde{T}^{\mu\nu} = r^\mu\tilde{F}^\nu - r^\nu\tilde{F}^\mu = d\tilde{L}^{\mu\nu}/d\tau$. Thus, the radiation of the orbital AMEF adds up to the radiation of the field momentum of the force.

The power of the radiation of the spin momentum is proportional to the Thomas's precession frequency $\Omega^{\mu\nu}_{Th}$ which is defined by this equation in the relativistic spin theory (see. [10])

$$\frac{d\pi^\mu}{d\tau} = \frac{1}{c^2}(v^\mu\omega^\nu - v^\nu\omega^\mu)\pi_\nu = \Omega^{\mu\nu}_{Th}\pi_\nu, \tag{3}$$

where π^μ is a well-known four-dimensional space-like spin vector. So if we put field momentum of force for the spin radiation into operation

$$\tilde{G}^{\mu\nu} = \frac{2}{3}\frac{e^2}{c}\Omega^{\mu\nu}_{Th} = \frac{d\tilde{\Pi}^{\mu\nu}}{d\tau}, \tag{4}$$

then Thomas's precession which until now was known as purely kinematic relativistic effect gets obvious dynamic interpretation.

3 Conclusion

The work presented here discovers new trend in the relativistic theory of radiation and the spin properties of relativistic particles.

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ПРЕЦЕССИЯ ТОМАСА И ЭЛЕКТРОМАГНИТНЫЙ УГЛОВОЙ МОМЕНТ ИЗЛУЧЕНИЯ РЕЛЯТИВИСТСКИХ ЗАРЯЖЕННЫХ ЧАСТИЦ СО СПИНОМ

Рассмотрена проблема релятивистской теории, связанная с излучением орбитального и спинового электромагнитных угловых моментов заряда. Показано, что полная мощность излучения полевого спинового углового момента электромагнитного поля пропорциональна прецессии Томаса и соответствует полевому моменту сил излучения.

Ключевые слова: *электромагнитное поле, спин, угловой момент; излучение; вращающий момент*

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