POSSIBILITY OF POLARIZING AN ELECTRON BEAM BY RELATIVISTIC RADIATION IN A MAGNETIC FIELD

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Spin flip due to radiation produced by the motion of electrons in a uniform magnetic field is considered. It is shown that an initially unpolarized beam becomes partially polarized, with the magnetic moment primarily in the direction of the field.

THE solutions corresponding to the two polarization states for a Dirac electron moving in a uniform magnetic field (cf. [1] Sec. 28; this reference contains a detailed bibliography on this problem) can be used to compute the probability of radiative quantum transitions in which the electron spin reverses direction. Assuming for simplicity that in the initial state the electron has no momentum along the field we obtain the following expression for the difference in radiation intensity, $\Delta W_{-1,1}$ (W_{-1} is the radiation intensity for the case where the magnetic moment is initially antiparallel to the field and the final position is parallel, while W_1 applies to the inverse case):

$$\Delta W_{-1,1} = W_{-1} - W_1 \approx \frac{35\sqrt{3}}{16}\frac{ce_0^2}{R^2}\left(\frac{\hbar}{m_0cR}\right)^2\left(\frac{E}{m_0c^2}\right)^8. \quad (1)$$

Here R is the radius of curvature of the electron orbit, E/m_0c^2 is the kinetic energy of the moving electron divided by its rest energy, and e_0 is the electron charge.

This formula indicates that the predominant quantum transitions will be those which leave the spin magnetic moment oriented in the direction of the magnetic field. Thus it appears that partial polarization can be realized in an electron beam that is initially unpolarized (an effect peculiar to emission).

The process in question should occur, for example, when electrons move in accelerators or storage rings. The effect should be stronger in the latter case because the particle storage time in storage rings is rather large. A macroscopic consequence of this effect is the appearance of a magnetic field in addition to that produced by the current; the additional magnetic field is proportional to the number of polarized electrons in the beam and reaches some fixed value in the course of time.

In addition, the beam polarization causes an additional spin-orbit interaction, which should cause splitting of the electron energy levels.

In conclusion we note that the result given in (1) also holds if the motion of the electron along the field is bounded by infinite potential walls.

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[1] A. A. Sokolov, Vvedenie v kvantovuyu elektrodinamiku (Introduction to Quantum Electrodynamics) Fizmatgiz, 1958.

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