Compton rotation in quantizing magnetic field

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The research is done according to the suggestion of V.G. Baryshevsky and V.V. Tikhomirov. The effect of Compton rotation of the plane of linear polarization of hard X- (soft gamma-) photons in the absence of magnetic field was predicted by V.G. Baryshevsky and V.L. Luboshitz in 1965 and at early 1970s experimentally tested on iron, where the degree of electron spin polarization didn't exceed 8% with the peak of rotation observed in hard X-region [1]. At the presence of quantizing magnetic field B the degree of electron spin polarization is expected to be close to 100%. At $\hbar\omega >> 2\mu_B B$ or $\hbar\omega << 2\mu_B B$ photon absorption at electron transitions between Landau levels can be neglected. Photon energies of 0,1–5 MeV satisfy the second case at $B \sim 10^{14} - 10^{15}$ Gs near the poles of magnetars, where almost all the electrons must be on the ground level ($n = 0$).

The Compton rotation angle of the plane of polarization of photon per unit path is proportional to the difference of Compton scattering forward amplitudes for right and left circular photon polarization [1]. If electron wave functions are distorted by magnetic fields, then one has to recalculate the results in [1]. The approach applied here was used for the calculation of resonant Compton cross section in magnetic field, though the integration was not performed ad finem [2].

Let's consider a photon moving in an almost totally spin polarized electron gas at angle θ to magnetic field strength lines. If e, n_e, p_z are electron charge, density and momentum along z-axis, respectively, ω is photon frequency, then, applying the approach [2] to the basic results in [1], one obtains the formula for Compton rotation angle of the plane of linear polarization of photon per unit path:

$$\frac{d\varphi}{dl} = \frac{\pi^2 ce^2 n_e \cos\theta(\varepsilon_0 - cp_z\cos\theta)\exp(-s)}{(\varepsilon_0 + \hbar\omega)\omega}\sum_{n=1}^{\infty}(2s)^{n-1}(t_n^{(+)} + t_n^{(-)}),$$

$$s = \frac{(\hbar\omega\sin\theta)^2}{2cBe\hbar}, \frac{1}{t_n^{(\pm)}} = \hbar\omega - \frac{2nBce}{\omega} \pm 2\varepsilon_0 - i\cdot 0, \varepsilon_0^2 = m^2c^4 + p_z^2c^2.$$

[1] V.G. Baryshevskii. Yadernaya Optika Polarizovannykh Sred (Nuclear Optics of Polarized Media); Moscow, Energoatomizdat (1995).
[2] P.I. Fomin, R.I. Kholodov; JETP, **90** Num 2, 281-286 (2000).