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ON THE ROTATION OF PLANE OF LINEAR PHOTON POLARIZATION IN THE MAGNETIZED FERROMAGNETIC

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К вопросу о вращении плоскости линейной поляризации гамма-квантов в намагниченном ферромагнетике

Исследуется энергетическая зависимость явления вращения плоскости линейной поляризации гамма-квантов при их прохождении через мишень с поляризованными электронами. В случае намагниченного до насыщения железа углы вращения плоскости поляризации при энергиях 230, 290 и 330 Кэв равны соответственно $4,12 \times 10^{-3}$ рад/см, $4,61 \times 10^{-3}$ рад/см и $4,83 \times 10^{-3}$ рад/см. Максимальное значение угла вращения, равное $5,32 \times 10^{-3}$ рад/см соответствует энергии 600 кэв. Результаты теоретических расчетов согласуются с экспериментальными данными.

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On the Rotation of Plane of Linear Photon Polatization in the Magnetized Ferromagnetic

Rotation of linear polarization plane of photon passing through a target with polarized electrons, its energy dependence in particular, has been investigated. In the magnetized saturated iron and at photon energies 230, 290 and 330 keV the angles of rotation of plane of linear photon polarization are 4.12×10^{-3} rad/cm, 4.61×10^{-3} rad/cm and 4.83×10^{-3} rad/cm, respectively, the maximum occuring at ~600 keV is 5.32×10^{-3}. Our theoretical results are in good agreement with the experimental data.

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We have just recently got to know the paper of Lobashov et al. published in "Pis'ma v ZhETF" [1]. These authors report the results of the experimental investigation of a rotation of plane of linear photon polarization in an iron scatterer at 230 and 290 keV photon energies. Analogous experiments at 230 and 330 keV are described in the paper of Bock and Luksch [2] [x]. Some years ago this rotation of plane of photon polarization in scattering by polarized electrons was investigated theoretically by Baryshevski and Lyuboshitz [3,4]. It was shown that the rotation of plane of photon polarization at the energies of the order of a few hundred keV - a few MeV was due to the contribution of the radiative corrections of the order of α^2 to the spin-dependent Compton forward scattering amplitude. Dispersion relations were used to calculate these radiative correc-

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x/ We are indebted to G.V. Frolov who kindly made us familiar with the preprint of the work[2].

tions. The right order of magnitude in agreement with the latest experiments /1,2/ of the rotation of plane of photon polarization was given.

In this note we wish to explore in details the dependence of the phenomenon considered on energy and, what seems to be of particular interest in the light of the latest experiments /1,2/, to compare our theoretical results with the experimental data.

In accordance with Eqs. (3) and (14) of reference /3/, the angle of rotation of plane of linear photon polarization, when passing the distance X through the scatterer, is given by the expression:

$$\phi = -N r_0^2 \, \psi(\kappa)(\vec{P}\vec{\ell}) X, \tag{1}$$

where $\vec{P}$ is the vector of the electron polarization, $\vec{\ell}$ is the unite vector parallel to the photon momentum,

$$\psi(\kappa) = 1 + 4\kappa^2 \left[\frac{\ln 4\kappa^2}{(1-4\kappa^2)^2} + \frac{1}{1-4\kappa^2} \right] + P \int_0^\infty \frac{2y - (1+y)\ln(1+2y)}{y(y^2-\kappa^2)} dy \tag{2}$$

N is the number of electrons per 1 cm^3, $r_0 = e^2/m_e c^2$ is the electromagnetic radius of an electron, $\kappa = E_\gamma / m_e c^2$, E_γ is the energy of the photon in the laboratory frame of reference x/.

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x/ The typographical errors which occur in Eq.(14) for $\psi(\kappa)$ in /4/ are absent however in the earlier publication /3/.

Positive values of δ correspond to the right-hand screw rotation photon polarization (clockwise, looking along the photon momentum).

Making use of the equality $P\int_0^\infty \frac{dy}{y^2-\kappa^2}=0$ Eq.(2) can be rewritten as

$$\psi(\kappa)=\frac{1}{1-4\kappa^2}-\frac{4\kappa^2\ln 4\kappa^2}{(1-4\kappa^2)^2}+\int_0^\infty\left[\frac{(1+\kappa)\ln(1+2\kappa)}{\kappa}-\frac{(1+y)\ln(1+2y)}{y}\right]\frac{dy}{y^2-\kappa^2} \qquad (3)$$

The numerical results of the function $\psi(\kappa)$ according to (3) for the κ range 0.1 ÷ 4 (E_γ ~ 50 - 2000keV) are presented in the Table:

κ	$-\psi(\kappa)$	κ	$-\psi(\kappa)$	κ	$-\psi(\kappa)$	κ	$-\psi(\kappa)$
0.1	0.075	1.1	0.395	2.1	0.365	3.1	0.319
0.2	0.164	1.2	0.395	2.2	0.360	3.2	0.315
0.3	0.234	1.3	0.394	2.3	0.356	3.3	0.311
0.4	0.285	1.4	0.392	2.4	0.351	3.4	0.307
0.5	0.322	1.5	0.390	2.5	0.346	3.5	0.303
0.6	0.349	1.6	0.386	2.6	0.341	3.6	0.299
0.7	0.367	1.7	0.383	2.7	0.337	3.7	0.295
0.8	0.380	1.8	0.378	2.8	0.332	3.8	0.291
0.9	0.388	1.9	0.374	2.9	0.328	3.9	0.287
1.0	0.392	2.0	0.370	3.0	0.323	4.0	0.284

It should be noted that the rotation of plane of linear photon polarization is characterized by a broad maximum in the energy range 500-700 keV ($\max |\psi(\kappa)| = |\psi(1.18)| = 0.3953$). It is interesting that in the region of the maximal values of the angle of rotation the spin-dependent part of the total cross-section of the Compton scattering is close to zero.

With a further photon energy increasing the absolute value of the rotational angle begins to decrease gradually. In particular, $\psi(5) = -0.252$, $\psi(10) = -0.161$, $\psi(100) = -0.023$. It is easy to show that as $\kappa \to \infty$ the simple asymptotic formula holds:

$$\psi(\kappa) = -P \int_0^\infty \frac{\ln y \, dy}{y^2 - \kappa^2} \simeq -\frac{\pi^2}{4\kappa} \qquad (4)^{x/}$$

It should be emphasized that the calculations result in the negative values of the function $\psi(\kappa)$. This means that in the case when the directions of the spins of electrons in ferromagnetic are parallel to the photon momentum (the magnetic induction is in the opposite direction with respect to the photon momentum), the right-hand screw rotation of plane of linear polarization should take

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x/ At energies $E_\gamma \gtrsim 1$ GeV the terms of the order of α^3 which are not taken into account here, make a main contribution to the magnitude of the angle ψ.

place. This conclusion is in agreement with the experimental results [2] at the energies 230 and 330 keV. We regret that in the works [3,4], due to the misunderstanding, the wrong sign of the function $\psi(\kappa)$ and consequently the wrong direction of the rotation of plane of polarization is given.

For the magnetized saturated iron the degree of the electron polarization $|\vec{P}| = 7.85 \times 10^{-2}$. Assuming that the density of iron equals 7.87 g/cm^3 and its atomic weight is 55.85 one can get the following formula for the angle of rotation of plane of linear polarization per 1 cm in the case when the spins of electrons are parallel to the photon momentum:

$$\phi_0 = -13.48 \times 10^{-3} \ \psi(\kappa) \ \text{rad/cm} . \qquad (5)$$

For the energies 230, 290 and 330 keV the theoretical values are equal to $+ 4.12 \times 10^{-3}$ rad/cm, $+4.61 \times 10^{-3}$ rad/cm and $+ 4.83 \times 10^{-3}$ rad/cm, respectively. The experimental [1] values of $|\phi_0|$ for 230 and 290 keV are $(4.25 \pm 0.16) \times 10^{-3}$ rad/cm and $(4.7 \pm 0.3) \times 10^{-3}$ rad/cm, respectively. In the reference [2] for the energies 230 and 330 keV the following experimental values of ϕ_0 are given: $+ (3.2 \pm 0.3) \times 10^{-3}$ rad/cm and $+ (4.7 \pm 0.3) \times$ $\times 10^{-3}$rad/cm.

Note that within the limit of errors there exists the agreement of theoretical values with the experimental data of Lobashov et al. /1/ and with the result of Bock and Luksch at 330 keV /2/. The maximal value of the angle ϕ_0 for the magnetized saturated iron according to (5) reaches 5.32×10^{-3} rad/cm.

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