turbulent friction force decrease by a factor m_i/m_e compared with formulas (4) and (7) so that $\nu_{turb} \sim (m_e/m_i)^2\omega_{pe}$. In this case, however, it is necessary, when $u \sim v_s$, to take into account the formation of a "plateau" on the distribution function [9].

In a moderately magnetized plasma ($\omega_{pe} \sim \omega_{He}$), ν_{turb} should lie in the range $(m_e/m_i)^2\omega_{pe} < \nu_{turb} < (m_e/m_i)\omega_{pe}$. The effective collision frequency ν_{exp} calculated from measurements of the conductivity for the data on the T-3 "Tokamak" [6] and the C-stellarator [5] lie within this range.

We are grateful to B. B. Kadomtsev and S. V. Peletminskii for a discussion of the work and valuable advice.

[1] B. B. Kadomtsev, In: Voprosy teoriii plazmy (Problems of Plasma Theory), No. 4, Atomizdat, 1964, p. 188.
[2] V. P. Tsytovich, Nelineinye effekty v plazme (Nonlinear Effects in Plasma), Nauka, 1967.
[3] R. Z. Sagdeev and A. A. Galeev, Lectures on Nonlinear Theory of Plasma, Trieste, September, 1966.
[4] P. Ya. Burchenko et al., Third Conf. on Plasma and Controlled Thermonuclear Reactions, Novosibirsk, 1-7 August 1968, Paper CN-24/D-6.
[5] I. G. Brown et al., ibid. Paper CN-24/D-3.
[6] L. A. Artsimovich et al., ibid. Paper CN-24/D-1.
[7] L. I. Rudakov and L. V. Korablev, Zh. Eksp. Teor. Fiz. 50, 220 (1966) [Sov. Phys.-JETP 23, 145 (1966)].
[8] V. A. Suprunenko, E. A. Sukhomlin, E. D. Volkov, and N. I. Rudnev, Zh. Tekh. Fiz. 31, 1057 (1961) [Sov. Phys.-Tech. Phys. 6, 771 (1962)].
[9] B. B. Kadomtsev and O. P. Pogutse, Zh. Eksp. Teor. Fiz. 53, 2025 (1967) [Sov. Phys.-JETP 26, 1146 (1968)].
[10] B. A. Demidov, N. I. Elagin, and S. D. Fanchenko, Dokl. Akad. Nauk SSSR 174, 327 (1967) [Sov. Phys.-Dokl. 12, 467 (1967)].
[11] V. G. Bar'yakhtar, S. V. Peletminskii, and A. A. Yatsenko, K teorii neravnovesnykh protsessov v statisticheskoi mekhanike (Contribution to the Theory of Nonequilibrium Processes in Statistical Mechanics) II, ITF-68-4, Kiev, 1968.

FEATURES OF PHOTON ECHO IN A GAS IN THE PRESENCE OF A MAGNETIC FIELD

A. I. Alekseev
Moscow Engineering Physics Institute
Submitted 6 February 1969
ZhETF Pis. Red. 9, No. 8, 472-475 (20 April 1969)

In both solids [1, 2] and gases [3], photon echo is customarily used to determine the relaxation time from the damping of the photon echo amplitude. Yet an investigation of the polarization effects of the photon echo can yield additional information concerning the physical processes in a medium. These polarization effects are particularly clearly pronounced in the presence of a magnetic field.

Let us consider photon echo in a gas situated in an external magnetic field $\vec{H}$. For concreteness, we confine ourselves to the quantum mechanical transition $J_2 = 1 \rightarrow J_1 = 0$ of a molecule with total angular momenta 1 and 0 of the upper and lower levels respectively. The passage of two successive light pulses and the formation of the photon echo are described by the well known Maxwell's equations and the quantum-mechanical density matrix. The final solution of the problem reduces to the following. During the time of passage of the short pulse, the influence of $\vec{H}$ can be neglected. The first light pulse polarizes the medium, directing the polarization current $\vec{j}(\vec{v})$ along the vector of the electric field intensity of this pulse. Owing to the Doppler dephasing, the average polarization current $\int \vec{j}(\vec{v})d\vec{v}$ vanishes in the course of time as a result of the reversible relaxation. However, the polarization current density $\vec{j}(\vec{v})$ of a group of molecules moving with velocity $\vec{v}$ does not vanish and retains the direction set by the transmitted pulse. After the passage of the first pulse, the interaction with the external magnetic field causes the polarization current $\vec{j}(\vec{v})$ to precess around $\vec{H}$ at a frequency $\Omega = g\mu_0 H/\hbar$, where μ_0 is the Bohr magneton and g is the hyromagnetic ratio. The rotation is clockwise when viewed in the direction of $\vec{H}$. Let the first and second transmitted pulses propagate along $\vec{H}$, and let their polarization vectors make an angle ψ. Then the amplitude of the photon echo is proportional to $\cos(\Omega\tau - \psi)$, where τ is the time between the transmitted pulses and the angle ψ is reckoned clockwise from the polarization vector of the first pulse. The pulses durations are small compared with τ. The photon-echo polarization vector will turn through an angle $\phi = \Omega\tau$ clockwise relative to the polarization vector of the second pulse. A field intensity H on the order of 1 Oe is required in order for the angle of rotation to be on the order of unity at typical values of the experimental parameters ($\tau \sim 10^{-7}$ sec). In the absence of $\vec{H}$, the photon-echo has the same polarization as the second pulse, in agreement with experiment [3]. The result is the same for the quantum-mechanical transition $J_2 = 0 \rightarrow J_1 = 1$.

The picture becomes much more complicated if both working energy levels are degenerate. However, the rotation of the photon-echo polarization in a gaseous medium situated in a magnetic field will always occur, provided the working energy levels of the active molecules are characterized by the total angular momentum. It must be emphasized that the obtained effect differs from the usual Faraday rotation, and also from the rotation of the polarization in optically active media. The angle of rotation of the latter is proportional to the path covered by the light. The rotation of the photon-echo polarization is due to the precession of the polarization current of the medium around $\vec{H}$ after the passage of the light pulses. This rotation is therefore independent of the linear dimensions of the gas medium, and is determined only by the values of τ and $\vec{H}$.

We present also the results of an investigation of the photon-echo in the quantum-mechanical transition $J_2 = 1/2 \rightarrow J_1 = 1/2$. This transition differs from all others in that it leads to a decomposition of the linearly polarized pulse into right- and left-polarized circular waves that propagate independently along $\vec{H}$. The photon-echo amplitude is independent of the angle ψ in this case, and the angle of rotation of the photon-echo polarization relative to the polarization vector of the primary momentum equals $2\psi + (g_1 + g_2)\mu_0 H\tau/\hbar \equiv 2\psi + \phi$. Here g_1 and g_2 are the gyromagnetic ratios of the lower and upper working levels, respectively, and the remaining quantities were defined above.

We noted features of the photon-echo in a gas in the presence of a magnetic field are quite significant from at least two points of view. The rotation of the polarization of the photon-echo makes it relatively easy to separate the photon-echo from the transmitted signals, which usually entails great difficulties because of the small value of τ and the equal polarizations of the photon-echo and one of the transmitted pulses. Finally, it is possible to determine the gyromagnetic ratios of the excited levels from the photon-echo rotation angle.

As is well known [4], an experimental determination of the gyromagnetic ratio by other methods is sometimes very difficult or impossible at all.

The angle ϕ_F of the rotation of the polarization of the electromagnetic wave on the path z as a result of the Faraday rotation in the gas equals, in order of magnitude, $\phi_F = N\lambda\!\!\!^{-2}\Omega\gamma T_0{}^2 z$, where N and $1/\gamma$ are the density and the radiative lifetime of the active atoms, $1/T_0$ is the Doppler width of the level, and $\lambda\!\!\!^{-}$ is the wavelength. For the parameters of the experiment of [3] we have $\phi_F \ll \phi$. In the general case it is necessary to add the contribution due to the Faraday rotation to the photon-echo polarization rotation angle ϕ obtained above.

As the result of the Faraday rotation, the polarizations of the transmitted light pulses and of the photon-echo will turn through the same angle ϕ_F, whereas the total angle of rotation of the photon-echo will equal the sum $\phi + \phi_F$. Therefore the separate contributions of each of the foregoing rotations can be easily determined experimentally.

The author is grateful to V. M. Galitskii for a discussion.

[1] N. A. Kurnit, I. D. Abella, and S. R. Hartmann, Phys. Rev. Lett. 13, 567 (1964).
[2] I. D. Abella, N. A. Kurnit, and S. R. Hartmann, Phys. Rev. 141, 391 (1966).
[4] C. K. N. Patel and R. E. Slusher, Phys. Rev. Lett. 20, 1087 (1968).
[5] M. Sargent, W. E. Lamb, and R. L. Fork, Phys. Rev. 164, 436 (1967).

MAGNETIC-COULOMB LEVELS NEAR THE SADDLE POINTS

E. I. Rashba and V. M. Edel'shtein
L. D. Landau Institute of Theoretical Physics, USSR Academy of Sciences
Submitted 20 February 1969
ZhETF Pis. Red. 9, No. 8, 475-480 (20 April 1969)

The hypothesis that metastable Coulomb levels arise near the critical energy saddle points $E(\vec{k})$ was advanced [1] in connection with the interpretation of the structure of the intrinsic-absorption spectra of a number of crystals. Its theoretical justification, however, encounters serious difficulties [2, 3], and the very occurrence of such resonances on the absorption curve can be proved apparently only under special assumptions (for example, at a large mass ratio [3] or for deep levels as a result of the finite volume of the Brillouin zone [4]).

We show below that electron Coulomb levels electrons should arise in strong magnetic fields near all the critical points (in an attractive field for the minima and type-M_2 crests, and in a repulsive field), for M_1 crests and maxima we determine the angular dependence of the parameters of the resultant states.

Assume that in the original rectangular coordinates (x, y, z) the effective masses are $m_x = m_y = m_\perp$ and $m_z = m_\parallel$, with the signs of $m_\perp$ and $m_\parallel$ arbitrary, that the magnetic field $\vec{H}$ is given by $H_x = 0$ and $H_y/H_z = \tan\theta$, and that the vector potential is $\vec{A} = (1/2)\vec{H} \times \vec{r}$. Then, in the oblique system (ξ, η, ζ) in which the ζ axis is chosen along $\vec{H}$ and the same scale is retained (the Jacobian of the conversion is equal to unity), we have

$$\xi = \left|\frac{m_\perp}{M_\perp}\right|^{1/2} x, \quad \eta = \left|\frac{M_\perp}{m_\perp}\right|^{1/2} (\cos\theta\, y - \sin\theta\, z),$$