CONTRIBUTION TO THE QUANTUM THEORY OF STIMULATED EMISSION OF ELECTRONS IN CROSSED FIELDS

A. A. Sokolov and Yu. G. Pavlenko
Physics Department, Moscow State University
Submitted 16 September 1965
JETP Pis'ma 2, 449-451 (1 November, 1965)

Schneider [1] has found theoretically, in the calculation of relativistic corrections, that stimulated emission of an electron moving in a magnetic field, i.e., maser action, is feasible. We will show that if an electrostatic field is superimposed on the magnetic one, this effect is intensified and has a nonrelativistic character.

Let us consider quantum-theoretically the stimulated emission of a nonrelativistic electron in a magnetic field $\vec{H}$ (constant, uniform, and directed along the z axis) in an electrostatic field with potential energy

$$V = -1/2a\, e_0^2\, r^2 , \tag{1}$$

where $r^2 = x^2 + y^2$, $e = -e_0$ is the electron charge, and a is some constant coefficient with dimension cm^{-3} ($0 < a < H^2/4m_0c^2$). Similar fields were used in theoretical analysis of the magnetron [2].

It follows from Schrodinger's equation that the energy spectrum should be discrete, and is determined, in the absence of momentum along the field ($p_z = 0$) by the expression:

$$E_{n\ell} = \frac{1}{2}\hbar\, [\Omega\ell + \Omega_1(n + 1)]. \tag{2}$$

Here

$$\Omega = e_0\, H/m_0\, c\ , \qquad \Omega\ = \Omega_1\left(1 - \frac{4a\ m_0\ c^2}{H^2}\right)^{1/2}, \tag{3}$$

and the numbers s = 0, 1, 2, 3, ...; $\ell = -\infty, \ldots, 0, 1, 2, \ldots$; $n = 2s + |\ell|$ will be called the proper radial, orbital, and principal quantum numbers. The eigenfunctions, on the other hand, will be expressed in terms of Laguerre polynomials.

Then, when the electron interacts with an unpolarized electromagnetic wave (frequency ω, electric field intensity in the electromagnetic wave $\vec{E}$) propagating at an angle θ to the z axis, stimulated emission and absorption of the following two frequencies is possible:

$$\omega_H = \frac{1}{2}(\Omega + \Omega_1), \qquad \omega_E = \frac{1}{2}(\Omega - \Omega_1). \tag{4}$$

The stimulated emission can predominate over absorption only at the frequency ω_E. The corresponding total radiation power per electron is:

$$\mathscr{P} = \frac{e_0^2\ \omega_E^2\ E^2}{4\tau\ m_0\ \Omega_1\ \omega}\ \frac{1 + \cos^2\theta}{(\omega - \omega_E)^2 + 1/4\tau^2} \tag{5}$$

where τ is the lifetime of the electron in the initial state. Unlike Schneider's case, this stimulated emission reaches a maximum in the region of sharp resonance ($\omega \sim \omega_E$).

Taking into account the fact that a maser with magnetic field of the order of 10^3 Oe has already been constructed [3], the superposition of an electrostatic field (1), reaching an order of 10^4 V at r = 1, should result in a more intense source, emitting electromagnetic waves with wavelength on the order of 10 cm.

We note that in the relativistic (and especially the ultrarelativistic) case, as in the case of the "radiating" electron (see [4]), we can use higher multipoles, i.e., start operating with shorter wavelengths.

[1] J. Schneider, Phys. Rev. Lett. 2, 504 (1959).

[2] P. L. Kapitza, UFN 78, 181 (1962), Soviet Phys. Uspekhi 5, 777 (1963).

[3] J. L. Hirshfield and J. M. Wachtel, Phys. Rev. Lett. 12, 533 (1964).

[4] A. A. Sokolov and I. M. Ternov, JETP 25, 698 (1953).

CORRELATION OF INTERNAL-CONVERSION ELECTRON POLARIZATION

V. F. Boldyshev

Submitted 17 September 1965

JETP Pis'ma 2, 451-454 (1 November, 1965)

The polarization state of internal-conversion electrons emitted in nuclear cascade transitions is determined by a correlation function $W(\vec{\nu}_1, \vec{\nu}_2, \vec{\zeta})$ which depends on the rest-frame directions of the first and second emitted particles $\vec{\nu}_1$ and $\vec{\nu}_2$ and of the polarization vector $\vec{\zeta}$. The calculation of such a correlation function with exact account of the Coulomb field of the nucleus is a rather complicated problem. There are at present no tables of "particle parameters" determining the correlation of the polarizations, and the existing [1] general formulas do not make it easy to obtain numerical values of these parameters. The need for numerically integrating radial integrals and the nontrivial kinematics of the rotation-group representations makes the calculation quite laborious.

However, by using the Furry-Sommerfeld-Maue approximation (cf. the bibliography in [2]), we can obtain for the polarization-dependent particle parameters, by relatively simple means, formulas that can be readily reduced to numerical form.

In this paper we present the results of calculations in this approximation.

If the correlation function of the directions of the double cascade "pure multipole γ transition - mixed 2^L magnetic + 2^{L+1} electric conversion transition on the K shell" is written in the form

$$W_{\gamma-e}(\vec{\nu}_\gamma, \vec{\nu}_e) = W^{I}(\vec{\nu}_\gamma, \vec{\nu}_e) + \delta W^{II}(\vec{\nu}_\gamma, \vec{\nu}_e) + \delta^2 W^{III}(\vec{\nu}_\gamma, \vec{\nu}_e), \qquad (1)$$

$$W^{J}(\vec{\nu}_\gamma, \vec{\nu}_e) = \sum_S B_S^J P_S(\cos\theta), \quad \cos\theta = (\vec{\nu}_\gamma, \vec{\nu}_e), \quad J = I, II, III, \qquad (2)$$

where δ is the ratio of the mixture in the mixed transition and $\vec{\nu}_\gamma$ and $\vec{\nu}_e$ are the photon and