RESONANT PHOTOPRODUCTION OF e^+e^--PAIR WITH PHOTON EMISSION IN STRONG MAGNETIC FIELD

P.I.Fomin[1,2] and R.I.Kholodov[2]

[1]N.N. Bogolyubov Institute for Theoretical Physics, NAS of Ukraine, Kiev;
[2]Institute of Applied Physics, NAS of Ukraine, Sumy;
e-mail: pfomin@bitp.kiev.ua

The quantum-electrodynamic process of electron-positron pair production by a photon is considered in a strong external magnetic field. The process is accompanied by emission of the final photon. Kinematics and resonance conditions are found in ultraquantum approximation, namely the approximation of the strong magnetic field and low-excited states of an electron and a positron. The resonance conditions are realized, if the energy of the final photon equals to the distance between the Landau levels of an electron. A probability of the resonance electron-positron pair production with photon emission is found in the form of the Breit-Wigner cross section. This value is comparable with the probability of e^+e^- pair production without photon emission.

PACS: 42.25-Ja; 41.60-Ap

1. INTRODUCTION

The simplest quantum-electrodynamic process of radiation of a photon by an electron (cyclotron radiation) was performed in the middle of the last century by Klepikov and Demeur [1]. This process in the field of more complicated configuration (magnetic field plus a plane wave along the field) was studied by Oleynik, as well as Rodionov and Ternov [2]. In 1998 there was investigated an electron-positron pair production by two photons in a magnetic field [3].

It should be noted that similar quantum electrodynamic processes can be accompanied by emitting of the additional final photon. The emitting photon, of course, adds an additional power of the fine structure constant, that in common case decreases a probability of the process. However, there exists a possibility of a resonant increase of probability.

This work is devoted to the study of such a situation, namely we study the process of an electron-positron pair production by a photon with photon emission in an external magnetic field. This work is a continuation of work [4] in which the kinematics of the process was investigational and the threshold values of energies and momenta of particles were found. Traditionally we use here the relativistic system of units: $\hbar = 1, c = 1$. The process kinematics in [4] was obtained from the analyses of the expressions for conservation laws of energy and momentum. In the external magnetic field a total momentum of a particle is not saved. However the conservation law for a component of momentum which is the longitudinal to magnetic field is executed in this case.

$$\omega = \omega + \varepsilon + \varepsilon^+, \qquad k_z = k_z + p + p^+, \tag{1}$$

where

$$\varepsilon = \sqrt{m^2 + 2l^- hm^2 + p_z^2},$$

$$\varepsilon^+ = \sqrt{m^2 + 2l^+ hm^2 + (p_z^+)^2}$$

$\overline{l}$, $\overset{+}{l}$ are Landau levels of electron and positron.

From Eq. (1) in paper [4] the following expressions for energies and momenta of an electron and a positron were obtained:

$$\varepsilon_{1,2} = \frac{a \pm b\cdot\beta}{2W(1-\beta^2)}, p_{1,2} = \frac{a\cdot\beta \pm b}{2W(1-\beta^2)};$$

$$\varepsilon_{1,2}^+ = \frac{a^+ \mp b\cdot\beta}{2W(1-\beta^2)}, \quad p_{1,2}^+ = \frac{a^+\cdot\beta \mp b}{2W(1-\beta^2)}, \tag{2}$$

where $a = W^2(1-\beta^2) + \tilde{m}^2 - m^{*2}$;

$$a^+ = W^2(1-\beta^2) - \tilde{m}^2 + m^{*2};$$

$$\tilde{m} = m\sqrt{1+2l^- h}, \quad m^* = m\sqrt{1+2l^+ h};$$

$$b^2 = a^2 - 4\tilde{m}^2 W^2(1-\beta^2);$$

$$W \equiv \omega - \omega', \quad \beta = \frac{k_z - k'_z}{\omega - \omega'}.$$

The process of pair production by a photon can take place, if the energy of a photon exceeds some threshold value. The energies and momenta of particles have the following thresholds values:

$$\varepsilon_m = \frac{\tilde{m}}{\sqrt{1-\beta^2}} = \frac{\tilde{m}}{\tilde{m}+m^*}W, \; p_m = \beta\cdot\varepsilon_m;$$

$$\varepsilon_m^+ = \frac{m^*}{\sqrt{1-\beta^2}} = \frac{m^*}{\tilde{m}+m^*}W, \qquad p_m^+ = \beta\cdot\varepsilon_m^+, \tag{3}$$

The final photon is radiated with frequency in the interval $0 \le \omega' \le \omega - (\tilde{m} + m^*)$, ($\beta = 0$), besides the angle of radiation of a photon θ' for arbitrary initial photon angle θ is limited by an interval between the limit values, that have the form:

$$u = \cos\theta', \quad v = \cos\theta;$$

$$u_{\min} = \frac{\omega\, v}{\omega'} - \frac{1}{\omega'}\sqrt{W^2 - (\tilde{m}+m^*)^2};$$

$$u_{\max} = \frac{\omega\, v}{\omega'} + \frac{1}{\omega'}\sqrt{W^2 - (\tilde{m} + m^*)^2}\ . \qquad (4)$$

In a common case a final photon is radiated under the angle for which $\cos\theta'$ is in the following interval $u_{\min} \le u \le u_{\max}$, *e.* $u_{\min} > -1$, $u_{\max} < 1$. In the examined process the momentum of the electron also depends on the direction of the photon movement. Such dependence is represented in Fig. 1.

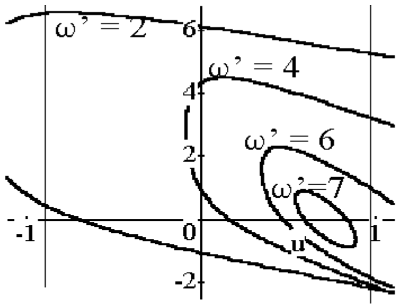

Fig. 1. *Dependence of electron momentum on the direction of the photon movement for different frequencies of the final photon. For h = 0.3,* $\bar{l} = 2$, $l^{+} = 1$, $\omega = 10$, $v = 0.5$

The left and right edges of these curves correspond to the threshold values.

2. AMPLITUDE OF THE PROCESS

The wave function of electron has the form [4-6]:

$$\Psi^- = \frac{1}{\sqrt{S}} e^{-i(\varepsilon\, t - p_y \cdot y - p \cdot z)}\ \Psi^-(\zeta)\,; \qquad (5)$$

$$\zeta = \sqrt{hm}(x + p_y / hm^2)\,, \quad h = H / H_0 = eH / m^2\,,$$

where $\Psi^-(\zeta)$ is bispinor, which is expressed through Hermits functions $U(\zeta)$.

$$\bar{\Psi}^-(\zeta_1) = N^- \bar{u}^- (-i\sqrt{\tilde{m} - \mu^- m} U_{l^-}(\zeta_1)$$
$$+\ \mu^- \sqrt{\tilde{m} + \mu^- m} U_{l^- -1}(\zeta_1)\gamma^1).$$

The wave function of photon has a standard form

$$\hat{A}(\mathbf{x}) = \frac{\sqrt{4\pi}\, e_\mu \gamma^\mu}{\sqrt{2\omega V}} e^{-i(kr) + ik_x x} \qquad (6)$$

The Green function of electron describes an intermediate state and has the following form:

$$G_H(g;\rho_1,\rho_2) = \sqrt{hm} \sum_{n_g=0}^{\infty} \frac{1}{g_0^2 - (m^2 + 2n_g hm^2 + p_g^2)} \qquad (7)$$
$$[U_{n_g}(\rho_1)\, U_{n_g}(\rho_2)(\gamma g + m)\alpha\ +$$
$$U_{n_g-1}(\rho_1)\, U_{n_g-1}(\rho_2)(\gamma g + m)\beta\ +$$
$$+i\sqrt{2n_g hm} U_{n_g-1}(\rho_1)\, U_{n_g}(\rho_2)\gamma^1\alpha\ -$$
$$-i\sqrt{2n_g hm} U_{n_g}(\rho_1)\, U_{n_g-1}(\rho_2)\alpha\gamma^1],$$

where α, β are the projection matrices, $\alpha = (1 + i\gamma^2\gamma^1)/2$, $\beta = 1 - \alpha$ and g is the 4-momentum of the intermediate state, $g = (g_0, 0, g_y, g_z)$, $\gamma g = \gamma^0 g_0 - \gamma^3 g_z$.

The amplitude of the process is constructed from the functions of particles and the Green function of the intermediate state by common rules of QED in the Furry representation and has the form [5,6]:

$$S_{if} = \frac{-ie^2 (2\pi)^4 e_\mu e'^*_\nu \delta^3\left(k - k' - p^+ - p^-\right)}{VS\sqrt{\omega\omega'}}$$
$$\times \int dx_1 dx_2 \bar{\psi}^-(\zeta_1),$$
$$[e^{ik_x x_2 - ik'_x x_1}\gamma^\nu G_H(g;\rho_1,\rho_2)\gamma^\mu$$
$$+e^{ik_x x_1 - ik'_x x_2}\gamma^\mu G_H(-f;\eta_1,\eta_2)\gamma^\nu]\psi^+(\xi_2), \qquad (8)$$

where

$$\xi = \sqrt{hm}x - \frac{p_y^+}{\sqrt{hm}}\,; \quad \rho = \sqrt{hm}x + \frac{g_y}{\sqrt{hm}}\,;$$

$$\eta = \sqrt{hm}x - \frac{f_y}{\sqrt{hm}}\ .$$

The function (5) has the form of a flat wave in relation to three variables, namely t, y, z, therefore, amplitude of the process (8) contains three Dirac delta functions, which correspond to the laws of conservation. Such an amplitude corresponds to the following Feynman diagrams.

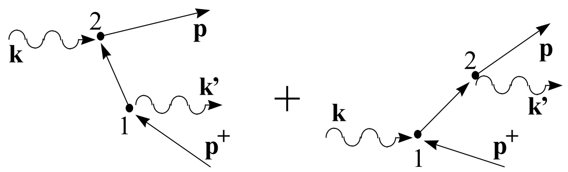

Fig. 2. *Feynman diagrams for the process of electron-positron pair photoproduction with emission of a photon*

In Fig. 2 wavy lines are photons, and the continuous lines correspond to electrons (positrons) with 4-momenta $\mathbf{p} = (\varepsilon, 0, 0, p)$, $\mathbf{p}^+ = (\varepsilon^+, 0, 0, p^+)$ respectively.

Solutions of Dirac equation in magnetic field form in amplitude (8) special functions which are known from papers [1,7]:

$$J_2(l^-, n_g) \equiv \sqrt{hm}\int dx \cdot e^{-ik'_x x} U_{l^-}(\zeta) U_{n_g}(\rho)\,;$$
$$J_1^*(l^+, n_g) \equiv \sqrt{hm}\int dx \cdot e^{ik_x x} U_{l^+}(\xi) U_{n_g}(\rho)\,. \qquad (9)$$

These integrals can be expressed through hypergeometrical functions:

$$J_2(l,n) = j_2(l,n)$$
$$\times \exp\left(i\frac{k'_x(2g_y - k'_y)}{2hm^2} + i(n-l)(\varphi' - \pi/2)\right);$$

$$j_2(l,n)=e^{-\eta'/2}\eta'^{\frac{n-l}{2}}\sqrt{\frac{n!}{l!}}\frac{1}{(n-l)!}F(-l,n-l+1,\eta')\ ,(10)$$

where

$$\eta=k_\perp^2/2hm^2,\ \eta'=k'^2_\perp/2hm^2,$$

and

$$F(-n,c,x)=1+\frac{-n}{c}x+\frac{-n(1-n)}{2!c(c+1)}x^2...$$

Note, that the energy of an electron is characterized by an integer number which is called the number of Landau level. The case of large values of this number corresponds to quasiclassical movement of an electron. This is known as a movement on a spiral. But we examine the opposite case of the strong magnetic field and the lowest Landau levels. Such an approximation is called ultraquantum approximation or the lowest Landau level (LLL) approximation [8,9]. In this approximation the magnetic field achieves a big value of an order of magnitude of about 10^{12} Gs and higher. Nevertheless we consider a magnetic field less than critical one $H_0=m^2/e\sim 4\times10^{13}$ Gs, so that the value of a field per unit of H_0 is a small parameter of the problem $h=H/H_0$. Thus, in LLL approximation the following conditions are performed:

$$lh<<1,\quad l-\text{small}\ . \tag{11}$$

In this approximation the frequencies of photons and momenta of a particle have the form:

$$\omega=\omega_m+\Delta\omega=(\tilde{m}+m^*+\omega')+d\ hm\ , \tag{12}$$

and

$$\omega'=\kappa\ hm,\ p_z^-=-p_z^+=\pm p,\ p=\sqrt{dhm}\ , \tag{13}$$

where d, k are numbers of order of a unit. Variables η, η' of the special functions (10) have the following form

$$\eta=\frac{\omega^2\sin^2\theta}{2hm}=\frac{2}{h}>>1;$$

$$\eta'=\frac{\omega'^2\sin^2\theta'}{2hm}=\frac{1}{2}\kappa\ h\sin^2\theta'<<1\ . \tag{14}$$

For such values of η, η' hypergeometrical functions are considerably simplified:

$$F(-l,n-l-1,\eta)=(-)^l\frac{(n-l)!}{l!}\eta^l\ ;$$

$$F(-l,n-l-1,\eta')=1\ .$$

It gives us a simple expression for the special functions:

$$j_1(l^+,n_g)\equiv j_g\ ,\ j_2(l^-,n_g-1)\equiv G_g/\sqrt{l^-}; \tag{15}$$

$$j_g^2=\frac{\eta^{l^++n_g}}{l^+!n_g!}e^{-\eta}\ ;$$

$$G_g^2=\eta'^{n_g-l^--1}\frac{(n_g-1)!}{(l^--1)!}\frac{1}{(n_g-l^--1)!^2}\ .$$

The most interesting case in kinematics of the process is the case of resonances. It takes place when the denominator of Green function (7) tends to zero. In this case the intermediate state goes to the mass surface and is a real particle. Physically resonance takes place when the energy of the final photon is equal to the distance between the Landau levels of an electron.

To avoid divergency in resonance it is necessary to use Breit rule

$$\varepsilon_g\to\varepsilon_g-i\Gamma_g/2\ ,\ \varepsilon_f\to\varepsilon_f-i\Gamma_f/2\ , \tag{16}$$

where Γ_g, Γ_f are widths of resonances in the first and the second diagrams (fig. 2) that are the total probabilities of decay of intermediate states, i.e., the probability of a single photon emission. Then the denominator can be written as following:

$$\begin{aligned}&g_0^2-\varepsilon_g^2\to 2m(g_0-\varepsilon_g+i\Gamma_g/2)\\&=2m(\omega'-\omega_{res}+i\Gamma_g/2).\end{aligned} \tag{17}$$

As a result the amplitude of probability in LLL approximation near-by resonance can be resulted to the form:

$$\begin{aligned}S_{if}&=\frac{ie^2(2\pi)^4\delta^3(k-k'-p^--p^+)}{2VS\sqrt{m\omega'}}\sqrt{h}e_zR\cdot\\&\times\left(\frac{-e^{i\Phi_g}\Pi'^+}{\omega'-\omega_r+i\dfrac{\Gamma_g}{2}}+\frac{e^{i\Phi_f}\Pi'^-}{\omega'-\omega_r+i\dfrac{\Gamma_f}{2}}\right),\end{aligned} \tag{18}$$

where

$$R=\sqrt{\frac{n_g}{l^-}}G_gj_g=\sqrt{\frac{n_f}{l^+}}G_fj_f$$

$$\Pi'^\pm=\cos\theta'\cos a'\pm i\sin a'e^{-ib'}\ ,$$

a', b' are the parameters which characterize polarization of the final photon. Φ_g, Φ_f are the phases of Feynman diagrams:

$$\Phi_g=\frac{g_y(k'_x-k_x)}{hm^2}+\frac{\pi}{2}(l^--l^+)+\varphi'(n_g-l^-)-\varphi(n_g-l^+)\ ,$$

$$\Phi_f=-\frac{p_yk_x+p_y^+k'_y}{hm^2}+\frac{\pi}{2}(l^--l^+)+\varphi'(l^+-n_f)-\varphi(l^--n_f)$$

It is more convenient for description of photons polarizations to pass to the Stock's parameters ξ_i, ξ'_i:

$$e_z^2=(1+\xi_3)/2\ ,$$

$$|\Pi'^\pm|^2=(1+\cos^2\theta')/2-\xi'_3\sin^2\theta'/2\pm\xi'_2\cos\theta'\ . \tag{19}$$

Thus, the amplitude (18) is obtained with arbitrary values of polarizations of photons and projections of the electron spin that enables to execute the analysis of polarization effects in the process.

3. PROBABILITY OF THE PROCESS

Probability can be obtained from the amplitude using standard rules. It is needed to calculate the number of the final states and to multiply by the square of amplitude.

The wave functions of the electron and the photon have normalized constants L_x, L_y, L_z:

$$\Psi \sim \frac{1}{\sqrt{S}} = \frac{1}{\sqrt{L_y L_z}}, A \sim \frac{1}{\sqrt{V}} = \frac{1}{\sqrt{L_x L_y L_z}} . \tag{20}$$

These values come into amplitude and probability of a unity state too:

$$A_{if} = M \frac{1}{SV} \delta^3, \; W_{if} 1 = |M|^2 \frac{1}{S^2 V^2} \cdot \frac{\delta^3 TS}{(2\pi)^3} , \tag{21}$$

where δ^3 are three Dirac delta functions in Eq. (18). The number of the final states is

$$dN = \frac{Sd^2 p \cdot Sd^2 p^+ \cdot Vd^3 k'}{(2\pi)^7} . \tag{22}$$

It should be noted that the physical values must not have any nonphysical constants such as L_x, L_y, L_z. It has place in case of a differential probability if we take into account that

$$L_x = 2|x_0| = 2|p_y| / hm^2 . \tag{23}$$

A differential probability of the process in time unit can be presented through the amplitude M in the following form [8,9]:

$$\frac{dW_{if}}{T} = hm^2 |M|^2 \delta(\varepsilon) \frac{dp \cdot d^3 k'}{2(2\pi)^{10}} . \tag{24}$$

Then the total probability equals to:

$$W_{if} = \int_0^{\omega'_{max}} d\omega' \int_{u_{min}}^{u_{max}} du \left(\frac{dW_{if}(p_1)}{d\omega' du} + \frac{dW_{if}(p_2)}{d\omega' du} \right) . \tag{25}$$

Before calculating this probability let us consider briefly simpler processes that are first order processes. Their probabilities have been known for a long time. In the LLL approximation probabilities of a photon pair production and a cyclotron radiation have the following form:

$$W_{pr} = \frac{\alpha\, hm^2 e_z^2}{2p} j_g^2 , \quad \frac{dW_{rad}}{du} = \frac{\alpha\, \omega' nh}{2l^-} G_g^2 \, |\Pi'^+|^2 . \tag{26}$$

In the case of a ground state of a pair $l^- = l^+ = 0$ for a magnetic field $h = 0.1$ or $H = 4 \cdot 10^{12}$Gs a pair production probability has order

$$W_{pr} \sim 10^{10} \; [1/c] . \tag{27}$$

The probability of cyclotron radiation has a simple form:

$$W_{rad} = \frac{4}{3} n\alpha\, h^2 m \equiv n \cdot \Gamma \tag{28}$$

and for $h = 0.1$

$$\Gamma \sim 10^{17} [1/c] . \tag{29}$$

It should be noted that amplitude consists of two elements that are two Feynman diagrams. If the second element is much less than the first, then the probability is the square of the first element. In this case in resonance conditions we succeeded to take the probability in the form of Breit-Wigner formula:

$$\frac{dW_g}{d\omega' d\Omega'} = \frac{1}{(2\pi)^2} \cdot \frac{W_{pr.e^+e^-} \cdot dW_{rad.e^-} / du}{((\omega' - \omega_r)^2 + n_g^2 \Gamma^2 / 4)} . \tag{30}$$

Numerator (30) is a product of probabilities that exactly coincide with (26). This means the following: in resonance this process breaks into two independent processes of the first order. Integration on an angle of the final photon gives estimation to the total probability ΔW_g. This value is equal to the probability of the first order process.

$$\Delta W_g = W_{pr.e^+e^-} . \tag{31}$$

In order to find a correct angular dependence and also a dependence on polarization and spin it is necessary to take into account both diagrams, both elements in the amplitude. The following expression corresponds to this case:

$$\frac{dW}{d\omega' d\Omega'} = \frac{B \cdot K(\xi', \Omega')}{(\omega' - \omega_r)^2 + n^2 \Gamma^2 / 4} , \; B = \frac{(\alpha Rhme_z)^2 \omega'}{(4\pi)^2 p} , \tag{32}$$

where

$$K(\xi', \Omega') = (1 + u^2) - (1 - u^2)\xi'_3 \tag{33}$$

$$+ [(1 - u^2) - (1 + u^2)\xi'_3] \cos(2\Delta n\chi) + 2u\xi'_2 \sin(2\Delta n\chi) ;$$

$$\chi = (\varphi' - \varphi) - \sin\theta' \sin(\varphi' - \varphi) .$$

This probability depends not only on the polar angles of the photons but also on the difference of the azimuthal angles. The angle dependence of probability is characterized by the function K(ξ',Ω'), which is represented in Fig. 3.

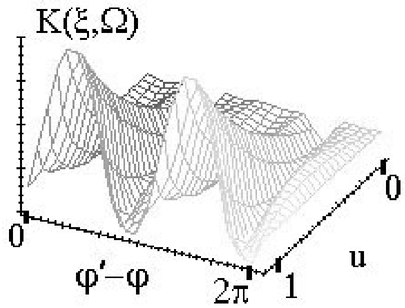

Fig. 3. *Angle dependence of probability for the case* $\xi'_2 = \xi'_3 = 1/\sqrt{2}$, $\Delta n\chi = \pi$

The probability has the maximal value for u=1, when a photon takes off along the magnetic field. It is needed to mark that in kinematics there are cases, when probability is equal to the doubled Breit-Wigner probability both for the first and for the second diagrams.

One of the interesting questions in this problem is a peculiarity in the probability of a pair production without the final photon. This value contains the momentum of particles in denominator from integration on momentum.

$$\delta(\omega - \varepsilon - \varepsilon^+) \cdot d\,p = \sum_1^2 \frac{\varepsilon\varepsilon^+ \delta(p - p_i)}{|p\varepsilon^+ + p^+\varepsilon|} \cdot d\,p .$$

When the longitudinal momentum tends to zero, the probability tends to infinity. Note, it takes place on the threshold of the process. With addition of the final photon this peculiarity disappears. But the frequency of this photon appears in the denominator.

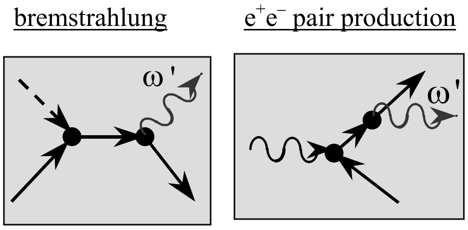

Fig. 4. *Feynman diagrams for bremstrahlung and pair production*

Here you can see a complete analogy with other processes, where a photon emits (see Fig. 4). For example, bremstahlung, where the cross section grows too, when the frequency approaches zero.

$$d\sigma_{brems} = d\sigma_0 \frac{dI}{\omega'} \sim \frac{1}{\omega'}, \qquad dW_{pairprod} \sim \frac{1}{\omega'}. \quad (34)$$

Thus, it is possible to conclude, that the process of a pair production necessarily must be accompanied by the radiation of soft photons the account of which removes unphysical divergency.

ACKNOWLEDGMENT

The authors are grateful to V.E. Storizhko for his constant help in holding this work and also to S.P. Roshchupkin for useful discussions.

REFERENCES

1. N.P. Klepikov. Photons and electron-positron pairs emission in magnetic field //*Zh. Eksp. Teor. Fiz.* 1954, v. 26, p. 19-34 (in Russian).
2. V.P. Oleynik. Production of electron-positron pair by a photon in field of electromagnetic wave and homogeneous magnetic field //*Zh. Eksp. Teor. Fiz.* 1971, v. 61, p. 27-35 (in Russian).
3. A.A. Kozlenkov, I.G. Mitrofanov. Two photon production of electron-positron pair in strong magnetic field //*Zh. Eksp. Teor. Fiz.* 1986, v. 91, p. 1978-1989 (in Russian).
4. P.I. Fomin, R.I. Kholodov. Photoproduction of the e+e⁻ pair with photon emission kinematics in strong magnetic field //*Probl. At. Sc. Thech*. 2005, N 6, p. 43-45.
5. A.A. Sokolov, I.M. Ternov. *Relativistic electron*. M.: ''Nauka'', 1974, 392 p. (in Russian).
6. A.I. Akhiezer and V.B. Berestetskiy. *Quantum Electrodynamics*. 4th ed. M.: "Nauka", 1981; Wiley, New York, 1965.
7. A.I. Nikishov, Problems of external field in quantum electrodynamics //*Tr. Fiz. Inst. Im. P.N.Lebedeva.* 1979, v. 111, p. 152.
8. P.I. Fomin, R.I. Kholodov. Resonance Compton scattering in an external magnetic field //*JETP*. 2001, v. 90, p. 281; *Zh. Eksp. Teor. Fiz.* 2001, v. 117, p. 319-325 (in Russian).
9. P.I. Fomin, R.I. Kholodov. Resonance double magnetic bremsstrahlung in a strong magnetic field //*JETP*. 2003, v. 96, p. 315; *Zh. Eksp. Teor. Fiz.* 2003, v. 123, p. 356-361 (in Russian).

РЕЗОНАНСНОЕ ФОТОРОЖДЕНИЕ e^+e^--ПАРЫ С ИСПУСКАНИЕМ ФОТОНА В СИЛЬНОМ МАГНИТНОМ ПОЛЕ

П.И. Фомин, Р.И. Холодов

Рассматривается квантово-электродинамический процесс рождения электрон-позитронной пары фотоном в сильном внешнем магнитном поле. Процесс сопровождается испусканием конечного фотона. Найдены кинематика и резонансные условия в ультраквантовом приближении, приближении сильного магнитного поля и слабо возбужденных состояний электрона и позитрона. Резонансные условия реализуются, если энергия конечного фотона равна расстоянию между уровнями Ландау электрона. Вероятность резонансного рождения электрон-позитронной пары с фотонной эмиссией получена в форме сечения Брейта-Вигнера. Эта величина одного порядка с вероятностью рождения e^+e^--пары без излучения фотона.

РЕЗОНАНСНЕ ФОТОНАРОДЖЕННЯ e^+e^--ПАРИ З ВИПРОМІНЮВАННЯМ ФОТОНА В СИЛЬНОМУ МАГНІТНОМУ ПОЛІ

П.І.Фомін, Р.І.Холодов

Розглядається квантово-електродинамічний процес народження електрон-позитронної пари фотоном в сильному зовнішньому магнітному полі. Процес супроводжується випромінюванням кінцевого фотона. Знайдено кінематику і резонансні умови в ультраквантовому наближенні, наближенні сильного магнітного поля і слабо збуджених станів електрона і позитрона. Резонансні умови реалізуються, якщо енергія кінцевого фотона дорівнює відстані між рівнями Ландау електрона. Імовірність резонансного народження електрон-позитронної пари з фотонною емісією здобута у формі перерізу Брейта-Вігнера. Ця величина одного порядку з імовірністю народження e^+e^--пари без випромінювання фотона.