Experiments on electron bremsstrahlung when passing through narrow slits and their interpretation in terms of inverse photoelectric effect

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In special experiments on slowing down soft electrons from the energy E_1 at the entry of a narrow slit down to $E_2 < E_1$ in the exit there was drawn a conclusion that the source of the retardation radiation with the energy $\Delta E_{12} = E_1 - E_2$ in the opening of the narrow slit is not the passing by electrons, but a radiation due to inverse photoelectric effect of valence electrons in the stationary structure of the edge of the hole. Here we consider only central-axial flight of electrons via a narrow slit (of the width < 0.2 μm) which generates quanta of light with the energy ΔE_{12}. If with the aid of external electrodes inside a wider slit (> 2 μm) to create a field with the same retardation potential $\varphi = \Delta E_{12}$ then despite of the same slowing down in it of central-axial flying by electrons there will be observed no emission of light quanta with the energy ΔE_{12}. This enables us to interpret in a different way the mechanism of induced radiation of matter under quantum transitions in it of particles. It looks such that the flying by electrons excites around themselves spherical zones of nonlinearity with radius ~ 0.2 μm. The orbitals (with energies E_1 and $E_2 < E_1$) of stationary valence electrons in the edge of the narrow orifice (of the width < 0.2 μm), falling in these zones, in accord with the Ritz combination rule gives from the difference of terms $\nu_1 = E_1/h$ and $\nu_2 = E_2/h$ the observed in experiments monochromatic radiation of the frequency $\nu_{12} = \nu_1 - \nu_2$. The passing of center-axial electrons via a wider gaps (> 2 μm) is not affected by the nonlinearity zones of the orbitals of stationary valence electrons in the edge of the slit. Thence, despite of the dragging by the external field of the diaphragm $\varphi = \Delta E_{12}$ in this case the flying by electrons does not radiate at the frequency $\nu_{12} = \Delta E_{12}/h$.

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1. CONVENTIONAL INTERPRETATION OF A PARTICLE'S QUANTUM TRANSITION

The micro-model, which treats the transition of an elementary particle from a stationary energy level E_1 to a lower level E_2, assumes that it is this particle that emits an electromagnetic (light) quantum of the energy $\Delta E_{12} = E_1 - E_2$ and frequency [1]:

$$\nu_{12} = (E_1 - E_2)/h = \Delta E_{12}/h. \quad (1)$$

However, there is no definite evidences that (1) is the radiation law of the very moving particle. Here we consider the radiation that arises when a preliminary accelerated particle uniformly moves towards a narrow slit in an opaque screen where it is hampered. The source of radiation in this scheme of macro-level observation is still the question of debate. Some believe that these are the flying by electrons themselves that radiate in the course of their slowing down in the narrow slit. Others associate this radiation with the electrons of the material that the border of the slit is made of which are supposedly excited due to retardation of flying by electrons [2]. There is especially emphasized in [2] that, by the logic of implementing action (1), a steadily moving particles does not radiate, while in case of flight through narrow slits with the uniform velocity ($V_{\mathtt{V-C}} = \mathtt{const}$)$> c/n$ there arises a (Vavilov-Cherenkov) radiation. In the experiments performed by me with softer electrons ($V_1 \ll V_{\mathtt{V-C}}$) the conditions are specified when the source of the bremsstrahlung with the frequency ν_{12} incited by the center-axial flying by electrons in narrow gaps (with width < 0.2 μm) is the inverse photo effect of valence electrons of gap's edge. Basing on the fact of the absence of the radiation with the frequency ν_{12} in the center-axial passing of the electrons through the slits wider than 2 μm there is suggested a nonconventional [3] interpretation of the processes of any emission arising in the "nearby" zone of a retarded, uniform or accelerated motion of an elementary particle.

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2. RESULTS OF EXPERIMENTS

Early in 1970s, making experiments on scattering soft electrons with energies $0.3 \div 100$ eV at narrow gaps [3], I disclosed an effect by which in the central-axial flight of electrons in the narrow slit the source of radiation appeared to be not the passing electrons themselves but the electrons of the atomic structure of the slit's border. The idea of the experiment is presented at Fig.1.

A speeded up to the energy E_1 electron moves in the laboratory vacuum with a uniform velocity $V_1 = \texttt{const}$. When passing through a narrow slit with electrodes at the inlet and outlet, forming a two-electrode brake diaphragm (BD), the electron can lose (or gain, for a reverse potential at the electrode diaphragm) a part of the kinetic energy (up to level $E_2 < E_1$). Further on, it continues to move with a reduced (or increased) uniform velocity $V_2 = \texttt{const}$ to the viewing screen S. Matrix of semiconductor sensors (MSS) records the density distribution of the arrival of electrons to the plane of the screen. The speeds V_1 and V_2 were monitored by direct measurements of the ratio $\Delta X_i/\Delta t_i$ (see Fig.1a), in which the interval Δt_i with measurement bases $0.2 \leq \Delta X_i \leq 2$ m has had the nanosecond scale ($10 \leq \Delta t_i \leq 80$ ns) with the resolution ~ 5 ns.

In the experiments reported the attention is focused at two reasons why electrons may be slowed down in passing through narrow slits provided with a pair of electrodes of a brake diaphragm (BD) at the entry and exit (see Fig.1a). The first reason is related with the retarding potential at electrodes of BD which is controlled in the experiment . The second reason is concerned with an electrodynamic interaction of a passing electron with the borders of the transit slit, and its consequences will be only the slowing down response. However, it became clear that with the accelerating potential at BD there are implemented modes of flight both with the acceleration and slowing down depending on the width of the gap (see below).

Observing a positive difference $V_1 - V_2$ in velocities (i.e. the positive energy difference $E_1 - E_2$) after the passing by each electron the zone BD, the process of slowing down can be regarded as a quantum transition from level E_1 to a lower level E_2. Modern quantum theory holds that such a "braking" process (when $E_2 < E_1$) is always associated with the emission of a photon with frequency $\nu_{12} = (E_1 - E_2)/h$. As might be expected, I registered in the opening of the slit the emission of light pulses having the frequency ν_{12} defined by (1). Light's pulses were recorded at the exit of the aperture of the narrow opening by means of the semiconductor photo-sensor (PS, Fig.1a), which was located at a distance of 10 μm from the edge of the outlet of BD and was connected to an amplifier of photo-pulses (APP). However, an interesting thing was found. In the case of electrons passing through center of the slit (i.e. in the absence of a mechanical contact of the electron with the edge of the slit) at one and the same difference of brake energies $E_1 - E_2$ light pulses in the exit of the aperture arose only for very narrow slits ($\delta X < 0.2$ μm) and were absent in case of wide slits ($\delta X > 2$ μm).

Using this scheme special observations were carried out of only those light flashes which arose from the electrons passed through the center of the slit depending on the width of the gap in the screen of BD and axial length δX of the slit's tunnel (i.e. depending on the thickness of the right by Fig.1a electrode of BD). In the experiments there were taken all available in these years measures in order to identify the coupling of the excitations of brake photo pulses of frequency (1) especially with the electrons flying along the central axis and thus having no mechanical core contact with the border of the slit. This relation was determined in particular by monitoring simultaneous emergence of pulses at the selector of central-axial electrons (SCAE) coming from the matrix of semiconductor sensors (MSS) and amplifier of photo-pulses (APP) to the electronic coincidence circuit with the resolution ~ 5 ns.

Thus, passing of electrons through the center of a "wide" slit (2 μm $< \delta X <$ 50 μm, Fig.1c) in the range of braking potentials $1 < \Delta E_{12} < 100$ eV at BD exhibited no radiation from the aperture of the slit. In this event, it can be seen that electrons spend for travel in the braking zone BD the time $10^{-12}\texttt{s} \leq \tau_{\texttt{slit}} \leq 10^{-14}\texttt{s}$, losing the speed $V_1 - V_2 = \Delta V_{12}$ and, respectively, the energy $E_2 < E_1$ in the range 1 eV$< (V_1^2 - V_2^2) \cdot m/2 < 100$ eV. On the other side, in the course of the central axial passage of electrons via narrow slits ($\delta X \leq 0.2$ μm, Fig.1b) light pulses of the bremsstrahlung are always registered by the SCAE apparatus, what is more, they occur not only when there is a braking potential on the plates of the capacitor BD ($|-U_{\texttt{brake}}| \neq 0$, Fig.1a), but also when it is absent ($U_{\texttt{brake}} = 0$). While in the latter case the central-axial passage of electrons should take place with a constant speed. But even if we will reverse the sign of the braking potential ($+U_{\texttt{brake}} \neq 0$), when the central-axial electrons should be accelerated (i.e. they do not radiate but absorb light quanta), the SCAE apparatus registers from the aperture of narrow slits (with critical radius $r_{\texttt{crit}} \leq 0.2$ μm, Fig.1b) the same output of the pulses of light radiation of spectral composition (1) as in the case ($U_{\texttt{brake}} = 0$).

In these experiments I was able to discover an interesting empirical regularity. Looking after photo-pulses at the exit hole of BD by means of the SCAE apparatus (see Fig.1a), I have found the disappearance of the radiation from the aperture of the outlet with the critical radius $r_{\texttt{crit}} \sim 0.2$ μm at the axial lengths $\delta X_{\texttt{crit}}$ of the slit's tunnel getting longer of the following critical value:

$$\delta X_{\texttt{crit}} \leq r_{\texttt{crit}} E_1/\Delta E_{\texttt{photoeffect}}, \tag{2}$$

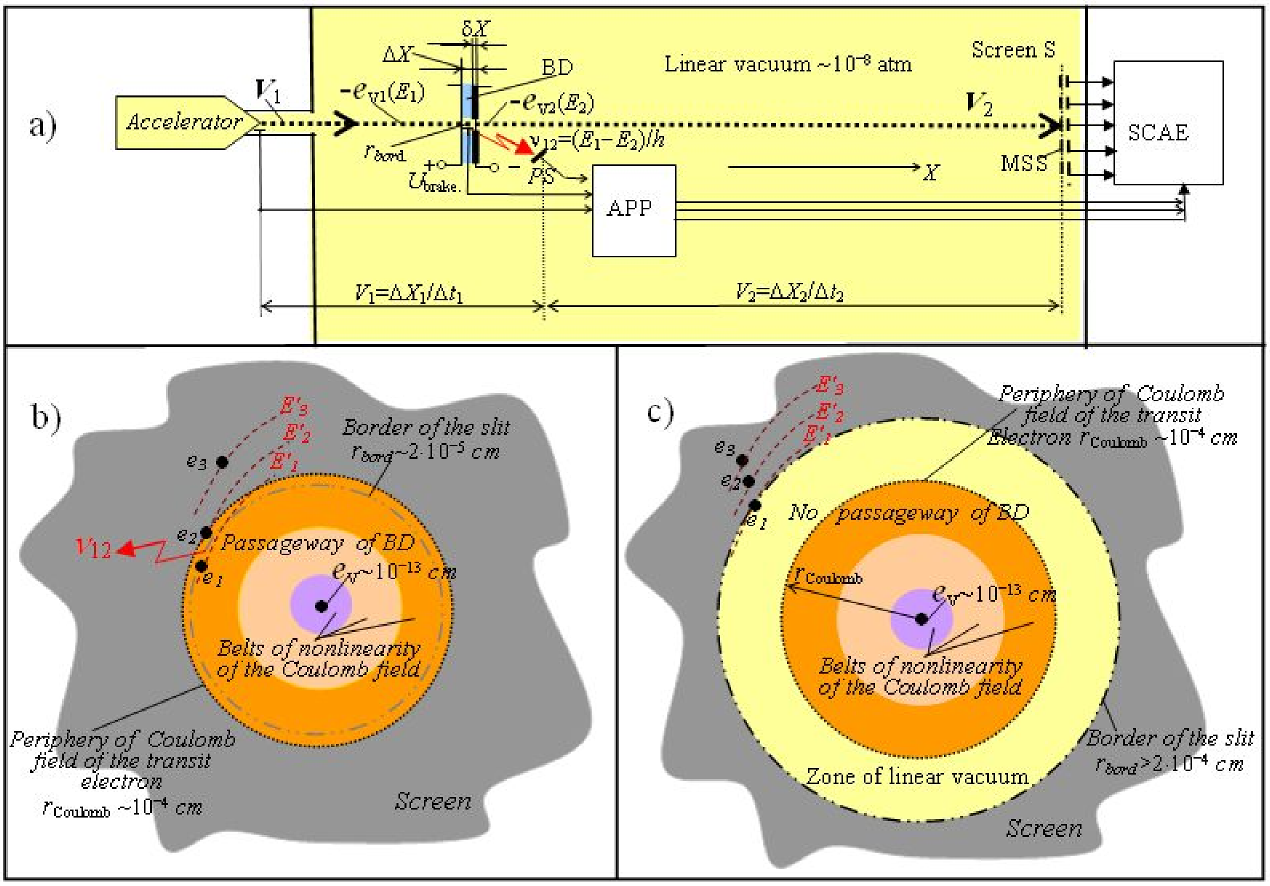

Рис. 1: The scheme of passing soft electrons (a) in the experiment with narrow slits, formed by the holes in the right-hand electrode of brake diaphragm (BD). This electrode, with δX as its thickness, performs three function: 1) the **slit** with a variable (from 0.05 microns to 10 microns) distance $r_{\texttt{bord.}}$ between its boundaries; 2) the "**spectrum analyzer**" of emitted photo-pulses due to the inverse photoelectric effect; 3) the **plate** of the capacitor of BD of retarding field in the gap ΔX. The following abbreviations are used: APP $-$ amplifier of photo-pulses from photo-sensor (PS), SCAE $-$ selector of central axial electrons registered by the sensor of electrons in the from of the matrix of photo-diodes (MPD). Energies of the nonlinearity zones around of the electrons: • $-\ 2 \div 3$ eV; • $-\ 3 \div 5$ eV; • $-\ 5 \div 8$ eV revealed by the right electrode of BD made, respectively, of CsAu, Ce, Ni. At insets b) and c) are shown two modes of observation;
$-$ the **occurrence** of electromagnetic radiation when passing of electrons e_{v1} through the center of "narrow" (b) slits (the width < 0.2 μm) in the opaque screen with BD (the electron does not touch the edges of the slit by the kernel of his dense body, but acts at it only by the high energy zone of his nonlinear Coulomb field, lowering thus own velocity by $\Delta V = V_1 - V_2$);
$-$ the **absence** of electromagnetic radiation when passing of electrons e_{v1} via the center of "wide" slits (width$\gg$ 1 μm) in opaque screen; in this event the passing through the center electron does not touch the edges of the slit neither by the kernel of his body nor by the high energy zone of his nonlinear Coulomb field, but the braking potential of the capacitor ensures the same level (ΔV) of his slowing down.

where $\Delta E_{\texttt{photoeffect}}$ is the work of photo-emission of light quanta from the material of the hole (in the right for Fig.1a electrode). One of the consequences of (2), found in the experiments, indicates that the length of the tunnel $\delta X_{\texttt{crit}}$ in BD at which there ceases the generation at the hole's exit of photo-pulses with the spectral energy $\Delta E_{\texttt{photoeffect}}$, is so times greater than the found by me independently value $r_{\texttt{bord.}} = r_{\texttt{crit}}$ as the energy E_1 of accelerated electrons at the entry of the hole of BD is greater than the energy $\Delta E_{\texttt{photoeffect}}$ of registered by means of SCAE photo-pulses. Besides the growth of E_1 proportionally to length $\delta X_{\texttt{crit}}$ of the tunnel there was found also, that in successive changing of materials, CsAu, Ce and Ni, for the right-hand (in Fig.1a) electrode the value of $r_{\texttt{crit}}$ decreased from ~ 0.3 μm to ~ 0.1 μm. These empirical regularities can be useful for further theoretical constructs of the micro-model of combination-bremsstrahlung due to the inverse photoelectric effect from edges of the narrow hole contactlessly (non-mechanically) incited by the center-flying electrons.

Thus the analysis of the results of these experiments testifies to that in the axial flight of electrons through wide holes (radius $> 2\ \mu$m) with the decelerating field formed by capacitor BD (see Fig.1a), despite of the retardation with the loss of the motion energy $\Delta E > \Delta E_{\texttt{photoeffect}}$ due to the braking potential $|-U_{\texttt{brake}}| \neq 0$, they do not radiate light pulses. The questions arise, whether there is correct the conventional consideration [2], that the light is radiated by the particle itself experienced the quantum transition of bremsstrahlung and wasting the kinetic energy of motion $E_1(V_1)$ to the level $E_2(V_2) < E_1(V_1)$? Whether the condition of light radiation from the aperture of the hole is the obligatory presence at the distances ≤ 200 nm from the passing by electron either the edge of narrow hole (as in my experiment) or of the atoms of any other substance?

3. DISCUSSION

The direct conclusion from the series of experiments thus performed is the **insufficiency** of the energy transition ("falling") of a free electron from a high E_1 to a lower $E_2 < E_1$ energy level in order that this electron was able to emit by itself a light pulse with the combinational frequency $\nu_{12} = (E_1 - E_2)/h$. It turns out that a relatively free speeded up electron in the absence of interaction with electrons of the BD hole's edge in the radius $< 0.2\ \mu$m by itself, $\gg 0.2\ \mu$m away from the edges, does not radiate during the time of its dragging (slowing down) at the sharp field gradient in vacuum.

Taking into account this result, the conventional view, that the slowing down the electrons is sufficient in order to induce their radiation, requires such a refinement that another interpretation of the radiation process becomes inevitable. It is meant first of all that the Ritz combination principle for the induced radiation is implemented neatly by (1). The point is that the difference combinations of the pairs of energies E_1 and E_2 in this principle requires the certainty of their magnitudes in the course of the all radiation process. According to (1), the constancy of the frequency ν_{12} in the course of radiation implies that during all the time period $\Delta t = t_2 - t_1$ the difference $\Delta E_{12} = E_1 - E_2$ is specified and fixed.

In order that the emission of light quanta by the flying electron itself occurred by the combination rule ($\Delta E_{12} = E_1 - E_2$) at a single as if anticipated mono-frequency (1) it should be exactly "known", from the beginning $t_1(E_1)$ to the end $t_2(E_2)$ of the process, the energies E_1 and E_2 which are deterministically, but not probabilistically, associated with the body of the quantum oscillator. The very slowing down electron hardly can be a carrier of two energy states and two frequency terms $\nu_1 = E_1/h$ and $\nu_2 = E_2/h$ from which there is composed by the rule (1) the difference frequency $\nu_{12} = (E_1 - E_2)/h$ of the light quantum generated in the course of quantal transition.

The indeterminism of the problem of monic radiator has been noticed by scientist as early as in 1930ies, and since then the discussion on this subject keeps its actuality. The conventional explanation of how the particle experienced a quantum transition (falling down) from the energy level E_1 to level $E_2 < E_1$ emits a quantum of light demands the explaining of an incredible phenomenon. Namely, how a closed on himself particle may "know" all the time in the course of the quantal transition the exact values of the energies E_1 and E_2 (in order to maintain the difference $\Delta E_{12} = E_1 = E_2 = \texttt{const}$ i.e. to ensure the monochromaticity of the radiation)? Since in the time of the transition it already abandoned the level E_1 and, passing in the course of the retardation all the magnitudes E_i of the energy range $E_1 > E_i > E_2$, it did not yet come to level E_2 and does not at all know what level it will fall at. The described above experiments have shown that a slowing down in vacuum particle (away from an interaction with other particles of the hole's edge at the distance more than $0.2\ \mu$m as was above said) does not radiate by itself. The presence of the monochromatic retardation radiation out of the opening of narrow slits and incited by the pumping the radiation of quantum generators (with the level of monochromaticity $\Delta\nu_{0.5}/\nu_{12} \sim 10^{-8} \div 10^{-6}$ [4]) makes clear why the combination radiation (1) is implemented only when the binary combination $\Delta E_{12} = E_1 = E_2 = \texttt{const}$ is certainly realized. This enables me to put forward an alternative interpretation of the radiation induced in quantum transitions.

If, according to the above described experiment, the decelerated by the field of a wide slit particle loses its energy, passing from the level E_1 to level $E_2 < E_1$, but emits by itself nothing then consequently this energy is accumulated by the source of the retardation field. When there is no retardation field, the uniformly moving particle spends its energy for exciting (polarizing) around himself a nanometer zone of nonlinearity of fine medium (physical vacuum, aether). In physical vacuum without particles the momentum and energy handed by the uniformly moving particle to nano-environment immediately are returned to it entirely and it, step by step, moves further according to conservation of its momentum.

Thus, in the course of the quantum transition there are seemingly formed around kinetically energetic particles excited nonlinearity regions of physical vacuum having radius up to $\sim 100 \div 200$ nm. When such a particles enters to the zone of radius $< 100 \div 200$ nm of interaction of atoms with any medium, all respectable pairs of stationary particles of this medium (with energies of orbitals $E_1 = h\nu_1$ and $E_2 = h\nu_2$ occupied by valence electrons of the medium) start to take away actively the part of the energy of this polarized zone spending it on a nonlinear-combinational transformation of frequency terms ν_1 and ν_2. It is this combinational-transformational process that impedes the speeded up particle but not the presence in vacuum of a retardation field which the uniformly moving particle is indeffrent to as an emitter. In the outcome, the nonlinear-combinational transformation of frequency terms by valence electrons of the medium are generated addition-subtraction combinations $\nu_{12} = \nu_1 \pm \nu_2$ and their harmonics [1]. Main harmonics of difference vibrations $\nu_{12} = \nu_1 - \nu_2$ represent, firstly, the “implementations of Ritz combinations” and, secondly, they are the observed by us in experiments light pulses (quanta) of radiation by substances (in my experiment $-$ due to inverse photo-effect from the slit’s edge), which are incited by the combinational-transformational contactless retardation of passing by electrons in narrow slits. Supposedly, in other known means of pumping the nonlinearity of the medium take place similar processes of radiating monochromatic quanta of light generated not properly by the passing by electrons, but by the particles of stationary atoms of the medium getting into regions of nonlinearity that are excited by the retardation processes of the thrown to the upper energy valence level E_1 of electrons by the "pumping".

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