Peculiarities in the emission from relativistic electrons moving in a polycrystalline target

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Abstract

Modification of two classical emission mechanism from relativistic electrons crossing a solid polycrystalline target (bremsstrahlung and transition radiation) is predicted. Peculiarities being considered appear due to the order in part atomic structure of the target.

Keywords: Bremsstrahlung; Textured polycrystal; Coherent bremsstrahlung; Transition radiation; Dynamical diffraction effects

1. Introduction

The classical Bethe–Heitler formula for the spectrum of bremsstrahlung from relativistic electrons scattered on an atom [1] describes well results of experiments with amorphous targets in the special case that the action of both Landau–Pomeranchuk–Migdal effect (bremsstrahlung suppression due to the influence of multiple scattering of emitting electrons [2,3]) and Ter-Mikaelian effect (bremsstrahlung suppression due to the polarization of target electrons [4]). It is important to keep in mind that the solid target possesses usually crystalline or polycrystalline atomic structure. Ordered location of atoms in crystalline lattice leads to radical changes in bremsstrahlung properties [5–7]. On the other hand, a good agreement between experimental data and Bethe–Heitler theory points to the fact that the difference between amorphous and polycrystalline radiators is not substantial. Nevertheless, this point of view does not appear as adequate one. We show in the paper that bremsstrahlung in real polycrystalline target can be essentially changed from that in an amorphous one because of texture which is often manifested in polycrystalline samples.

The second effect predicted in the paper appears in a polycrystalline radiator as well, but it connects with the emission mechanism known as transition radiation [8]. The transition radiation from relativistic electrons crossing a boundary between two perfect microcrystals with different orientations is considered here. It is clear that the emission being discussed is not possible within the frame of traditional approach because dielectric susceptibilities are the same on each side of the boundary. Situation is changed with account of dynamical diffraction effects [9]. The effective susceptibility of the microcrystal contains an addition caused by dynamical effects with a strong dependence on the orientation of crystallographic lattice relative to the emitting electron velocity. It is this above difference between orientations of neighboring microcrystals that gives rise to transition radiation. When a relativistic electron moves in a polycrystalline target it crosses many perfect microcrystals with different orientations. Because of this it emits electromagnetic waves by outlined emission mechanism.

The paper is organized as follows. The contribution of coherent bremsstrahlung from relativistic electrons crossing a textured polycrystalline target is considered in Section 2.

Dynamical transition radiation is studied in Section 3. Our conclusions are presented in Section 4.

Relativistic system of units $\hbar = c = 1$ is used in the paper.

2. Bremsstrahlung from relativistic electrons moving in a textured polycrystal

Let us consider a polycrystal consisting of perfect microcrystals with main crystallographic axes uniformly distributed over the solid angle $\mathbf{\Psi}$ around the axis of emitting electron beam, so that the distribution function $f(\mathbf{\Psi})$ has the form $f(\mathbf{\Psi})\,\mathrm{d}\psi\,\mathrm{d}\varphi = [\sigma(\psi)\sigma(\xi-\psi)\sin\psi/2\pi(1-\cos\xi)]\mathrm{d}\psi\,\mathrm{d}\varphi$, ξ is the maximum value of ψ, $\sigma(x)=1$ if $x>0$ and $\sigma(x)=0$ if $x<0$. Obviously, the model being discussed is reduced to that of a monocrystal in the limiting case $\xi \to 0$, otherwise $(\xi \to \pi)$ it describes a polycrystal without texture.

It is clear that an emitting electron interacts independently with each microcrystal. In addition to this let us assume that the velocity vector of this electron is far from the directions corresponding to planar channeling in average potential of main atomic planes. In conditions under consideration one can consider the interaction of incident electron with a single microcrystal as a number of consecutive independent collisions of this electron with atomic string with the proviso that the orientation angle ψ between electron's velocity and the axis of atomic string is fixed. Spectral-angular distribution of the number of quanta emitted owing to a single collision is given by

$$\omega\frac{\mathrm{d}N_{\psi,b}}{\mathrm{d}\omega\,\mathrm{d}\Omega} = \frac{\mathrm{e}^2}{4\pi^2}\left\langle \left| \int \frac{\mathrm{d}t}{1-\sqrt{\varepsilon}\mathbf{n}\mathbf{V}_t}\mathrm{e}^{\mathrm{i}\omega(t-\sqrt{\varepsilon}\mathbf{n}\mathbf{r}_t)}\left(\mathbf{W}_t - \frac{\mathbf{n}-\sqrt{\varepsilon}\mathbf{V}_t}{1-\sqrt{\varepsilon}\mathbf{n}\mathbf{V}_t}\right)\right|^2 \right\rangle,$$
$$\mathbf{W}_t = -\frac{\mathrm{i}e}{m\gamma}\int \mathrm{d}^3g(\mathbf{g}-\mathbf{V}_t\cdot(\mathbf{g}\mathbf{V}_t))\varphi_{A\mathbf{g}}\mathrm{e}^{\mathrm{i}\mathbf{g}\mathbf{r}_t}\sum_l \mathrm{e}^{-\mathrm{i}g_{x'}al-\mathrm{i}\mathbf{g}\mathbf{u}_l}, \tag{1}$$

where $\mathbf{r}_t = \mathbf{r}(t,b,\psi)$ is the trajectory of an emitting electron, b is the impact parameter, $\mathbf{V}_t = \frac{\mathrm{d}}{\mathrm{d}t}\mathbf{r}_t$, $\mathbf{W}_t = \frac{\mathrm{d}}{\mathrm{d}t}\mathbf{V}_t$, $\varepsilon = 1-\omega_0^2/\omega^2$ is the dielectric permeability, ω_0 is the plasma frequency, $\varphi_{A\mathbf{g}}$ is the Fourier-transform of the potential of an atom, $g_{x'}$ is the component of $\mathbf{g}$ parallel to the axis of atomic string, a is the distance between two neighboring atoms in a string, $\mathbf{u}_l$ is the thermal displacement of lth atom, brackets $\langle\rangle$ mean the averaging over $\mathbf{u}_l$, γ is the Lorentz factor of an emitting electron, $\mathbf{n}$ is the unit vector to the direction of an emitted photon propagation. The result (1) is valid within the frame of classical electrodynamic, which is to say that $\omega \ll m\gamma$.

Formula (1) allows one to determine the spectral-angular distribution of bremsstrahlung intensity for fixed orientation angle ψ (for fixed microcrystal)

$$\omega\frac{\mathrm{d}N_\psi}{\mathrm{d}t\,\mathrm{d}\omega\,\mathrm{d}\Omega} = n_0 a\sin\psi\int_{-\infty}^{\infty}\mathrm{d}b\frac{\mathrm{d}N_{\psi,b}}{\mathrm{d}\omega\,\mathrm{d}\Omega}, \tag{2}$$

where n_0 is the density of atoms in the target. The spectrum of bremsstrahlung from a polycrystalline target of interest to us follows from (2) in the form

$$\omega\frac{\mathrm{d}N}{\mathrm{d}t\,\mathrm{d}\omega} = \int\mathrm{d}\Omega\int_0^\xi\mathrm{d}\psi\int_0^{2\pi}\mathrm{d}\varphi f(\mathbf{\Psi})\frac{\mathrm{d}N_\psi}{\mathrm{d}\omega\,\mathrm{d}\Omega} = \frac{\mathrm{d}N^{\mathrm{inc}}}{\mathrm{d}t\,\mathrm{d}\omega}+\frac{\mathrm{d}N^{\mathrm{coh}}}{\mathrm{d}t\,\mathrm{d}\omega}, \tag{3}$$

where $\mathrm{d}N^{\mathrm{inc}}/\mathrm{d}t\,\mathrm{d}\omega$ and $\mathrm{d}N^{\mathrm{coh}}/\mathrm{d}t\,\mathrm{d}\omega$ are incoherent and coherent parts of bremsstrahlung, respectively.

Assuming the scattering angle of an emitting electron in a string potential to be less than the characteristic emission angle for relativistic particle γ^{-1} we use a simple dipole limit of the emission theory [6]. As this takes place the simplest approximation $\mathbf{r}_t = \mathbf{b}+\mathbf{V}t$, $\mathbf{b}\mathbf{V}=0$, $\mathbf{V} = \mathbf{e}_x(1-\frac{1}{2}\gamma^{-2})$ for the trajectory of an emitting electron in the field of an atomic string is valid. As a result, integrations in formulae (1)–(3) become simple and incoherent part of bremsstrahlung intensity can be obtained in the form

$$\omega\frac{\mathrm{d}N^{\mathrm{inc}}}{\mathrm{d}t\,\mathrm{d}\omega} = \frac{8Z^2\mathrm{e}^6 n_0}{3m^2\gamma^2\rho^2}\left[\ln(1+m^2R^2)+\frac{1-\mathrm{e}^{-m^2U_\mathrm{T}^2}}{1+m^2R^2} - \left(1+\frac{U_\mathrm{T}^2}{R^2}\right)\mathrm{e}^{\frac{U_\mathrm{T}^2}{R^2}}\times\left(E_1\left(\frac{U_\mathrm{T}^2}{R^2}\right) - E_1\left(\frac{U_\mathrm{T}^2}{R^2}+m^2U_\mathrm{T}^2\right)\right)\right] \approx \frac{16Z^2\mathrm{e}^6 n_0\ln(mU_\mathrm{T})}{3m^2\gamma^2\rho^2}, \tag{4}$$

where $\rho^2 = \gamma^{-2}+\omega_0^2/\omega^2$, R is the screening radius in the Fermi–Thomas atom model, U_T is the mean square amplitude of thermal vibrations of atoms.

It should be noted that the result (4) differs from the classical limit of Bethe–Heitler formula by both the coefficient $\gamma^2\rho^2 = \omega^2/(\omega^2+\gamma^2\omega_0^2)$ describing an influence of Ter-Mikaelian effect of dielectric suppression [4] and the replacement $\ln(mR)\to\ln(mU_\mathrm{T})$, which takes into account the effect of bremsstrahlung suppression due to ordered locations of atoms in a crystalline lattice [5]. The last effect is quite natural. In the limiting case $U_\mathrm{T}\to 0$, when atoms form an ideal crystalline lattice, incoherent part of bremsstrahlung tends to zero in accordance with exact formula in (4).

The coherent addition to bremsstrahlung yield following from (2),(3) can be presented by the formula

$$\omega\frac{\mathrm{d}N^{\mathrm{coh}}}{\mathrm{d}t\,\mathrm{d}\omega} = \frac{4Z^2\mathrm{e}^6 n_0}{m^2\gamma^2\rho^2}\frac{\pi R}{a(1-\cos\xi)}\int_1^\infty\mathrm{d}x\left(\frac{1}{x^2}-\frac{2}{x^3}+\frac{2}{x^4}\right)\times\left[\arcsin\left(\frac{\sin\xi}{\sqrt{1+\alpha^2x^2}+\alpha x\cos\xi}\right)+\frac{\alpha x}{\sqrt{1+\alpha^2x^2}}\frac{\sin\xi}{\sqrt{1+\alpha^2x^2}+\alpha x\cos\xi}\right], \tag{5}$$

where $\alpha = \omega R\rho^2/2\sin\xi$ is the ratio if the path of an emitting electron in a string potential $R/\sin\xi$ to the emission formation length $2/\omega\rho^2$. Notice that the influence of thermal displacement of atoms in atomic strings was neglected when deriving (5).

It is interested to match the formula for total bremsstrahlung spectrum following from (4) and (5) to Bethe–

Heitler one. In the case of weak texture ($\xi \sim 1$) such formula can be presented in the form

$$\omega \frac{dN^{tot}}{dt d\omega} = \frac{dN_{B\text{-}H}}{dt d\omega} \frac{\frac{\omega}{\gamma\omega_0}}{\frac{\omega}{\gamma\omega_0} + \frac{\gamma\omega_0}{\omega}} \left[1 - \frac{\ln(R/U_T)}{\ln(mR)} + \frac{\pi R}{a \ln(mR)} \frac{\xi}{1 - \cos\xi} \right],$$

$$\frac{dN_{B\text{-}H}}{dt d\omega} = \frac{16 Z^2 e^6 n_0 \ln(mR)}{3 m^2 \omega}, \tag{6}$$

where $\frac{dN_{B\text{-}H}}{dt d\omega}$ is the classical limit of the Bethe–Heitler result. Two additions in square brackets (6) are caused by ordered structure of a polycrystalline target. The first of them is well known [6] and caused by the ordered location of atoms in a single microcrystal. The value of this addition is about 10%. The second addition describes the contribution of coherent bremsstrahlung from incident electrons on atomic strings. This contribution depends strongly on the value of the parameter ξ determining the texture. It will be readily seen that the second addition is less than first one, if $\xi \sim 1$, so that the formula (6) substantiates the possibility to neglect the contribution of coherent bremsstrahlung to total bremsstrahlung yield from relativistic electrons moving through an ordinary polycrystal with weakly oriented microcrystals.

On the other hand, the contribution being discussed becomes substantial in the case of strongly textured polycrystalline target ($\xi \ll 1$). In accordance with (6) the contribution of coherent part of bremsstrahlung covers 50% for $\xi \sim 0.2$–0.3. Since the presented result is of importance to interpretation of bremsstrahlung experiments one should consider the process in more detail. The formula for coherent addition in (6) coincides with that [6] describing the coherent bremsstrahlung from relativistic electrons crossing an atomic string at the angle ξ along the rectilinear trajectory. In the task being considered all electrons move at angles $\psi < \xi$ relative to the axis of an atomic string, which is why the coherent addition in (6) increases indefinitely in the limiting case $\xi \to 0$. It is well known however, that the trajectory of an emitting electron is bent by the average potential of the string within the frame of orientation angles $\psi \leqslant \psi_c$ (ψ_c is the critical angle of axial channeling [6]). As this takes place, the coherent growth of bremsstrahlung yield is saturated [6] and hence the field of application of the result (6) is bounded by the condition $\psi_c \ll \xi$ (this condition means that the approximation of rectilinear trajectory is valid for the most part of emitting electrons).

In conditions $\xi \ll 1$ under consideration the formula (5) can be reduced to simple form

$$\frac{dN^{coh}}{dt d\omega} = \frac{16 Z^2 e^6 n_0}{m^2 \omega_0^2 a} F(x, y),$$

$$F = y^2 \left\{ \alpha \ln\left(\frac{1}{\alpha} + \sqrt{1 + \frac{1}{\alpha^2}} \right) - 1 + 2\alpha^2 \left[\frac{2}{3} + \frac{1}{3}\left(1 + \frac{1}{\alpha^2}\right)^{\frac{3}{2}} - \left(1 + \frac{1}{\alpha^2}\right)^{\frac{1}{2}} \right] \right\}, \tag{7}$$

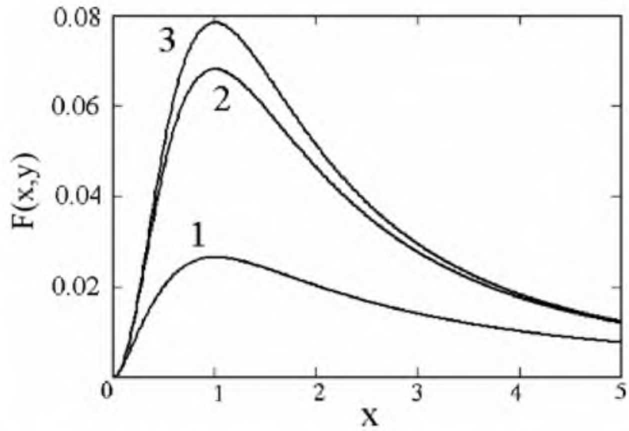

Fig. 1. Spectral distribution of coherent addition to bremsstrahlung spectrum. The function $F(x, y)$ and its arguments are determined in Eq. (7). The curve **1** corresponds to the value of the parameter $y = .1$, **2** – $y = .5$, **3** – $y = 1$.

where $x = \omega/\gamma\omega_0$, $y = \omega_0 R/2\gamma\xi$, $\alpha = y(x + 1/x)$. Universal function $F(x)$ is presented by the curves in Fig. 1 calculated for different values of the parameter y. These curves demonstrate the saturation of coherent bremsstrahlung contribution with increase in the parameter y (nevertheless, one should take in mind that the typical value of y is small). It should be noted that the maxima of the curves in Fig. 1 are explained by the bremsstrahlung suppression in the range of small frequencies $\omega \leqslant \gamma\omega_0$ due to Ter-Mikaelian effect [4].

Let us estimate the conditions for experimental observation of the predicted effect. Since the maximum of coherent bremsstrahlung spectrum is located near to $\omega = \gamma\omega_0$ (see Fig. 1) and the value of ω_0 is close to 20–50 eV for targets with $Z \leqslant 30$, the energy diapason for emitted photon registration is 4–10 keV for emitting electrons with energies of the order of 100 MeV. As this takes place, the relative value of coherent bremsstrahlung contribution depends strongly on the parameter ξ in accordance with formulae (6), (7) and Fig. 1.

3. Dynamical transition radiation from relativistic electrons moving through a polycrystal

When a relativistic electron moves in a medium it can emit electromagnetic waves by not only the scattering of this electron in the potential of medium's atoms, but the scattering of electron's Coulomb field by atomic electrons as well. Let us consider the last emission process to fit the course-grained polycrystalline target. The possible emission occurring when an electron crosses an interface between two different grains, or microcrystals is of interest to us. Since a single microcrystal posses a perfect crystalline structure, one should use the dynamical diffraction theory [9] to describe the electromagnetic field excited in this microcrystal by the fast electron

$$\left(k^2-\omega^2(1+\chi_0)\right)\mathbf{E}_{\omega\mathbf{k}}-\mathbf{k}(\mathbf{k}\cdot\mathbf{E}_{\omega\mathbf{k}})$$
$$-\omega^2\sum_{\mathbf{g}}{}'\chi_{-\mathbf{g}}\mathbf{E}_{\omega\mathbf{k}+\mathbf{g}}=4\pi\mathrm{i}\omega\mathbf{J}_{\omega\mathbf{k}},\tag{8}$$

where $\mathbf{E}_{\omega\mathbf{k}}=(2\pi)^{-4}\int \mathrm{d}t\mathrm{d}^3r\mathbf{E}(\mathbf{r},t)\mathrm{e}^{\mathrm{i}\omega t-\mathrm{i}\mathbf{k}\mathbf{r}}$ is the Fourier-transform of the electric field, $\chi_0(\omega)$ and $\chi_{\mathbf{g}}(\omega)$ are the components of the dielectric susceptibility $\chi(\omega,\mathbf{r})=\chi_0(\omega)+\sum'_{\mathbf{g}}\chi_{\mathbf{g}}(\omega)\mathrm{e}^{\mathrm{i}\mathbf{g}\mathbf{r}}$, $\mathbf{g}$ is the reciprocal lattice vector, $\mathbf{J}_{\omega\mathbf{k}}$ is the Fourier-transform of the fast electron current density.

Taking into account that the field $\mathbf{E}_{\omega\mathbf{k}}$ is approximately transverse ($\mathbf{k}\mathrm{E}_{\omega\mathbf{k}}\simeq 0$) for relativistic emitting electrons and expressing the component $\mathbf{E}_{\omega\mathbf{k}+\mathbf{g}}$ in (8) in terms of $\mathbf{E}_{\omega\mathbf{k}}$ by the equation

$$\left((\mathbf{k}+\mathbf{g})^2-\omega^2(1+\chi_0)\right)\mathbf{E}_{\omega\mathbf{k}+\mathbf{g}}=\omega^2\sum_{\mathbf{g}'}{}'\chi_{-\mathbf{g}'}\mathbf{E}_{\omega\mathbf{k}+\mathbf{g}+\mathbf{g}'},\tag{9}$$

additional to (8), one can obtain the following equation for $\mathbf{E}_{\omega\mathbf{k}}$

$$\left(k^2-\omega^2(1+\chi_0)-\omega^4\sum_{\mathbf{g}}{}'\frac{\chi_{-\mathbf{g}}\chi_{\mathbf{g}}}{(\mathbf{k}+\mathbf{g})^2-\omega^2(1+\chi_0)}-\dots\right)\mathbf{E}_{\omega\mathbf{k}}$$
$$=4\pi\mathrm{i}\omega\mathbf{J}_{\omega\mathbf{k}},\tag{10}$$

where the items omitted in the left side of (10) can be presented in the form of coefficients of higher-order in $\chi_{\mathbf{g}}\ll 1$.

Obviously, the left side of (10) can be rewritten in the form

$$\left(k^2-\omega^2\varepsilon(\omega,\mathbf{k})\right)\mathbf{E}_{\omega\mathbf{k}},\ \varepsilon(\omega,\mathbf{k})$$
$$=1+\chi_0(\omega)+\omega^2\sum_{\mathbf{g}}{}'\frac{\chi_{-\mathbf{g}}\chi_{\mathbf{g}}}{(\mathbf{k}+\mathbf{g})^2-\omega^2(1+\chi_0)},\tag{11}$$

characteristic for an amorphous medium with space-dispersion. Effective dielectric permeability $\varepsilon(\omega,\mathbf{k})$ contains the addition caused by the dynamical diffraction effects. The property of $\varepsilon(\omega,\mathbf{k})$ of fundamental importance consists in the dependence of $\varepsilon(\omega,\mathbf{k})$ on the value and direction of the vector $\mathbf{g}$. Indeed, since orientations of neighboring microcrystals in a polycrystalline target do not coincide, effective values of $\varepsilon(\omega,\mathbf{k})$ are not the same in these microcrystals. As this takes place, transition radiation from incident electrons crossing an interface between neighboring microcrystals becomes possible.

Let us consider main properties of the emission mechanism being discussed. Since transition radiation theory is well known [10], we present the final formula for the emission spectral-angular distribution

$$\omega\frac{\mathrm{d}N}{\mathrm{d}\omega\,\mathrm{d}^2\theta}=\frac{\mathrm{e}^2}{\pi^2}\theta^2\left|\frac{1}{\gamma^{-2}+\theta^2-\chi_{\mathrm{eff}}^{(1)}}-\frac{1}{\gamma^{-2}+\theta^2-\chi_{\mathrm{eff}}^{(2)}}\right|^2,\tag{12}$$

where γ is the Lorentz factor of an emitting electron, two-dimensional angular variable $\mathbf{\Theta}$ is introduced by the formulae

$$\mathbf{V}=\mathbf{e}\left(1-\frac{1}{2}\gamma^{-2}\right),$$
$$\mathbf{n}=\mathbf{e}\left(1-\frac{1}{2}\theta^2\right)+\mathbf{\Theta},\quad \mathbf{e\Theta}=0.\tag{13}$$

Here $\mathbf{e}$ is the unit vector to direction of the emitting electron propagation, $\mathbf{n}$ is the unit vector to the direction of emitted photon observation. Quantities $\chi_{\mathrm{eff}}^{(1,2)}$ in (12) are determined by

$$\chi_{\mathrm{eff}}^{(1,2)}=\chi_0+\sum_{\mathbf{g}_{1,2}}{}'\frac{\omega^2\chi_{\mathbf{g}_{1,2}}\chi_{-\mathbf{g}_{1,2}}}{\omega^2(\gamma^{-2}-\chi_0+\theta^2)+g^2+2\omega\mathbf{n}\mathbf{g}_{1,2}}.\tag{14}$$

It should be noted that the emission yield (12) tends to zero without account of dynamical diffraction effects ($\chi_{\mathrm{eff}}=\chi_0$), or for the same orientation of neighboring microcrystals ($\mathbf{n}\mathbf{g}_1=\mathbf{n}\mathbf{g}_2$, it is clear, that $\mathbf{n}\approx\mathbf{e}$ in (14)).

To estimate an intensity of the emission being discussed let us consider mosaic graphite as a target, when only one reciprocal lattice vector $\mathbf{g}$ makes essential contribution to the sum in (14). Assuming the emission formation length $l_{\mathrm{coh}}\sim 2\gamma^2/\omega$ to be less than the characteristic size of graphite microcrystals $\langle l\rangle$, one can obtain from (12) and (14) the following expression

$$\omega\frac{\mathrm{d}N}{\mathrm{d}t\,\mathrm{d}\omega\,\mathrm{d}^2\theta}=\frac{2\mathrm{e}^2}{\pi^2}\frac{\theta^2}{|\delta|^4}\frac{\omega^4}{g^4}|\chi_{\mathbf{g}}\chi_{-\mathbf{g}}|^2\frac{1}{\langle l\rangle}$$
$$\times\left\{\left\langle\frac{1}{\left|1+\frac{\omega^2}{g^2}\left(\delta-\frac{\chi_{\mathbf{g}}\chi_{-\mathbf{g}}}{\delta}\right)+2\frac{\omega}{g^2}\mathbf{eg}\right|^2}\right\rangle-\left\langle\frac{1}{\left|1+\frac{\omega^2}{g^2}\left(\delta-\frac{\chi_{\mathbf{g}}\chi_{-\mathbf{g}}}{\delta}\right)+2\frac{\omega}{g^2}\mathbf{eg}\right|}\right\rangle^2\right\},\tag{15}$$

where $\delta=\gamma^{-2}-\chi_0+\theta^2$, brackets $\langle\rangle$ mean averaging over the angular distribution of $\mathbf{g}$. Let $\langle\mathbf{g}\rangle=-\mathbf{e}g\cos\eta\approx-\mathbf{e}g(1-\frac{1}{2}\eta^2)$, that is to say, the velocity of a fast electron $\mathbf{V}$ is perpendicular to average position of graphic crystallographic plane. Using for two-dimensional mosaicity angle $\vec{\eta}\equiv(\eta,\varphi)$ the distribution function $f(\eta,\varphi)\mathrm{d}\eta\,\mathrm{d}\varphi=(\eta/\pi\langle\eta^2\rangle)\exp(-\eta^2/\langle\eta^2\rangle)\mathrm{d}\eta\,\mathrm{d}\varphi$ one can obtain from (15) the following final expression for the dynamical transition radiation intensity

$$\omega\frac{\mathrm{d}N}{\mathrm{d}t\,\mathrm{d}\omega\,\mathrm{d}^2\theta}=2\frac{\mathrm{e}^2}{\pi^2}\frac{|\chi_{\mathbf{g}}\chi_{-\mathbf{g}}|^2}{(\sigma'')^2}\frac{\theta^2}{|\delta|^4}\frac{1}{\langle l\rangle}\Phi(z,w),$$
$$\Phi(z,w)=w^2\left\{\mathrm{e}^z\int_z^\infty\frac{\mathrm{d}t\mathrm{e}^{-t}}{t^2+w^2}-\left(\mathrm{e}^z\int_z^\infty\frac{\mathrm{d}t\mathrm{e}^{-t}}{\sqrt{t^2+w^2}}\right)^2\right\},\tag{16}$$

where $z=(2/\langle\eta^2\rangle)(1-2\omega/g)$, $w=\sigma''/2\langle\eta^2\rangle$, $\sigma=-\delta+\chi_{\mathbf{g}}\chi_{-\mathbf{g}}/\delta\equiv\sigma'+\mathrm{i}\sigma''\approx\chi_0'-\gamma^{-2}-\theta^2+\mathrm{i}\chi_0'''$. The expression (16) is valid in the vicinity $\omega=g/2$. The universal function $\Phi(z,w)$ describing the spectrum of the emission being discussed is presented in Fig. 2. In accordance with Fig. 2 energies of emitted photons ω fall in the range $\omega>g/2$ for small values of the parameter w. From this figure we

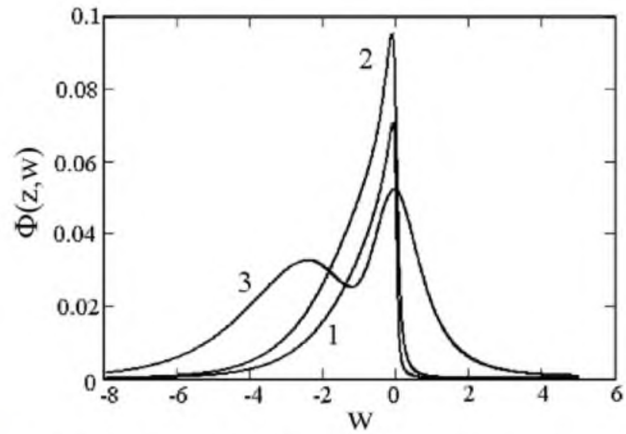

Fig. 2. Universal function describing the spectrum of dynamical transition radiation. The function $\Phi(z,w)$ and its arguments are determined in Eq. (16). The curve **1** corresponds to the value of the parameter $w = .1$, **2** – $w = .05$, **3** – $w = 1$.

notice that the dynamical transition radiation is realized as a sharp peak in conditions $w^2 \ll 1$ under consideration. On the other hand, the spectral peak spreads out and its amplitude decreases proportional to w^{-4} in the range $w > 1$ as it follows from (16).

Let us estimate the yield of dynamical transition radiation. Using typical values for the parameters $\chi_g \sim \chi_0' \sim 10^{-5} - 10^{-6} \gg \gamma^{-2}$, $\sigma'' \sim \chi_0' \sim 10^{-6} - 10^{-7}$, $\langle l \rangle \sim 2 \times 10^{-4}$ cm one can obtain the following estimation for the emission yield $\mathrm{d}N/\mathrm{d}t\,\mathrm{d}\omega \sim 5 \times 10^{-7}$ phot/el eV cm.

It is important to keep in mind that the formula (16) does not take into account an interference between elementary waves emitted from interfaces between different microcrystals. Such interference is slow and can be neglected with the proviso that the emission formation length $l_{\mathrm{coh}} \sim 2/\omega(\gamma^{-2} - \chi_0) \sim 2\omega/\omega_0^2$ is much less than $\langle l \rangle$ (ω_0 is the plasma frequency of the target). It is easy to verify that the condition $l_{\mathrm{coh}} \ll \langle l \rangle$ is valid for chosen parameters of graphite target.

4. Conclusions

In accordance with performed analysis replacement of an amorphous radiator by a polycrystalline one can change substantially the properties of such emission mechanisms from relativistic electrons as bremsstrahlung and transition radiation.

Characteristics of bremsstrahlung from amorphous and polycrystalline media are practically the same in the case of fully accidentally oriented microcrystals comprising the pollycrystalline target. On the other hand, bremsstrahlung from textured polycrystal can differ substantially from that of amorphous target. Such difference is caused by the contribution of coherent bremsstrahlung from incident electrons on atomic strings in the target.

Relativistic electrons moving through a polycrystalline target can emit transition radiation waves on interfaces between different microcrystals comprising the target. The emission being discussed appears due to the dynamical diffraction effects only and has large enough intensity, so that it may be observed.

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