COHERENT X-RAY RADIATION BY RELATIVISTIC ELECTRON IN A STRUCTURE "AMORPHOUS LAYER – PERIODIC LAYERED MEDIUM"

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The dynamic theory of coherent X-ray radiation by relativistic electron crossing a two-layer structure consisting of an amorphous layer and a layer with artificial periodic structure has been developed. The process of radiation and propagation of X-ray waves in an artificial periodic structure has been considered based on two-wave approximation of dynamic diffraction theory in Laue scattering geometry.

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INTRODUCTION

When a relativistic electron crosses an amorphous plate, the transition radiation (TR) arises near the boundaries of the plate and then the TR photons propagate at a small angle to direction of electron velocity vector [1]. In the case of a monocrystalline plate, the TR will undergo the dynamical diffraction on a system of atomic planes in the crystal and will be reflected in the Bragg direction, forming the diffracted transition radiation (DTR) [2 - 5]. By analogy with DTR in the crystal, an electron crossing periodic layered medium generates TR whose photons diffract on system of layers of periodical layered medium in the plate forming the DTR in the direction near Bragg direction [6]. Together with DTR in layered media the parametric X-ray radiation (PXR) [7 - 9] occurs as a result of diffraction of pseudo-photons of coulomb field of relativistic electron on the system of parallel atomic plane in the crystal or on the system of layers in the multilayered target.

A theory of coherent X-ray radiation generated by a relativistic electron in the crystal were developed in the network of two wave approximation of dynamical theory of X-ray waves diffraction in the works [10 - 14]. In the works [10, 11] the coherent X-ray radiation was treated in special case of symmetric reflection, when the reflecting system of atomic planes of the crystal is situated parallel to the target surface (in the case of Bragg scattering geometry) or perpendicular (in the case of Laue scattering geometry). In the works [12 - 14] the dynamic theory of coherent X-ray radiation of relativistic electron in crystal was developed for the general case of asymmetric to relate of the crystal surface reflection of the electron coulomb field, when a system of parallel reflecting atomic planes in the target can be situated at arbitrary angle to the target surface.

Traditionally the radiation of relativistic electron was considered in a separated amorphous, crystalline or multilayer target. A theoretical description of coherent radiation of relativistic electron in composite targets was not considered previously. The experimental research of generation of coherent X-ray radiation [15 - 19] in composite structures had shown the possibilities of considerable increase of intensity of DTR yield because of increase of target boundaries number.

Recently in [20 - 22] the theory of coherent X-ray radiation of relativistic electron crossing composite structure "amorphous layer – crystalline layer" and "amorphous layer-vacuum-crystalline layer" was developed in framework of dynamic theory of diffraction. The expressions describing DTR and PXR of relativistic electron in such structures were derived and investigated. The possibility of considerable increase of spectral-angular density of DTR because of constructive interference of TR on the target boundaries was shown.

The present work is devoted to investigation of coherent X-ray radiation of relativistic electron crossing the two-layer structure "amorphous layer – periodic layered medium". In the framework of two-wave approximation of dynamic diffraction theory of X-ray waves in the single crystal the expressions describing the spectral-angular characteristics of the radiation in such structures are derived. The expressions describing the DTR and PXR spectral-angular densities and their interference in the considered structure have been obtained for general case of asymmetric reflection of the electron coulomb field from the layer with artificial periodic structure.

RESULTS AND DISCUSSION

1. RADIATION AMPLITUDE

Let us consider the radiation generated by a relativistic electron crossing rectilinearly with a velocity $\mathbf{V}$ a two-layer structure consisting of an amorphous layer (of thickness a) and a layer with artificial periodic structure (of thickness b) (Fig. 1).

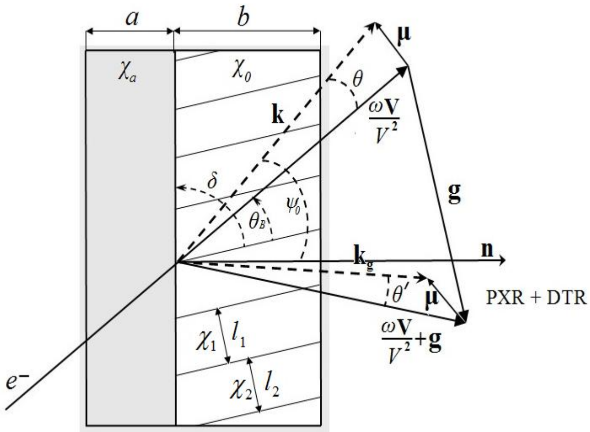

Fig. 1. Geometry of the radiation process and the system of the using parameters notations, θ and θ' are the radiation angles, θ_B is Bragg angle, $\mathbf{k}$ and $\mathbf{k}_g$ are wave vectors of incident and diffracted photons

The dielectric susceptibility of the amorphous layer we will designate as χ_a respectively. The dielectric susceptibility of layers in periodical layered structure are χ_1 and χ_2, and their thicknesses are l_1 and l_2, the period is $T = l_1 + l_2$.

While solving the problem, let us consider an equation for a Fourier image of an electromagnetic field

$$\mathbf{E}(\mathbf{k},\omega) = \int dt\, d^3\mathbf{r}\, \mathbf{E}(\mathbf{r},t)\exp\left(i\omega t - i\mathbf{k}\mathbf{r}\right). \qquad (1)$$

Since the field of a relativistic particle could, to a good accuracy, be taken as being transverse, the incident $\mathbf{E}_0(\mathbf{k},\omega)$ and diffracted $\mathbf{E}_\mathbf{g}(\mathbf{k},\omega)$ electromagnetic waves are determined by two amplitudes with different values of transverse polarization:

$$\begin{aligned} &\mathbf{E}_0(\mathbf{k},\omega) = E_0^{(1)}(\mathbf{k},\omega)\mathbf{e}_0^{(1)} + E_0^{(2)}(\mathbf{k},\omega)\mathbf{e}_0^{(2)}, \\ &\mathbf{E}_\mathbf{g}(\mathbf{k},\omega) = E_\mathbf{g}^{(1)}(\mathbf{k},\omega)\mathbf{e}_1^{(1)} + E_\mathbf{g}^{(2)}(\mathbf{k},\omega)\mathbf{e}_1^{(2)}, \end{aligned} \qquad (2)$$

where the unit vectors of polarization $\mathbf{e}_0^{(1)}$ and $\mathbf{e}_0^{(2)}$ are perpendicular to vector $\mathbf{k}$, and vectors $\mathbf{e}_1^{(1)}$ and $\mathbf{e}_1^{(2)}$ are perpendicular to vector $\mathbf{k}_g = \mathbf{k} + \mathbf{g}$. Vectors $\mathbf{e}_0^{(2)}$, $\mathbf{e}_1^{(2)}$ are situated on the plane of vectors $\mathbf{k}$ and $\mathbf{k}_g$ (π-polarization) and $\mathbf{e}_0^{(1)}, \mathbf{e}_1^{(1)}$ are perpendicular to this plane (σ-polarization); $\mathbf{g}$ is similar to the reciprocal lattice vector in a single crystal medium – it is perpendicular to the layers of the structure and its magnitude is $g = \frac{2\pi}{T}n$, $n = 0, \pm 1, \pm 2, \ldots$

The system of equation for the Fourier transform images of electromagnetic field in two-wave approximation of dynamic theory of diffraction has the following view [23]:

$$\begin{cases} (\omega^2(1+\chi_0) - k^2)E_0^{(s)} + \omega^2\chi_{-\mathbf{g}}C^{(s)}E_\mathbf{g}^{(s)} = \\ = 8\pi^2 ie\omega\theta VP^{(s)}\delta(\omega - \mathbf{kV}), \\ \omega^2\chi_\mathbf{g}C^{(s)}E_0^{(s)} + (\omega^2(1+\chi_0) - k_\mathbf{g}^2)E_\mathbf{g}^{(s)} = 0, \end{cases} \qquad (3)$$

where $\chi_0 = \chi_0' + i\chi_0''$ is the average dielectric susceptibility, $\chi_\mathbf{g}$ and $\chi_{-\mathbf{g}}$ are the coefficients of the Fourier expansion of the dielectric susceptibility of the artificial periodic structure over the vectors $\mathbf{g}$:

$$\begin{aligned} \chi(\omega,\mathbf{r}) &= \sum_\mathbf{g} \chi_\mathbf{g}(\omega)\exp(i\mathbf{gr}) = \\ &= \sum_\mathbf{g} \left(\chi_\mathbf{g}'(\omega) + i\chi_\mathbf{g}''(\omega)\right)\exp(i\mathbf{gr}). \end{aligned} \qquad (4)$$

The values $C^{(s)}$ and $P^{(s)}$ are defined in the system (3) as

$$\begin{aligned} &C^{(s)} = \mathbf{e}_0^{(s)}\mathbf{e}_1^{(s)},\ C^{(1)} = 1,\ C^{(2)} = \cos 2\theta_B, \\ &P^{(s)} = \mathbf{e}_0^{(s)}(\boldsymbol{\mu}/\mu),\ P^{(1)} = \sin\varphi,\ P^{(2)} = \cos\varphi, \end{aligned} \qquad (5)$$

where $\boldsymbol{\mu} = \mathbf{k} - \omega\mathbf{V}/V^2$ is the virtual photon momentum vector component perpendicular to the particle velocity vector $\mathbf{V}$ ($\mu = \omega\theta/V$), where $\theta << 1$ is the angle between $\mathbf{k}$ and $\mathbf{V}$), θ_B is the Bragg angle, φ is the azimuthal angle of incidence of radiation measured from the plane formed by electron velocity vector $\mathbf{V}$ and vector $\mathbf{g}$, the value of the vector $\mathbf{g}$ is shown by expression $g = 2\omega_B \sin\theta_B / V$, ω_B is Bragg's frequency. The angle between vector $\frac{\omega\mathbf{V}}{V^2} + \mathbf{g}$ and diffracted wave vector $\mathbf{k}_\mathbf{g}$ is defined as θ'. The equation system (3) under s=1, describes the fields of σ-polarization, and under s=2 the fields of π-polarization.

The values χ_0 and $\chi_\mathbf{g}$ for considered periodic structure have the following view:

$$\begin{aligned} &\chi_0(\omega) = \frac{l_1\chi_1 + l_2\chi_2}{T}, \\ &\chi_\mathbf{g}(\omega) = \frac{\exp\left(-igl_1\right) - 1}{igT}\left(\chi_2 - \chi_1\right). \end{aligned} \qquad (6)$$

If we perform the analytical procedures similar to those used in [20, 21] we will obtain the expressions for the radiation amplitude. As the result the expression for the radiation amplitude $E_\mathbf{g}^{(s)Rad} = E_{DTR}^{(s)} + E_{PXR}^{(s)}$ contained the contributions of PXR and DTR radiation mechanisms was derived:

$$E_\mathbf{g}^{(s)Rad} = E_{\mathrm{DTR}}^{(s)} + E_{\mathrm{PXR}}^{(s)}, \qquad (7a)$$

$$E_{\mathrm{PXR}}^{(s)} = \frac{8\pi^2 ieV\theta P^{(s)}}{\omega}\frac{\omega^2\chi_\mathbf{g}C^{(s)}}{2\omega\frac{\gamma_0}{\gamma_\mathbf{g}}\left(\lambda_\mathbf{g}^{(1)} - \lambda_\mathbf{g}^{(2)}\right)}\exp\left(i\left(\frac{\omega\chi_0}{2} + \lambda_\mathbf{g}^*\right)\frac{(a+b)}{\gamma_\mathbf{g}}\right)\cdot\left[\left(\frac{1}{\chi_0 - \theta^2 - \gamma^{-2}} + \frac{\omega}{2\frac{\gamma_0}{\gamma_\mathbf{g}}\left(\lambda_\mathbf{g}^* - \lambda_\mathbf{g}^{(1)}\right)}\right)\times\right.$$

$$\left.\times\left(\exp\left(i\frac{\lambda_\mathbf{g}^{(1)} - \lambda_\mathbf{g}^*}{\gamma_\mathbf{g}}b\right) - 1\right) - \left(\frac{1}{\chi_0 - \theta^2 - \gamma^{-2}} + \frac{\omega}{2\frac{\gamma_0}{\gamma_\mathbf{g}}\left(\lambda_\mathbf{g}^* - \lambda_\mathbf{g}^{(2)}\right)}\right)\times\left(\exp\left(i\frac{\lambda_\mathbf{g}^{(2)} - \lambda_\mathbf{g}^*}{\gamma_\mathbf{g}}b\right) - 1\right)\right], \qquad (7b)$$

$$E_{\mathrm{DTR}}^{(s)} = \frac{8\pi^2 ieV\theta P^{(s)}}{\omega}e^{\left(i\left(\frac{\omega\chi_0}{2} + \lambda_\mathbf{g}^*\right)\frac{(a+b)}{\gamma_\mathbf{g}}\right)}\cdot\frac{\omega^2\chi_\mathbf{g}C^{(s)}\left(\exp\left(i\frac{\lambda_\mathbf{g}^{(1)} - \lambda_\mathbf{g}^*}{\gamma_\mathbf{g}}b\right) - \exp\left(i\frac{\lambda_\mathbf{g}^{(2)} - \lambda_\mathbf{g}^*}{\gamma_\mathbf{g}}b\right)\right)}{2\omega\frac{\gamma_0}{\gamma_\mathbf{g}}\left(\lambda_\mathbf{g}^{(1)} - \lambda_\mathbf{g}^{(2)}\right)}\times$$

$$\times\left[\left(\frac{1}{\theta^2 + \gamma^{-2} - \chi_a} - \frac{1}{\theta^2 + \gamma^{-2}}\right)\cdot\exp\left(-i\frac{\omega\grave{a}}{2\gamma_0}\left(\theta^2 + \gamma^{-2} - \chi_a\right)\right) + \left(\frac{1}{\chi_a - \theta^2 - \gamma^{-2}} - \frac{1}{\chi_0 - \theta^2 - \gamma^{-2}}\right)\right], \qquad (7c)$$

where

$$\lambda_{\mathbf{g}}^{(1,2)} = \frac{\omega}{4}\left(\beta \pm \sqrt{\beta^2 + 4\chi_{\mathbf{g}}\chi_{-\mathbf{g}}C^{(s)^2}\frac{\gamma_{\mathbf{g}}}{\gamma_0}}\right),\ \beta = \frac{1}{\omega^2}(k_{\mathbf{g}}^2 - k^2) - \chi_0\left(1 - \frac{\gamma_{\mathbf{g}}}{\gamma_0}\right),$$

$$\lambda_{\mathbf{g}}^* = \frac{\omega\beta}{2} + \frac{\gamma_{\mathbf{g}}}{\gamma_0}\lambda_0^*,\ \gamma_0 = \cos\psi_0,\ \gamma_{\mathbf{g}} = \cos\psi_{\mathbf{g}},\ \lambda_0^* = \omega\left(\frac{\gamma^{-2} + \theta^2 - \chi_0}{2}\right), \quad (8)$$

ψ_0 is the angle between incident wave vector **k** and vector normal to the plate surface **n**, ψ_g is the angle between wave vector $\mathbf{k}_g$ and the vector **n** (see Fig. 1). As the dynamical corrections $|\lambda_0| << \omega$ and $|\lambda_{\mathbf{g}}| << \omega$, we can show that $\theta \approx \theta'$ (see Fig. 1), and hereinafter will use θ in all the occasions.

2. SPECTRAL-ANGULAR DENSITY OF RADIATION

To clarify and analyze the effects that are not associated with absorption, we consider a simple case of a thin nonabsorbing target ($\chi_0'' = \chi_a'' = 0$). From (7) we have obtained the expressions for the spectral-angular density of PXR and DTR in the propagation direction of the emitted photon $\mathbf{k}_{\mathbf{g}} = k_{\mathbf{g}}\mathbf{n}_{\mathbf{g}}$ (see Fig. 1):

$$\omega\frac{d^2N_{\mathrm{PXR}}^{(s)}}{d\omega d\Omega} = \frac{e^2}{4\pi^2}\frac{P^{(s)^2}}{|\chi_0'|}\cdot\frac{\Omega^2}{(\Omega_0^2+1)^2}R_{\mathrm{PXR}}^{(s)}, \quad (9a)$$

where the expression $R_{\mathrm{PXR}}^{(s)}$ describing PXR spectrum has a view

$$R_{\mathrm{PXR}}^{(s)} = 4\left(1 - \frac{\xi}{\sqrt{\xi^2+\varepsilon}}\right)^2 \frac{\sin^2\left(\frac{B^{(s)}}{2}\left(\sigma^{(s)} + \frac{\xi - \sqrt{\xi^2+\varepsilon}}{\varepsilon}\right)\right)}{\left(\sigma^{(s)} + \frac{\xi - \sqrt{\xi^2+\varepsilon}}{\varepsilon}\right)^2}, \quad (9b)$$

$$\omega\frac{d^2N_{\mathrm{DTR}}^{(s)}}{d\omega d\Omega} = T_{DTR}^{(s)} = T_1^{(s)} + T_2^{(s)} + T_{\mathrm{int}}^{(s)}, \quad (10a)$$

$$T_1^{(s)} = \frac{e^2}{4\pi^2}\frac{P^{(s)^2}}{|\chi_0'|}\Omega^2\left(\frac{1}{\Omega_0^2} - \frac{1}{\Omega_0^2 + \frac{\chi_a'}{\chi_0'}}\right)^2 R_{\mathrm{DTR}}^{(s)}, \quad (10b)$$

$$T_2^{(s)} = \frac{e^2}{4\pi^2}\frac{P^{(s)^2}}{|\chi_0'|}\Omega^2\left(\frac{1}{\Omega_0^2 + \frac{\chi_a'}{\chi_0'}} - \frac{1}{\Omega_0^2+1}\right)^2 R_{\mathrm{DTR}}^{(s)}, \quad (10c)$$

$$T_{\mathrm{int}}^{(s)} = \frac{e^2}{4\pi^2}\frac{P^{(s)^2}}{|\chi_0'|}2\Omega^2\left(\frac{1}{\Omega_0^2} - \frac{1}{\Omega_0^2 + \frac{\chi_a'}{\chi_0'}}\right)\left(\frac{1}{\Omega_0^2 + \frac{\chi_a'}{\chi_0'}} - \frac{1}{\Omega_0^2+1}\right)\cos\left(B^{(s)}\cdot\frac{a}{b}\cdot\frac{1}{\nu^{(s)}}\left(\Omega_0^2 + \frac{\chi_a'}{\chi_0'}\right)\right)R_{\mathrm{DTR}}^{(s)}, \quad (10d)$$

where the expression describing DTR spectrum has the following view

$$R_{\mathrm{DTR}}^{(s)} = \frac{4\varepsilon^2}{\xi^{(s)}(\omega)^2 + \varepsilon}\sin^2\left(\frac{B^{(s)}\sqrt{\xi^{(s)}(\omega)^2+\varepsilon}}{\varepsilon}\right). \quad (10,e)$$

In expressions (9-10) following notations are accepted

$$\Omega_0^2 = \Omega^2 + \Gamma^2,\ \Omega = \frac{\theta}{\sqrt{|\chi_0'|}},\ \Gamma = \frac{1}{\gamma\sqrt{|\chi_0'|}},$$

$$B^{(s)} = \frac{1}{2\sin(\delta - \theta_B)}\frac{b}{L_{ext}^{(s)}},$$

$$\sigma^{(s)} = \frac{\pi n}{C^{(s)}|\chi_2' - \chi_1'|\left|\sin\left(\frac{\pi n}{1+r}\right)\right|}\left(\theta^2 + \gamma^{-2} - \chi_0'\right),$$

$$\xi^{(s)}(\omega) = \frac{2\pi^2 n^2}{T^2\omega_B}L_{ext}^{(s)}\left(1 - \frac{\omega}{\omega_B}\left(1 - \theta_{//}\sqrt{\frac{T^2\omega_B^2}{\pi^2 n^2} - 1}\right)\right) + \frac{1-\varepsilon}{2\nu^{(s)}},$$

$$L_{ext}^{(s)} = \frac{1}{C^{(s)}\omega}\frac{\pi n}{\left|\sin\left(\frac{\pi n}{1+r}\right)\right||\chi_2' - \chi_1'|},\ \varepsilon = \frac{\sin(\delta+\theta_B)}{\sin(\delta-\theta_B)},$$

$$\nu^{(s)} = \frac{C^{(s)}\left|\sin\left(\frac{\pi n}{1+r}\right)\right|}{\frac{\pi n}{1+r}}\left|\frac{\chi_2' - \chi_1'}{\chi_1' + r\chi_2'}\right|,\ \chi_0' = \frac{l_1\chi_1' + l_2\chi_2'}{T},$$

$$r = \frac{l_2}{l_1}. \quad (11)$$

Parameter $B^{(s)}$ is a half of the electron path in crystal layer expressed in the extinction lengths of wave in the crystal $L_{ext}^{(s)}$.

In (10,a) the quantity $T_{DTR}^{(s)}$ is presented as sum of the terms describing the diffracted radiation from the first and second boundaries, $T_1^{(s)}$ and $T_2^{(s)}$ correspondingly and their interference summand $T_{\mathrm{int}}^{(s)}$.

The interference of PXR and DTR mechanisms may considerably effects spectral-angular density of the resulting radiation. Using (7,b) and (7,c) we will obtain the expression describing the interference of the radiation mechanisms DTR and PXR in two-layer structure

$$\omega\frac{d^2N_{INT}^{(s)}}{d\omega d\Omega} = \frac{e^2}{4\pi^2}\frac{P^{(s)^2}}{|\chi_0'|}T_{\mathrm{PXR,DTR}}^{\mathrm{int}(s)}, \quad (12a)$$

where

$$T_{\mathrm{PXR,DTR}}^{\mathrm{int}(s)} = \frac{\Omega^2}{\Omega_0^2+1}\left[\left(\frac{1}{\Omega_0^2 + \chi_{\grave{a}}'/\chi_0'} - \frac{1}{\Omega_0^2}\right)R_{INT}^{(s)(1)} + \left(\frac{1}{\Omega_0^2+1} - \frac{1}{\Omega_0^2 + \chi_{\grave{a}}'/\chi_0'}\right)R_{INT}^{(s)(2)}\right], \quad (12b)$$

$$R_{INT}^{(s)(1)} = 8\varepsilon \frac{\xi^{(s)} - \sqrt{\xi^{(s)2} + \varepsilon}}{\xi^{(s)2} + \varepsilon} \frac{1}{\Sigma_1^{(s)}} \sin\left(\frac{B^{(s)}\sqrt{\xi^2 + \varepsilon}}{\varepsilon} \right) \sin\left(\frac{B^{(s)}}{2} \Sigma_1^{(s)} \right) \cos\left(\frac{B^{(s)}}{2} \left(\frac{2\grave{a}}{b} \cdot \frac{1}{\nu^{(s)}} \left(\Omega_0^2 + \frac{\chi'_a}{\chi'_0} \right) + \Sigma_2^{(s)} \right) \right), \quad (12c)$$

$$R_{INT}^{(s)(2)} = 8\varepsilon \frac{\xi^{(s)} - \sqrt{\xi^{(s)2} + \varepsilon}}{\xi^{(s)2} + \varepsilon} \frac{1}{\Sigma_1^{(s)}} \sin\left(B^{(s)} \frac{\sqrt{\xi^2 + \varepsilon}}{\varepsilon} \right) \sin\left(\frac{B^{(s)}}{2} \Sigma_1^{(s)} \right) \cos\left(\frac{B^{(s)}}{2} \Sigma_2^{(s)} \right), \quad (12d)$$

where

$$\Sigma_2^{(s)} = \sigma^{(s)} + \left(\xi^{(s)} + \sqrt{\xi^{(s)2} + \varepsilon} \right) / \varepsilon,$$

$$\Sigma_1^{(s)} = \sigma^{(s)} + \left(\xi^{(s)} - \sqrt{\xi^{(s)2} + \varepsilon} \right) / \varepsilon \, . \quad (13)$$

The contributions of interference terms in the radiation spectrum $R_{INT}^{(s)(1)}$ and $R_{INT}^{(s)(2)}$ describe the interference of PXR and DTR from the first boundary of amorphous layer and PXR and DTR from the boundary between amorphous and periodic layered medium layers correspondently. The expressions (9), (10) and (12), described the spectral-angular characteristics of PXR and DTR of relativistic electrons crossing a thin non-absorptive bilayer structure and their interference summand is the main result of the present work. These expressions can be used for analyze of spectral-angular properties of PXR and DTR in considered bilayer structure and effects of their interference. Particularly, we can study the contribution of the TR X-ray waves separately from the first and the second boundaries of the structure to DTR, and also the interference of PXR and DTR.

3. NUMERICAL CALCULATIONS

As example we will demonstrate an opportunity of soft X-Ray wave generation in such a structure. Let an relativistic electron with energy *E*=250 MeV cross the bilayer structure consisted of amorphous tungsten (W) layer of depth *a*=1 μm and periodical layered structure "carbon – tungsten" (C-W) with period *T*=0.01 μm.

Let us choose the angle between layers of the periodic layered medium and the target surface δ=10° and angle between electron velocity vector and reflecting layers θ_B=5°. The calculations we will carry out for σ-polarized waves (*s*=1) under value of the azimuthal angle of electron incidence $\varphi=\pi/2$, and harmonica number *n*=1.

The curves in Fig. 2 plotted by formulae (10,a) describe the DTR spectral density under fixed observation angle under maximum of angular density of DTR (θ=2 mrad). The curves are calculated for different value of layer thickness *b* in layered medium and really show the possibility of the generation of intensive beam of soft X-Ray photons in considered bilayer target.

The curves in Fig. 3 describe the DTR spectral density under fixed thickness *b*=1 μm and different relation ratio l_2/l_1 (see Fig. 1). One can see that under increase of ratio l_2/l_1 i.e. under increase of thickness of tungsten layer and decrease of carbon layer the DTR became more monochromatic.

In Fig. 4 the curves demonstrate the dependence of angular density of DTR in soft X-Ray diapason on relation of layer thicknesses in periodic layered structure. The curves are calculated by expression (10,a) integrated by variable $\frac{d\omega}{\omega}$.

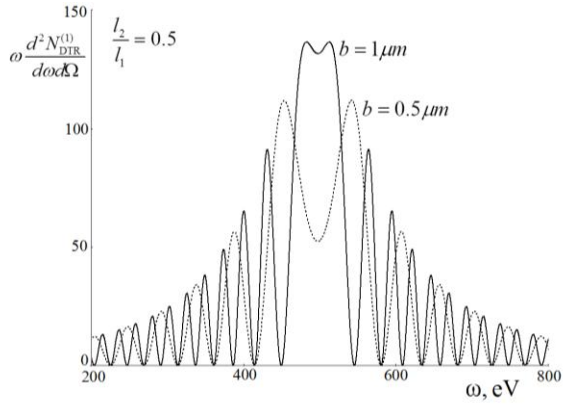

Fig. 2. DTR angular density for different values of layered medium thickness b and fixed ratio l_2/l_1 and angle $\theta = 2\,mrad$

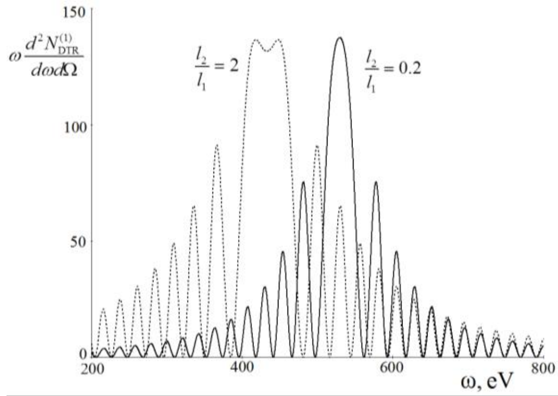

Fig. 3. DTR spectral density for different values of the ratio l_2/l_1 under fixed values $\theta = 2\,mrad$ and $b = 1\,\mu m$

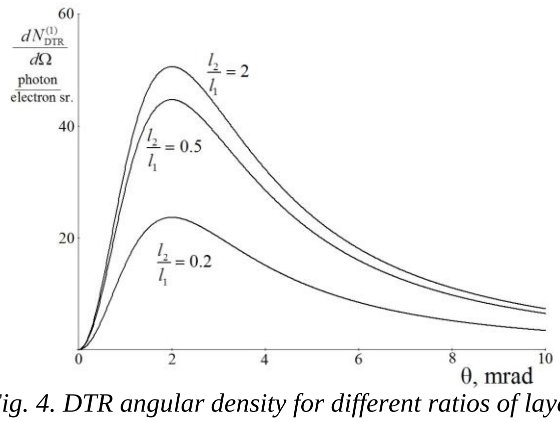

Fig. 4. DTR angular density for different ratios of layer width in layered medium under fixed value $b = 1\,\mu m$

CONCLUSIONS

In the present work the dynamic theory of coherent radiation generated by relativistic electron crossing a composite bilayer structure consisting of an amorphous layer and a layer of periodic multilayered medium has been developed. The expressions describing spectral-angular densities of PXR, DTR and their interference summand in such a structure have been obtained. The possibility of the generation of intensive beam of soft

X-ray photons in considered bilayer target has been shown. It has been shown that under change of the relation of depth of the layers in periodic layered structure the spectral-angular characteristics of DTR significantly change. The high angular density of DTR in diapason of soft X-ray radiation in considered structure has been demonstrated.

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КОГЕРЕНТНОЕ РЕНТГЕНОВСКОЕ ИЗЛУЧЕНИЕ РЕЛЯТИВИСТСКОГО ЭЛЕКТРОНА В СТРУКТУРЕ «АМОРФНЫЙ СЛОЙ – ПЕРИОДИЧЕСКАЯ СЛОИСТАЯ СРЕДА»

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Развита динамическая теория когерентного рентгеновского излучения релятивистского электрона, пересекающего двухслойную структуру, состоящую из аморфного слоя и слоя из искусственной периодической структуры. Процесс излучения и распространения рентгеновских волн в искусственной периодической структуре рассмотрен на основе двухволнового приближения динамической теории дифракции в геометрии рассеяния Лауэ.

КОГЕРЕНТНЕ РЕНТГЕНІВСЬКЕ ВИПРОМІНЮВАННЯ РЕЛЯТИВІСТСЬКОГО ЕЛЕКТРОНА В СТРУКТУРІ «АМОРФНИЙ ШАР – ПЕРІОДИЧНЕ ШАРУВАТЕ СЕРЕДОВИЩЕ»

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Розвинена динамічна теорія когерентного рентгенівського випромінювання релятивістського електрона, що перетинає двошарову структуру, що складається з аморфного шару і шару зі штучної періодичної структури. Процес випромінювання і поширення рентгенівських хвиль у штучній періодичній структурі розглянуто на основі двохвильового наближення динамічної теорії дифракції в геометрії розсіяння Лауе.