DYNAMIC THEORY OF COHERENT X-RADIATION OF RELATIVISTIC ELECTRON WITHIN A PERIODIC LAYERED MEDIUM IN BRAGG SCATTERING GEOMETRY

S. Blazhevich [1] and A. Noskov [2]

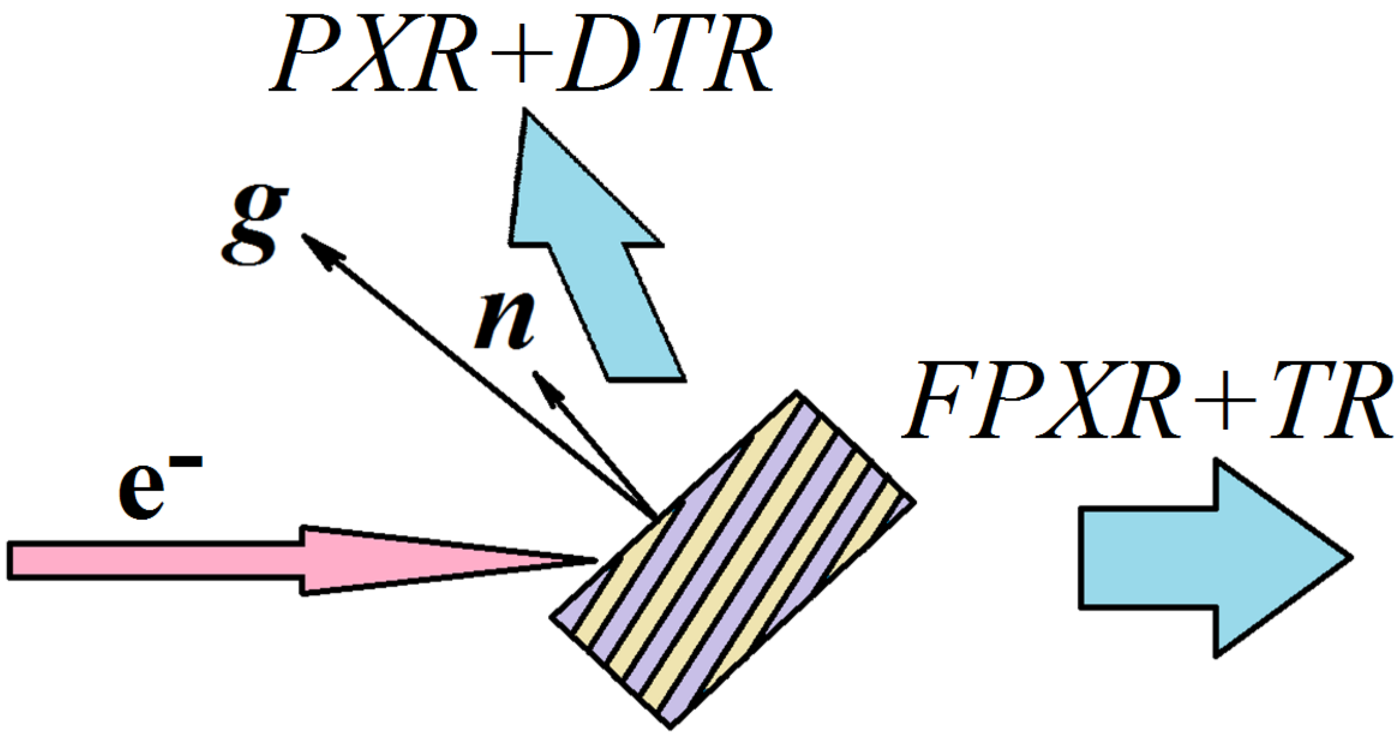
([1])*Belgorod State University, Belgorod, Russia*
([2]) *Belgorod University of Consumer's Cooperation, Belgorod, Russia*

References

- Radiation in layered medium

- As the resonance transition radiation:
- 1. Ter-MikaelianM*High-Energy Electromagnetic Process in Condensed Media* (New York: Wiley), 1972.
- 2. Piestrup M.A, Boyers D.G., C.I. Pincus et al., *Phys.Rev. A,* **45**,(1992), 1183.
- As the coulomb field pseudo photon scattering in layered medium (symmetric case):
- 3. Nasonov N.N., KaplinV.V., UglovS.R., PiestrupM.A., GaryC.K., *Phys. Rev.*68,(2003) 3604.
- by analogy with the Radiation in crystal:
  - 4. Garibian G,YangC*J. Exp. Theor. Phys.***61**, (1971)930.
  - 5. Baryshevsky V, Feranchuk I *J. Exp. Theor. Phys.***61**, (1971) 944.
  - 6. Baryshevsky V, Feranchuk I *J. Physique* (Paris) **44**,(1983) 913.
  - 7. Caticha A., *Phys.Rev. A.***40**, **(**1989) 4322.
- Pseudo photon scattering in layered medium in Laue geometry
- (general asymmetric case)
- 8. Blazhevich S.V., Kolosova I.V., Noskov A.V. *J. Exp. Theor. Phys.****114***, (2012) 547.
- 9. Blazhevich S., Noskov A. IL Nuovo Cimento Vol. 34C. Issue 04. pp 231-241.(DOI 10.1393/ncc/i2011-10922-x)
- 10. Blazhevich S., Kolosova I and Noskov A J. Phys.: Conf. Ser. 2012. V. 357, 012016 doi: 10.1088/1742-6596/357/1/012016
- 12. Blazhevich S., Noskov A. IL Nuovo Cimento Vol. 34C. Issue 04. pp 243-252. (DOI 10.1393/ncc/i2011-10970-2)

RADIATION MECHANISMS' CONTRIBUTIONS



- PXR – parametric X-radiation
- FPXR – forward-scatter PXR
- TR – transition radiation
- DRT – diffracted TR

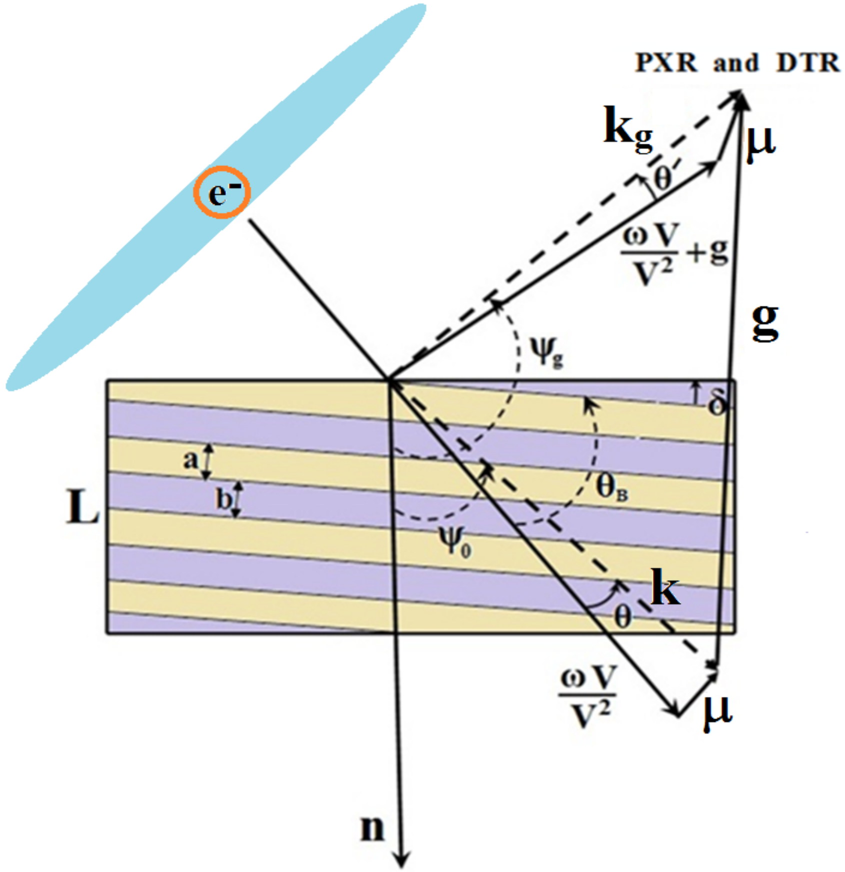
Spectral-angular density of the radiation

$$\omega \frac{d^2 N}{d\omega d\Omega} = \omega^2 (2\pi)^{-6} \sum_{s=1}^{2} \left| E_{\mathrm{Rad}}^{(s)} \right|^2$$

$$E_{\mathrm{Rad}}^{(s)} = E_{PXR}^{(s)} + E_{DTR}^{(s)}$$

$$E_{PXR}^{(s)} = E_{PXR}^{(s1)} + E_{PXR}^{(s2)}$$

Geometry of the radiation process



- **V** is electron velocity vector, **k** and $\mathbf{k_g}$ are the wave vectors of <u>incident</u> and <u>diffracted</u> pseudo-photons of the electron coulomb field

$$E_{\mathrm{Rad}}^{(s)} = E_{PXR}^{(s)} + E_{DTR}^{(\mathrm{s})}$$

$$E_{PXR}^{(s)} = \frac{8\pi^2 ieV\theta P^{(s)}}{\omega} \frac{\omega^2 \chi_{\mathbf{g}} C^{(s,\tau)}}{2\omega\left(\lambda_{\mathbf{g}}^{(2)} \exp\left(i\frac{\lambda_{\mathbf{g}}^{*} - \lambda_{\mathbf{g}}^{(2)}}{\gamma_{\mathbf{g}}}L\right) - \lambda_{\mathbf{g}}^{(1)} \exp\left(i\frac{\lambda_{\mathbf{g}}^{*} - \lambda_{\mathbf{g}}^{(1)}}{\gamma_{\mathbf{g}}}L\right)\right)} \times$$

$$\times\left[\left(\frac{2\omega \exp\left(i\frac{\lambda_{\mathbf{g}}^{*} - \lambda_{\mathbf{g}}^{(1)}}{\gamma_{\mathbf{g}}}L\right)}{4\frac{\gamma_0^2}{\gamma_{\mathbf{g}}^2}\left(\lambda_{\mathbf{g}}^{*} - \lambda_{\mathbf{g}}^{(2)}\right)} + \frac{\omega}{2\frac{\gamma_0}{|\gamma_{\mathbf{g}}|}\lambda_0^{*}}\right)\left(1 - \exp\left(i\frac{\lambda_{\mathbf{g}}^{*} - \lambda_{\mathbf{g}}^{(2)}}{\gamma_{\mathbf{g}}}L\right)\right) - \right.$$

$$\left. - \left(\frac{2\omega \exp\left(i\frac{\lambda_{\mathbf{g}}^{*} - \lambda_{\mathbf{g}}^{(2)}}{\gamma_{\mathbf{g}}}L\right)}{4\frac{\gamma_0^2}{\gamma_{\mathbf{g}}^2}\left(\lambda_{\mathbf{g}}^{*} - \lambda_{\mathbf{g}}^{(1)}\right)} + \frac{\omega}{2\frac{\gamma_0}{|\gamma_{\mathbf{g}}|}\lambda_0^{*}}\right)\left(1 - \exp\left(i\frac{\lambda_{\mathbf{g}}^{*} - \lambda_{\mathbf{g}}^{(1)}}{\gamma_{\mathbf{g}}}L\right)\right)\right],$$

$$E_{\mathrm{DTR}}^{(s)} = \frac{8\pi^2 ieV\theta P^{(s)}}{\omega} \frac{\omega^2 \chi_{\mathbf{g}} C^{(s,\tau)}}{2\omega\left(\lambda_{\mathbf{g}}^{(2)} \exp\left(-i\frac{\lambda_{\mathbf{g}}^{(2)}}{\gamma_{\mathbf{g}}}L\right) - \lambda_{\mathbf{g}}^{(1)} \exp\left(-i\frac{\lambda_{\mathbf{g}}^{(1)}}{\gamma_{\mathbf{g}}}L\right)\right)} \times$$

$$\times\left[\frac{1}{\frac{\gamma_0}{|\gamma_{\mathbf{g}}|}\left(-\chi_0 - \frac{2}{\omega}\frac{\gamma_0}{\gamma_{\mathbf{g}}}\lambda_{\mathbf{g}}^{*} + \beta\frac{\gamma_0}{\gamma_{\mathbf{g}}}\right)} + \frac{\omega}{2\frac{\gamma_0}{|\gamma_{\mathbf{g}}|}\lambda_0^{*}}\right]\left(\exp\left(-i\frac{\lambda_{\mathbf{g}}^{(2)}}{\gamma_{\mathbf{g}}}L\right) - \exp\left(-i\frac{\lambda_{\mathbf{g}}^{(1)}}{\gamma_{\mathbf{g}}}L\right)\right)$$

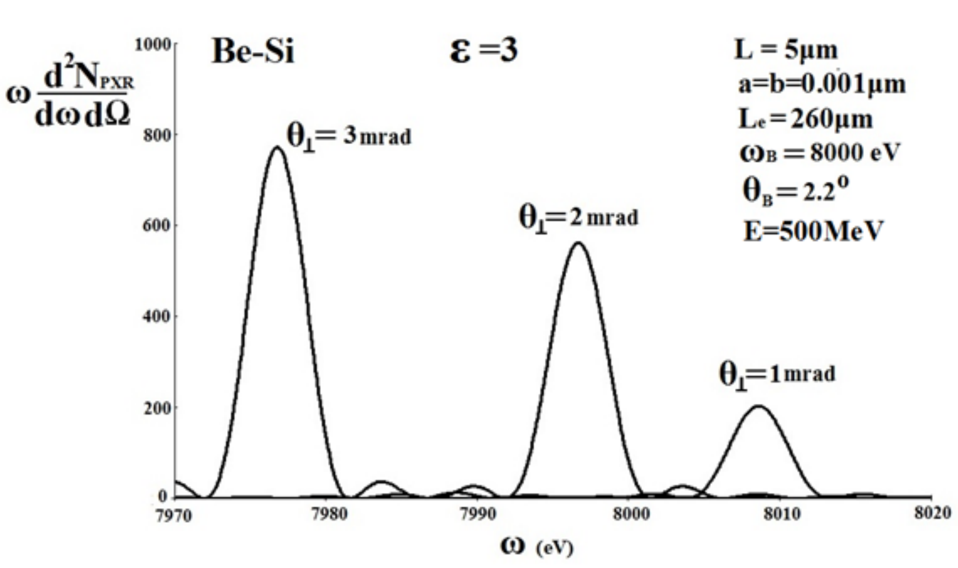
λ_0 and λ_g are the dynamic additions to the wave vectors of incident and diffraction waves correspondently

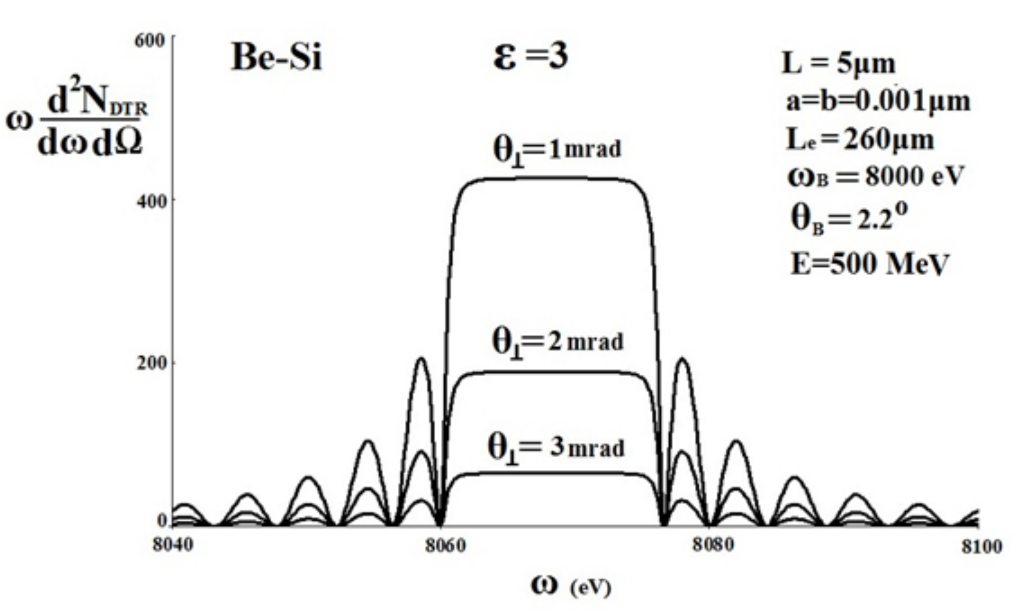
$$\mathrm{k} = \omega\sqrt{1+\chi_0} + \lambda_0 \qquad \mathrm{k}_g = \omega\sqrt{1+\chi_0} + \lambda_g$$

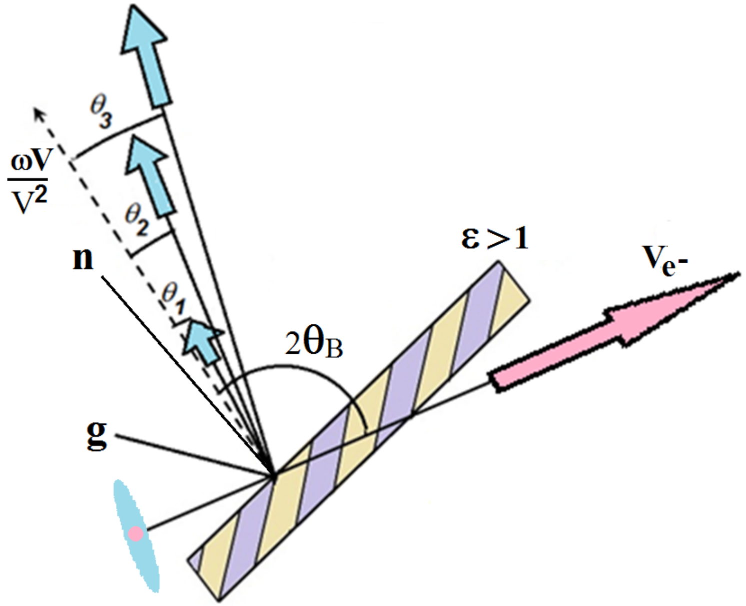
$$\lambda_g = \frac{\omega\beta}{2} + \lambda_0 \frac{\gamma_g}{\gamma_0}$$

$$\gamma_g = \cos\psi_g \qquad \gamma_0 = \cos\psi_0$$

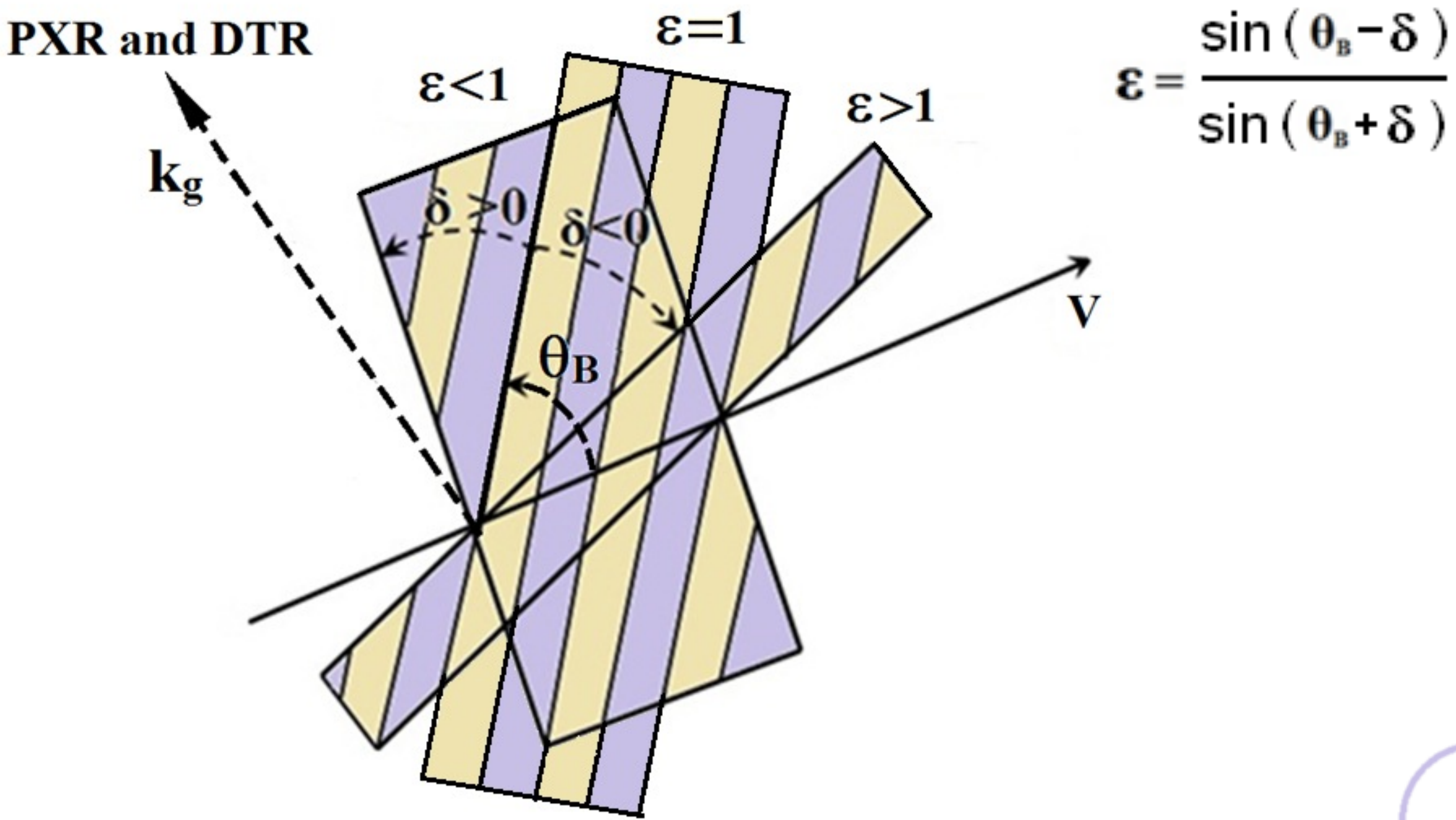
$$\beta = \alpha - \chi_0\left(1 - \frac{\gamma_g}{\gamma_0}\right) \qquad \alpha = \frac{1}{\omega^2}\left(\mathrm{k}_g{}^2 - \mathrm{k}^2\right)$$


Be-Si
ε =3
L = 5μm
a=b=0.001μm
Le=260μm
ωB = 8000 eV
θB=2.2°
E=500MeV
ω d²NPXR / dω dΩ
θ⊥= 3mrad
θ⊥=2 mrad
θ⊥=1mrad
1000
800
600
400
200
0
7970
7980
7990
8000
8010
8020
ω (eV)

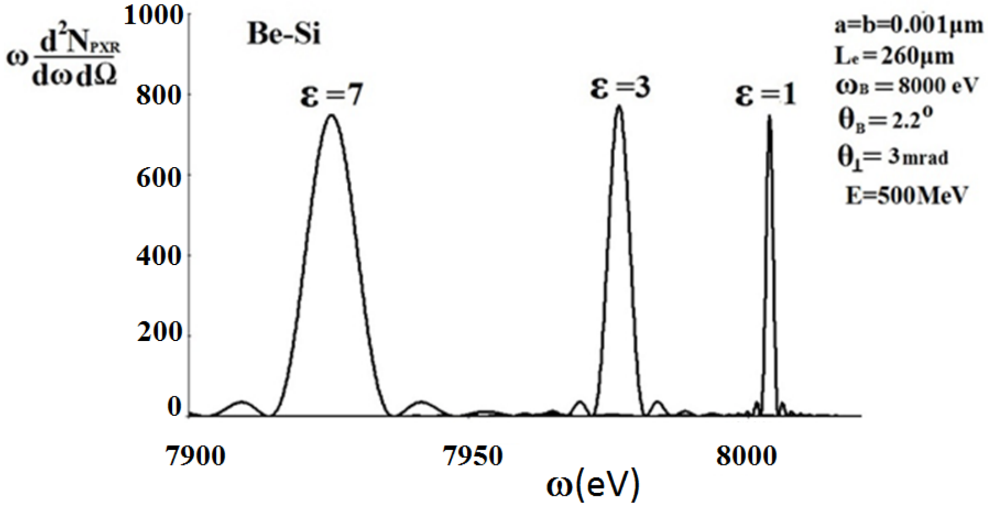

Be-Si
ε =3
L = 5μm
a=b=0.001μm
Le=260μm
ωB = 8000 eV
θB=2.2°
E=500 MeV
ω d²NDTR / dω dΩ
θ⊥=1mrad
θ⊥=2 mrad
θ⊥= 3mrad
600
400
200
0
8040
8060
8080
8100
ω (eV)

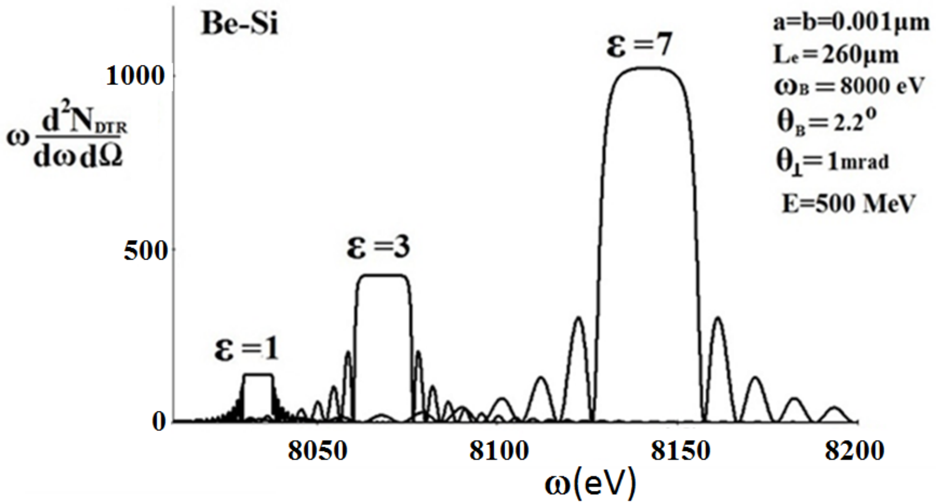

ωV / V²
n
g
θ3
θ2
θ1
2θB
ε>1
Ve-

Different multilayered targets under condition of fixed Bragg angle θ_B and the path of electron

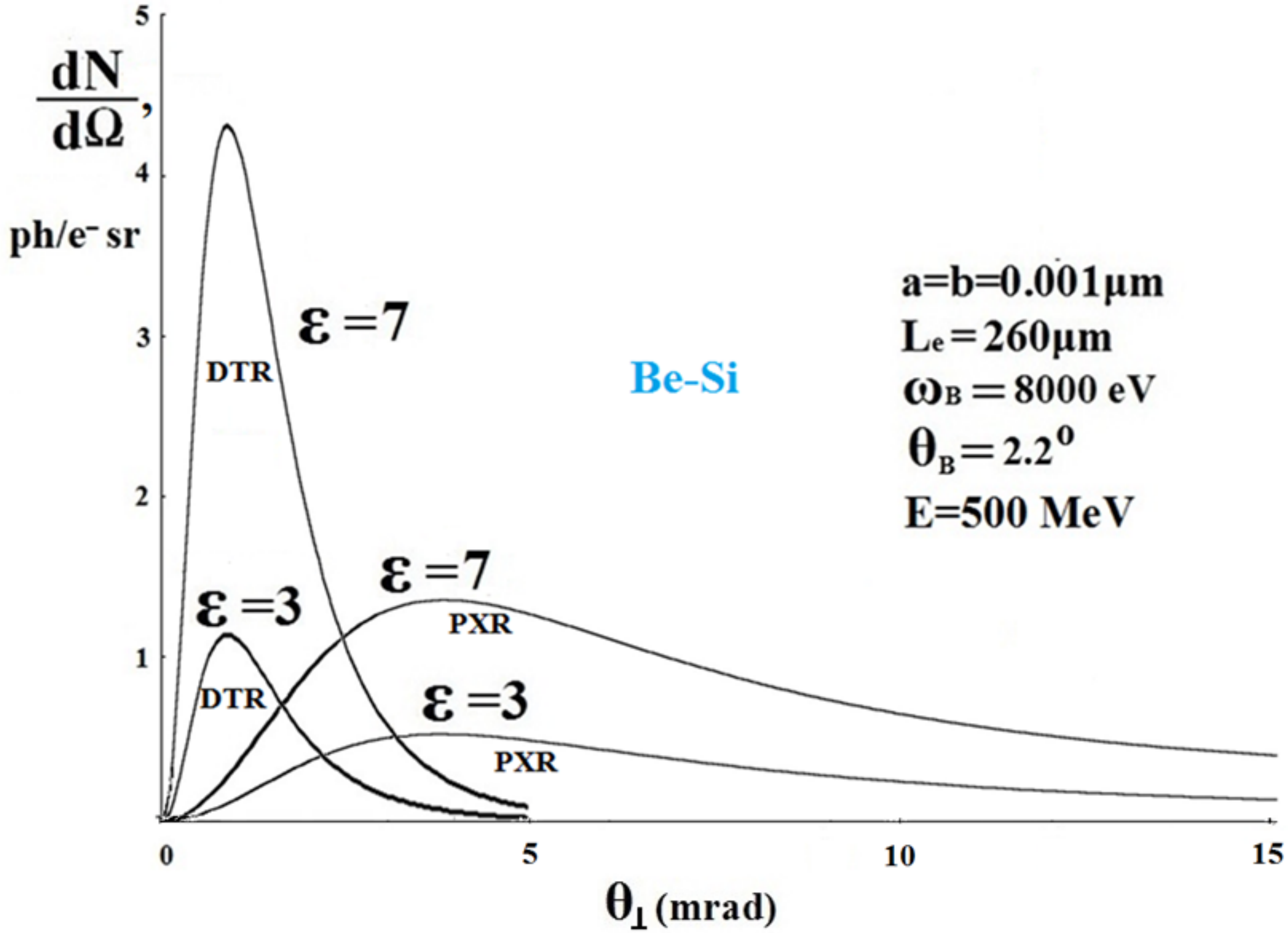


Dependence of PXR spectral-angular density on asymmetry parameter ε

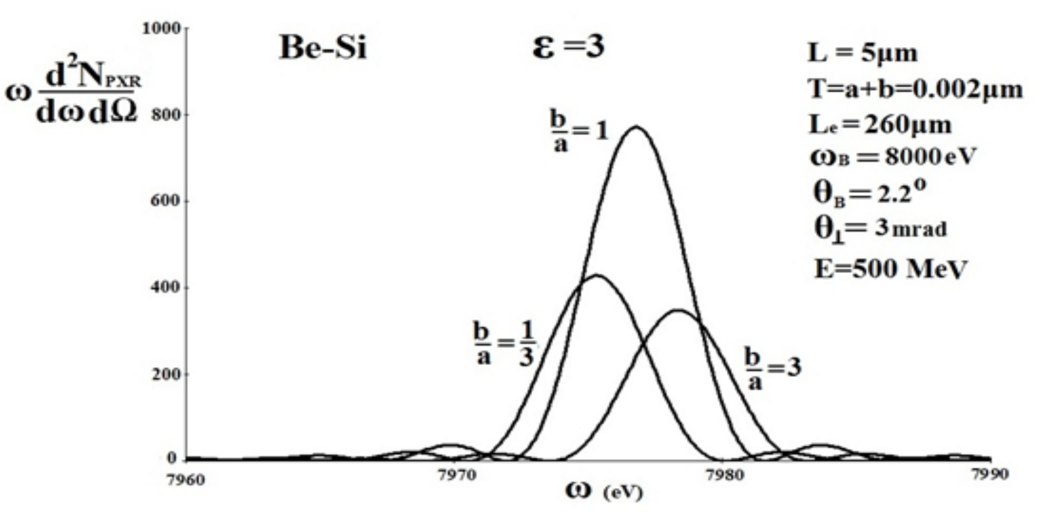


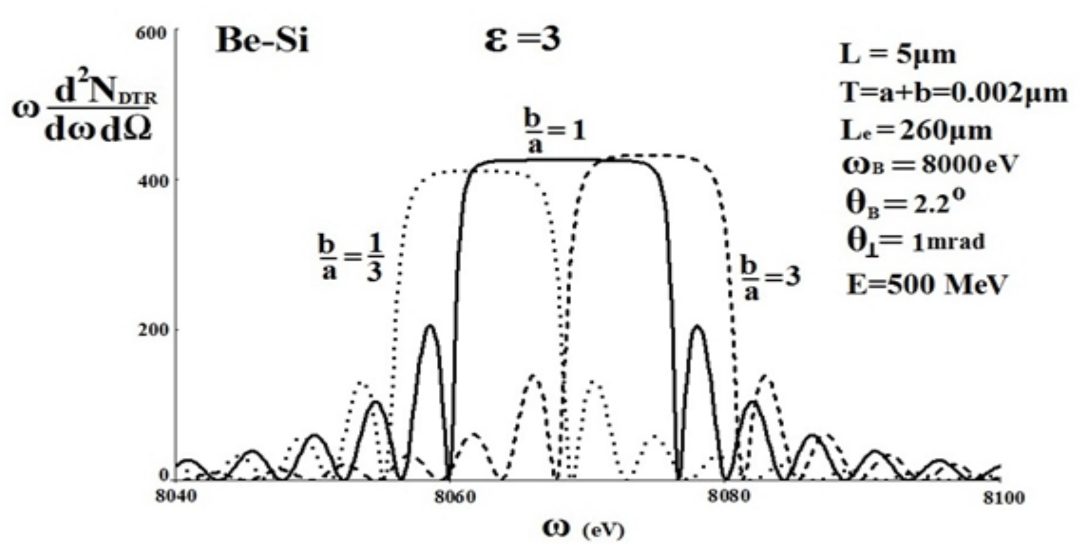


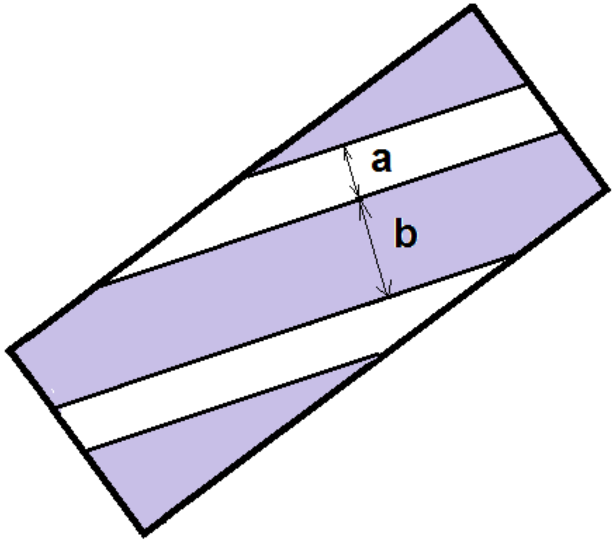
Dependences of PXR and DTR angular density on asymmetry parameter ε



Dependence of the PXR spectrum on the ratio of layers thicknesses b/a



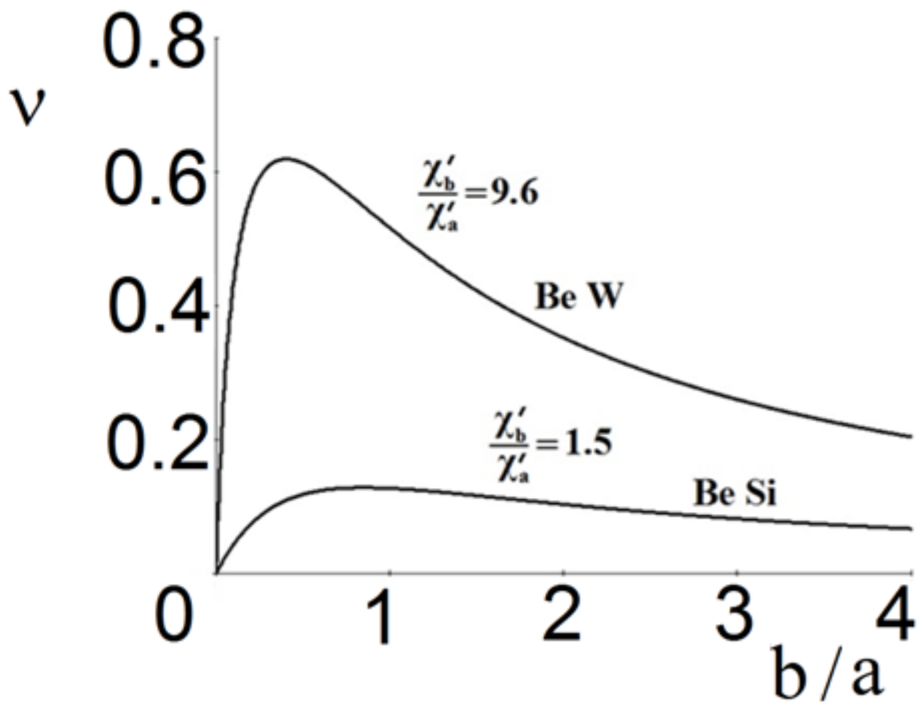




The coherent radiation efficiency (parameter ν), depending on the ratio b/a

$$\nu^{(s)} = \frac{2C^{(s)}\left|\sin\left(\frac{ga}{2}\right)\right|}{g}\left|\frac{\chi'_b - \chi'_a}{a\chi'_a + b\chi'_b}\right|$$

$$\nu = \frac{1}{\pi}\left(1+\frac{b}{a}\right)\left|\frac{\chi'_b}{\chi'_a} - 1\right| \frac{\sin\left(\frac{\pi}{1+\frac{b}{a}}\right)}{1+\frac{b}{a}\frac{\chi'_b}{\chi'_a}}$$



$0 \le \nu^{(s)} \le 1$

$\nu^{(s)} \approx 1$ constructive interference

$\nu^{(s)} \approx 0$ destructive interference

Conclusion

- In the present work a theory of the coherent X-radiation generated by the relativistic electron crossing a periodic layered medium in Bragg scattering geometry is build up.
- The dependences of the spectral-angular density of the radiation on the ratio of the different layers thicknesses and on the asymmetry of the field reflection from the layered structure are revealed.
- The growth of the frequency range of total reflection as well as the appropriate growth of DTR spectrum width is reveal under decrease of the angle of electron incident on the target that is companied by the considerable increase of angular density of DTR.
- Thus, in periodic layered media as in the single crystal the dynamic effects into the coherent X-radiation which are connected with the asymmetry in the reflection of the relativistic electron coulomb field, are also brightly manifested.

Thank you for your attention!