X-ray radiation for beam diagnostics

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Oral paper at Channeling 2016 **Charged & Neutral Particles Channeling Phenomena, Sirmione-Desenzano del Garda, Italy, on September 25-30, 2016.**

Possibilities for optical diagnostics of intensive beams with small transverse size are restricted because of diffraction limitations (for beam sizes about or less than 1 um) and coherent emission from dense beams (beam bunches). In order to overcome both these limitations, one can use radiation of accelerated particles in the X-ray range.

Recently, application the PXR was proposed for beam diagnostics.

1. Gogolev A, Potylitsyn A, Kube G, J. Phys.: Conf. Ser. 357 012018 (2012)
2. Takabayashi Y Phys. Lett. A 376 2408 (2012)
3. Takabayashi Y, Sumitani K, Phys. Lett. A 377 2577 (2013)

In present paper we analyze possibilities for application of three kinds of X-ray radiation excited in solid targets for beam diagnostics.

We find areas of applicability of characteristic X-ray radiation (CXR), parametric X-ray radiation (PXR), and diffracted transition radiation (DTR).

Three kinds of X-ray radiation can be used for diagnostics of relativistic electron beams

Yield and energy of characteristic X-ray radiation (CXR)

Calculations of the yield of the CXR excited by relativistic electrons, we use the formula

$$Y_{CXR}=\left(\frac{dN}{d\Omega}\right)_{CXR}=\frac{\omega_K T_e n_0 \sigma_K}{4\pi}\left[1-\exp\left(-\frac{T}{T_e\cos\frac{\theta}{2}}\right)\right]$$

Yield and energy of parametric X-ray radiation (PXR)

Calculations of the PXR yield have been performed by formula according to the small-angle approximation of Ter-Mikaelian theory.

$$Y_{PXR}=\frac{dN_{PXR}}{d\Omega}=\frac{\alpha\cdot z^2\cdot M\cdot\left|\chi_{\vec g}(\omega_{PXR})\right|^2}{\left(\frac{c}{V\sqrt{\varepsilon}}-\cos\theta\right)^2}\cdot\frac{\delta_\perp^2+\delta_\parallel^2\cdot\cos^2 2\phi}{\left(\gamma_{eff}^{-2}+\delta_\perp^2+\delta_\parallel^2\right)^2}$$

$$M=\frac{T_e}{2\pi}\left|\vec g\cdot\vec v\,\frac{\vec t\cdot\vec\Omega}{\vec t\cdot\vec v}\right|\left[1-\exp\left(-\frac{T}{T_e\left|\vec t\cdot\vec\Omega\right|}\right)\right]$$

$$\omega_{PXR}=\frac{g\cdot V\cdot\sin\phi}{1-\frac{V\cdot\sqrt{\varepsilon}}{c}\cos\theta}$$

Yield and energy of diffracted transition X-ray radiation (DTR)

Calculations of the DTR yield have been performed by formula

$$Y_{DTR}=\frac{dN_{DTR}}{d\Omega}=\frac{\alpha\cdot z^2}{\pi^2}\frac{\delta_{v\perp}^2}{\left(\gamma_{eff}^{-2}+\delta_{v\perp}^2\right)^2}\frac{d\omega}{\omega},$$

$$\omega_B=\frac{cg^2}{2\sqrt{\varepsilon}\left|\vec\Omega\cdot\vec g\right|}$$

$$\frac{d\omega}{\omega}=\left(\frac{2\hbar\omega_p}{c\hbar g}\right)^2\frac{\left|\chi_{\vec g}\right|}{\left|\chi_0\right|}$$

is the energy equivalent of the Darwin table width. It is constant for every crystallographic plane. *J.H. Beaumont, M. Hart, J. Phys 7(1974)823-829*

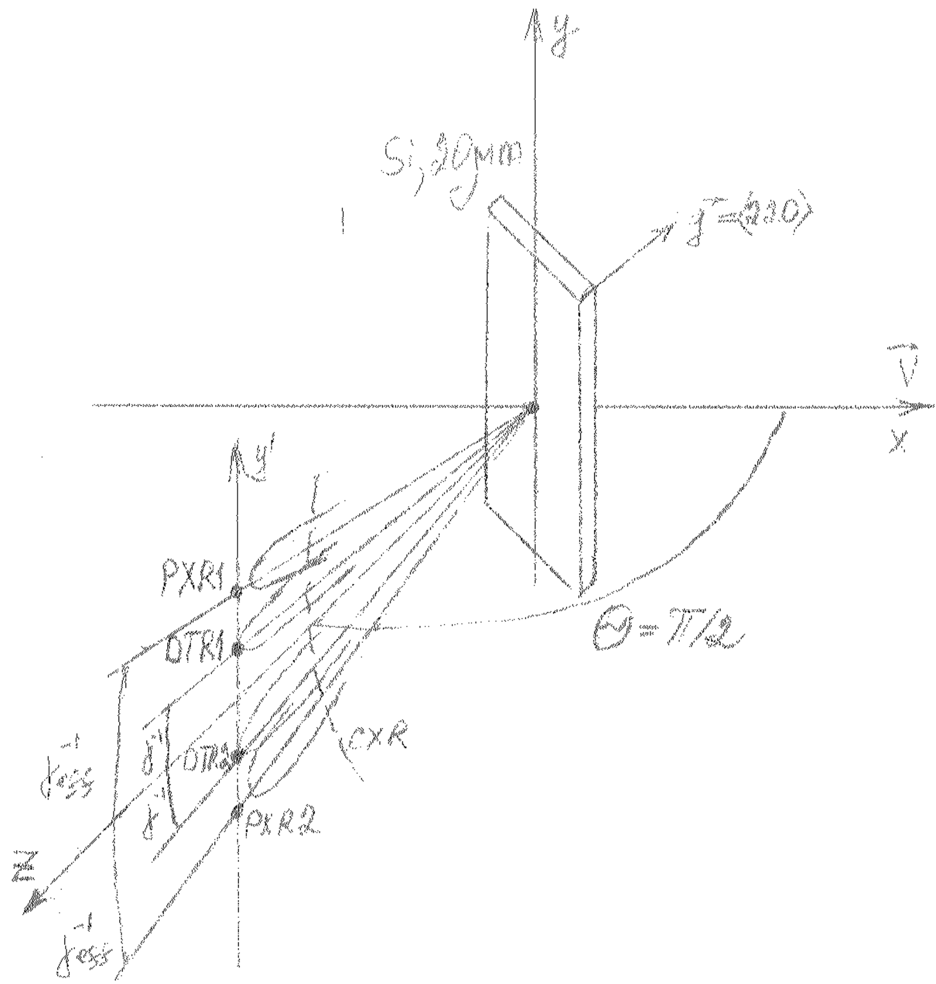

Fig. 1. The scheme for production of radiation The Si single-crystalline slab T is installed at electron beam. The CXR, PXR, DTR radiation is observed by the detector at observation angle 90 degrees with respect to the electrons velocity vector. Crystallographic planes that provide PXR and DTR are denoted by the reciprocal lattice vector. Angular distributions of CXR, PXR, DTR are schematically shown by curves. In order to observe maximum yield of the PXR or DRT, one has to install detector in points PXR 1,2 and DTR1,2.

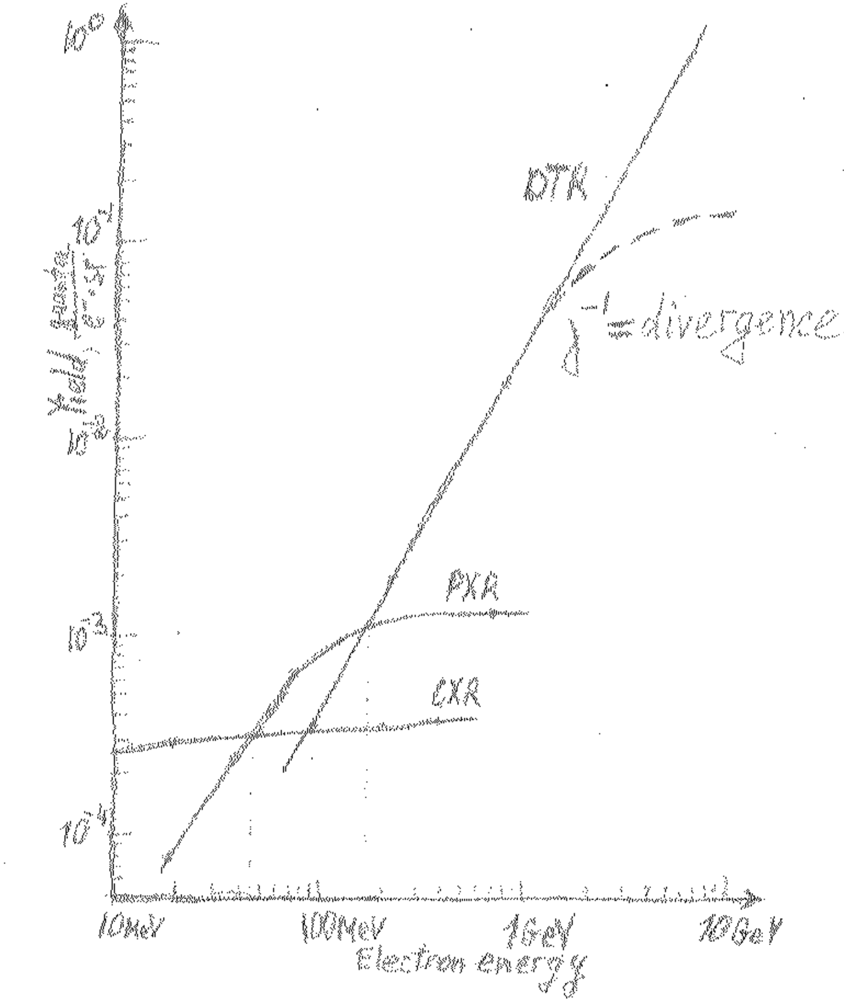

Fig. 2. Differential yields of the CXR with energy 1.74 keV,

PXR with energy 4.566 keV,
DTR with energy 4.567 keV
from Si 20um (220) crystal
in maxima of angular distribution

Smearing of the DTR angular distribution is considered in:
Yu A Gaponov, M A Sidnin, K Sumitani, Y Takabayashi, I E Vnukov NIM A 2016

- **Results and discussion**
- The most intensive kinds of quasi-monochromatic X-ray radiations are:

- **CXR** at electron energy < tens MeVs
- **PXR** tens MeVs < at electron energy < hundreds MeV -
- **DTR** at electron energy > hundreds MeV -

- **These kinds of radiation can be used for beam diagnostics.**

- **X-ray optics: pinhole, Fresnel zone plate, concave X-ray lenses.**

- **To increase the aperture, one can use an array of such optical elements.**

- **Thanks for discussions to P. Karataev.**

- **Thanks for attention**