1.2 GEV ELECTRON RADIATION SPECTRA IN THICK TUNGSTEN SINGLE CRYSTALS AND TOTAL RADIATION LOSSES IN TUNGSTEN, GERMANIUM AND SILICON SINGLE CRYSTALS

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The experimental investigation of radiation energy losses of ultra relativistic electrons in aligned crystals of various atomic number are of great interest for several reason. On the one hand, they helps in searching optimal conditions for γ-quantum beam generation and in achieving maximum convertion factor of electron energy to that of γ-radiation. On the other hand, being compared with calculation performed according to various theoretical models, they allows one to choose the model that describes an electron interaction with ordered crystal structure most completely.

Such experimental data have been obtained at Kharkov 2GeV linear in NSC KhIPT.

The experimental data measured for the radiation angles near the angle $\theta_\gamma = mc^2 / E_0$ are most interesting. We present below the results of our measurements of electron energy radiation losses for radiation angles interval 0.5 to 5 θ_γ. Measurements were done for 0.52 and 1.18 mm tungsten single crystals at electron energy 0.9 and 1.2 GeV, the electron beam being directed along axes <111> and <100> respectively and for 0.8 mm germanium and 15 mm silicon crystals at electron energy 1.2 GeV. On all cases the total radiation losses were measurement with a quantometer and a technique described in ref.[1].

Besides, the total radiation losses in 1.18 mm tungsten and 15 mm silicon crystals were found by means of integration the spectral distributions of γ-radiation over energy, as it is described in ref. [2]. The total radiation losses obtained by means of both technique are in a satisfactory agreement with each other. The γ-radiation spectrum from the tungsten crystals of various thickness are interesting in itself.

A new measurement technique [3] permitting one to exclude the spectra distortion through the multiplicity of γ-quantum creation by a single electron made it possible:

-to obtain information about "true" radiation spectrum from heavy crystal of large thickness, up to unit of radiation length;

-to make clear the effect of the shape of radiation spectrum on the total radiation losses.

The radiation spectrum from the tungsten crystals of various thickness averaged over measured experimental points, are presented in fig. 1 and 2. It is seen from fig.l, that the spectrum curve for the tungsten crystals of 1.18 and 3.2 mm thickness have practically coinciding maximum at the γ-quanta energy $\omega_\gamma^{max} = 22$ MeV. They are shifted to the hard part of the spectrum in comparison with intensity maximum in silicon crystal, placed at $\omega_\gamma^{max} = 15$ MeV [8]. But these spectra considerably differ from each other in intensity in the whole interval of γ-quanta energy (ω). The most visible decrease in intensity is observed in the hard part of spectrum, beginning from ω>20 MeV (see fig.2). This is likely to be caused by decrease in a number of γ-quanta because of pair creation. The intensity decrease in the hard part of spectra together with γ-quanta beam space distribution broadening which is due to the effect of electron multiple scattering getting larger, leads to the fall In the total radiation losses in a fixed solid angle with the growth of the crystal thickness.

The measurements we have performed show that for sharply directed radiation (the collimation angle $\theta_c = 0.51\theta_\gamma$) the total radiation losses in the tungsten crystal of 3.2 mm thickness (unit radiation length is 1.5 times as small as in 1.18 mm tungsten crystal in a wide γ-quanta energy interval (for example 0-320 MeV). They confirm the conclusion of the ref. [1, 8] that It is expedient to employ as a gamma converter the single crystals of optimal thickness (see also fig3).

The dependence of the radiation losses (the convertion factor) of 1.2 GeV electrons in various crystals on the collimation angle are shown in fig.3. It is seen that the total radiation losses are maxlmal for the optimal crystal thickness, which is 15 mm for silicon and 0.52 mm for tungsten (about 0.16 radiation length).

The solid and dashed lines represent the results of theoretical calculations of the total radiation losses performed according to a model taking into account above only barrier particles radiation. The only parameters, with which the curve were fitted, were values of the electron multiple scattering angles in the crystals under consideration.

The spectral-angular distribution of radiation from tungsten crystal is of interest too [10]. It is presented in fig.4 for 1.18 mm tungsten crystal and electron energy 0.9 GeV; electron beam being directed along <100> axis. At the γ-quanta energy corresponding to the spectral density maximum (ω_γ^{max}=20 MeV) the angular distribution width is three times as large as in silicon crystal [3].

The angular distributions of γ-quanta with the energy exceeding 20 MeV do not have anomalies, which were observed in silicon crystal [3]. This difference can be explained by stronger electron multiple scattering in tungsten crystal in comparison with silicon crystal.

The most significant parameter describing the directional characteristic of radiation is a radiation brightness $\Delta E / \Delta\Omega$. Our summary data concerning the brightness dependence on the collimation angle for all the crystal at energy I .2 GeV and 1.18 mm tungsten at energy 0.9 GeV are presented in fig.5 [9].

One should pay attention to value of γ-radiation from the 15 mm silicon crystal which is the highest in the whole range of the collimation angles. Our data for energy 0.9 GeV are in good agreement with the Tomsk group's data [4]. Comparison between the radiation brightness from the tungsten crystal in the angle $\theta_c/\theta_\gamma \approx 1$ at energies 0.9 GeV and 1.2 GeV shows that the dependence of radiation brightness on electron energy, similar to a silicon crystal [8], is filled by the law E_0^3. The difference between the radiation brightness in the collimation angle $\theta_c/\theta_\gamma \approx 1$ for silicon and tungsten crystals of the optimal thickness is small, about 10 %, which agrees with calculations [5].

Therefore, a tungsten crystal, contrary to the optimistic forecast, does not have any advantages over the other crystals. This conclusion holds true when we compare total electron radiation losses at essentially higher energies: in a silicon crystal at E=10 GeV [6] and tungsten one at E=28 GeV [7].

Making extrapolation of the radiation losses in a 10 mm diamond crystal at E_0=0.9 GeV [4] to the energy 1.2 GeV we can expect a higher radiation brightness then for a silicon crystal. However, on the basis of our data and taking into account accessibility of silicon single crystals we can come to the conclusion that the converters from silicon single crystals are more preferable for employing as a directional γ-radiation source, which confirms the conclusions of ref. [8].

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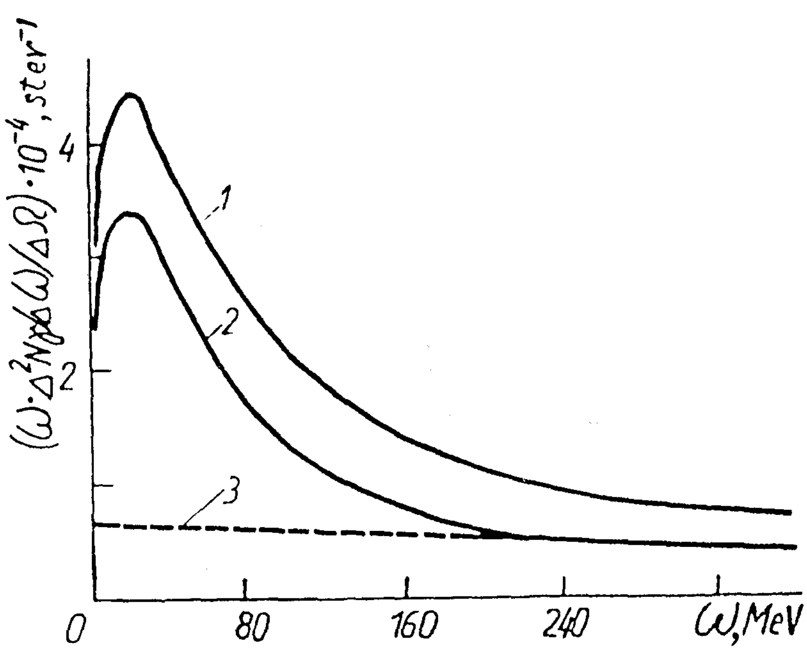

Fig.1. 1,2 GeV electron radiation spectra from tungsten crystals. The collimation angle Θ_k=0.213 mrad (Θ_k= 0.51 θ_γ)
1 – W, <100> , 1.18 mm thickness;
2 – W, <111> , 3.2 mm thickness;
3 – W, random, 3.2 mm thickness.

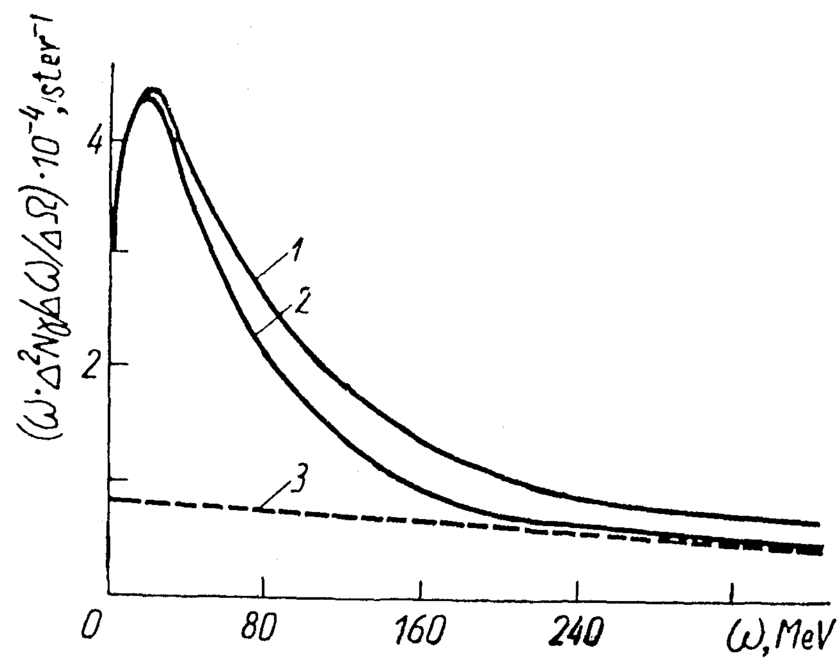

Fig. 2. The spectrum of fig.1, fetted at the energy ω_γ = 16 MeV.
3 – W, random 1,18 mm thickness.

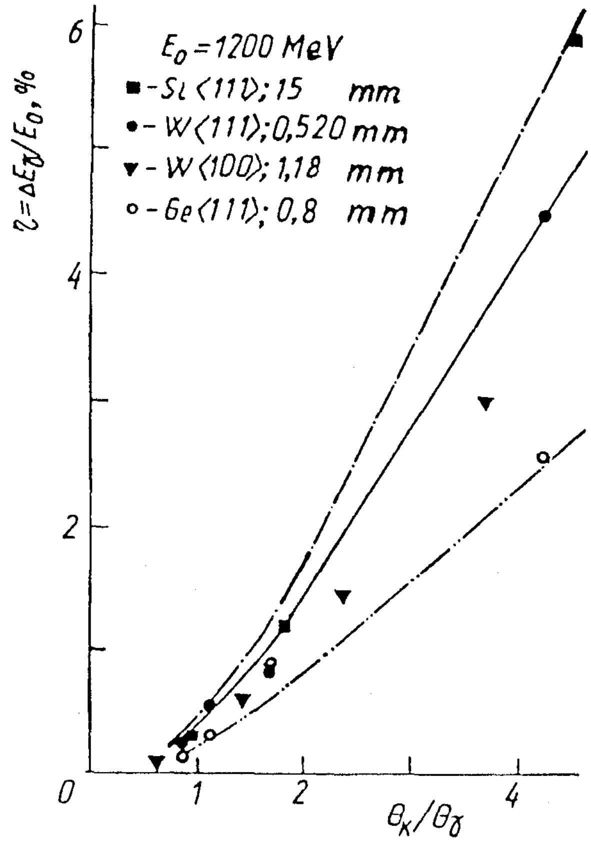

Fig. 3.
Dependence of convertion factor $\eta = \Delta E_\gamma / E_0$ on collimation angle θ_K / θ_γ for various single crystals; $\theta_\gamma = mc^2 / E_0$, E_0 is an initial electron energy.

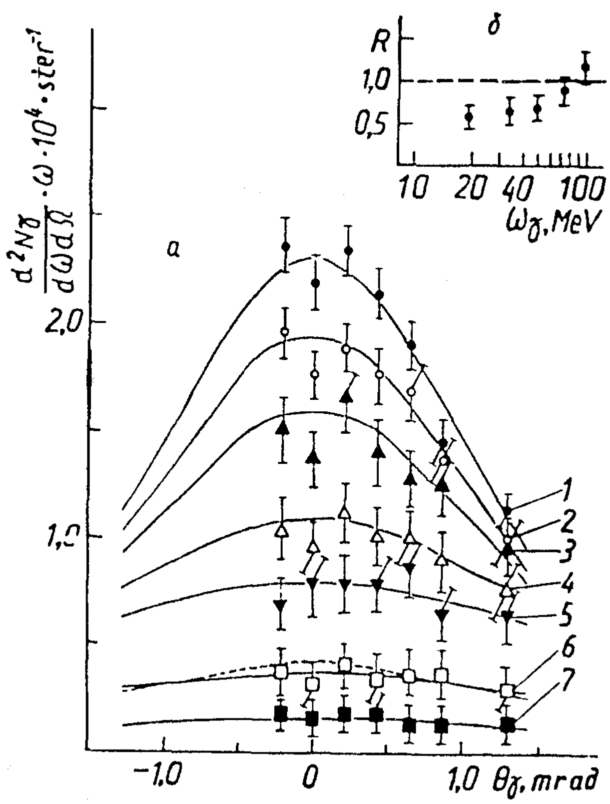

Fig. 4.
Spectral-angular distributions of gamma-quanta radiation from tungsten single crystal, 1,18 mm thickness, for various energy ω_γ (a);
1 - 20 MeV; 2 - 35 MeV;
3 - 50 MeV; 4 - 75 MeV;
5 - 100 MeV; 6 - 200 MeV;
7 - 600 MeV.
Solid lines - Gaussian function fitted to experimental points; dashed line - angular distribution for random crystal;
(b) R - ratio widths of distributions aligned to random orientation as function of ω_γ.

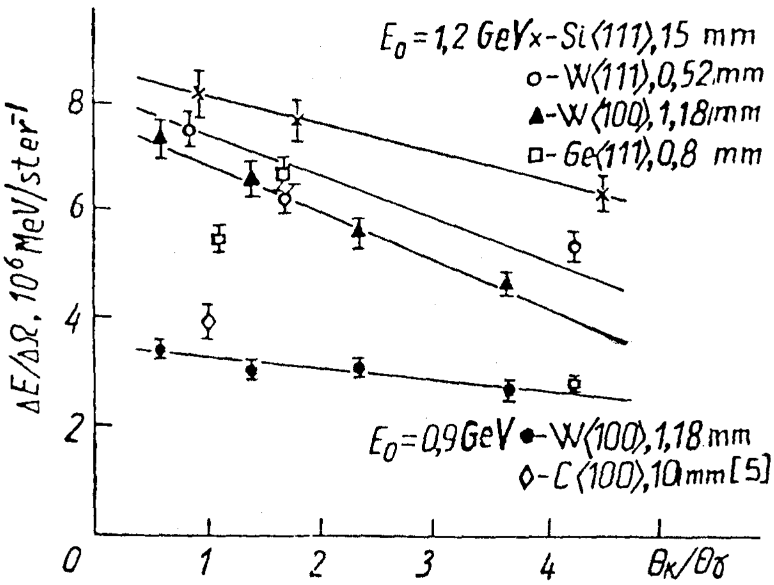

Fig.5. Dependence of radiation brightness on collimation angle for various crystals and initial electron energies.