COLLECTIVE EFFECTS IN POLARIZATION X-RAY BREMSSTRAHLUNG OF RELATIVISTIC ELECTRONS AND MICROSTRUCTURE ANALYSIS OF MEDIA*

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Abstract

Peculiarities of collective effects in polarization X-ray bremsstrahlung (PB) which occur due to coherent interaction of fast charged particles with atomic electrons are discussed. Results of experimental study performed on base of 2.4 MeV electron CW linear accelerator of MSU are reported. The predicted strong difference between polarization bremsstrahlung properties for amorphous and polycrystalline targets in important for different applications region of X-ray radiation photon energies at 1- 10 keV is observed for the first time manifesting clearly the polycrystalline structure of used aluminium target. The possibility of development of a method to test the structure of different substances with PB is indicated.

1. INTRODUCTION

The new emission mechanism known as the polarization bremsstrahlung (PB) is realised in the process of fast charged particle collision with an atom and interpreted as being due to scattering of the equilibrium electromagnetic field associated to this particle on atomic electrons [1]. Usually PB properties are investigated conformable to the process of fast particle interaction with a separate atom. Meanwhile theory predicts the strong dependence of PB characteristics in condensed medium upon the structure of this medium. The mentioned peculiarity is stipulated by the great enough value of PB effective impact parameter comparable with a size of atom. Due to this circumstance the collective response of medium atoms on the electromagnetic perturbation from the side of fast particle takes place for the case of condensed medium. In particular the strong difference between PB properties for the cases of amorphous and polycrystalline structures of a medium was predicted in [2]. The aim of this work is to research experimentally the peculiarities of relativistic electrons PB in a polycrystalline aluminium foil.

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2. EXPERIMENT

The experiment has been performed at Institute of Nuclear Physics of Moscow Lomonosov State University linac (a 2.4 MeV continuos electron beam has been used). The block diagram of an experimental set-up is traditional. A beam of accelerated electrons with cross section 2 mm×2 mm is directed into aluminium foil with the thickness of 2 mkm placed in vacuum chamber. Electrons passing through the target are absorbed in a Faraday cup. Photons emitted in the process of relativistic electron beam interaction with the target in X-ray energy range are registered by a semiconductor Si(Li) cooling detector in a small solid angle (~1.5 msr) given by the photon channel located at an angle of 90° with respect to the incident electron beam (the plane of the target surface is located at an angle of 45° to beam axis). The distance between the target and the detector is about 0.5 m. The described geometry is most suitable for the achievement of contribution of normal bremsstrahlung comparable with the measured photon yield. The characteristic spectrum obtained in the experiment is presented in Fig. 1 simultaneously with the spectrum of external background measured on condition of the closed by lead plate photon channel. The dominant contribution to total number of registered photons is determined by Al K -x-ray peak located in the vicinity of 1.5 keV (in accordance with the theory PB intensity has on condition of the performed experiment a value less than 1% of Al-K x-ray intensity). Therefore the spectrum in the Al-K x-ray frequency range is not

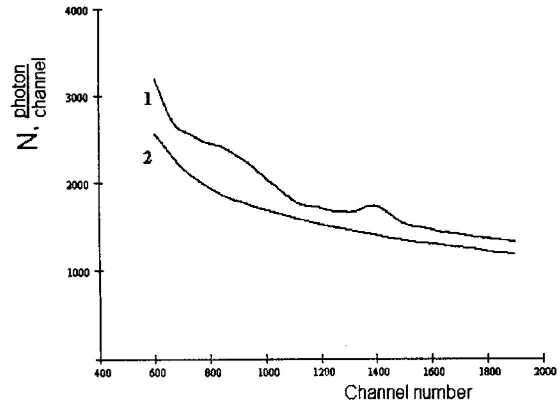

Figure 1. Experimental data: 1 is signal, 2 is background

shown in Fig. 1. The final observed spectrum is presented in Fig. 2 without the contribution of external background. The spectrum has been smoothed out in the limit of the detector energy resolution (~200 eV) in order to make use of the accumulated statistics in the right way.

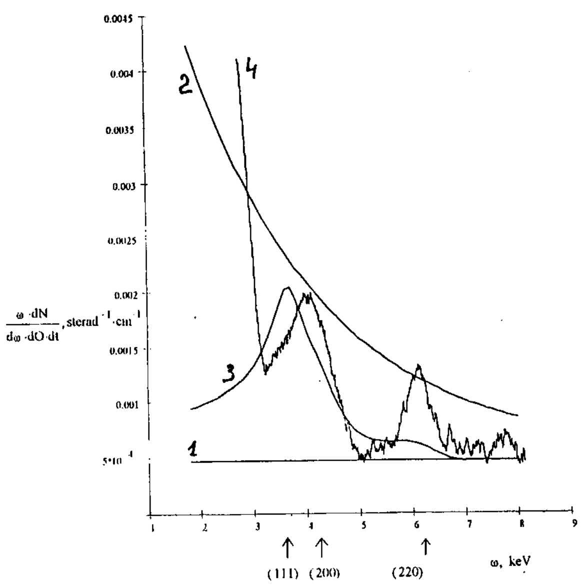

Figure 2. Spectral-angular distribution of PB intensity. Curve 1 is normal bremsstrahlung; curve 2 is PB in amorphous aluminium; curve 3 is PB in polycrystalline aluminium (theory); curve 4 presents the experimental data after external background subtraction.

3. DISCUSSION

There are some theoretical curves in Fig. 2. in addition to the experimental one. The curve 1 describes the spectrum of normal bremsstrahlung intensity of relativistic electrons moving in an aluminium. The curve 2 describes the spectrum of collimated PB intensity of relativistic electrons moving in amorphous aluminium. This curve is calculated with taking into account the effect of isotropic spectral-angular distribution of relativistic particle PB [2] and the contribution of normal bremsstrahlung as well. The curve 3 describes the theoretical spectrum of PB intensity emitted by relativistic electrons moving through a polycrystalline target. This curve is calculated by the formula [2] with taking into account the contribution of normal bremsstrahlung and coherent part of the polarization bremsstrahlung by relativistic electrons interacting with accidentally oriented microcrystals constituting a polycrystal. The incoherent part of a fast particle PB in a polycrystal is suppressed strongly [2]. Therefore the PB yield in the case of amorphous target is greater than that in the case of polycrystalline one in the spectral region outside the vicinity of coherent peaks. Curve 4 presents the corresponding experimental data after external background subtraction. The nature of peaks mentioned above is analogous to that of Debye-Scherrer ones in the process of x-ray scattering in polycrystals [2]. The coherent PB peaks corresponding to Al crystallographic planes (111), (200), and (220) make the main contribution to PB yield on condition of performed experiment (the calculated spectral distributions of these peaks are shown especially in Fig. 3, each taken separately).

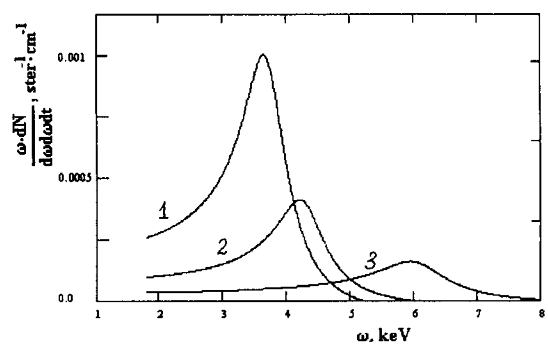

Figure 3. The peaks corresponding to the coherent scattering of particle's coulomb field on crystallographic planes of aluminium crystal. The curve 1 corresponds to (111), 2 to (200), and 3 to (220) planes.

One can see that the position of spectral peaks contained in measured spectrum corresponds to theoretical prediction. The value of the measured PB yield in the vicinity of (111) and (200) peaks is in agreement with the theory, but the essential discrepancy between theoretical prediction and observed contribution of the peak (220) takes place. The possible cause of this discrepancy connects with the coherent Bragg reflection of an incident electron electromagnetic field from the texture being available in the surface layer of the target. Thus, the spectral properties of PB of relativistic particles moving through a polycrystalline target differ strongly from that manifested in the case of relativistic particle interaction with an amorphous target in contrast to normal bremsstrahlung [3]. Taking into account the difference between observed spectrum and that obtained earlier in experimental investigation of PB by relativistic electrons moving through a carbon like diamond film [4] one can affirm that PB mechanism is very sensitive to the target structure. This circumstance is of interest for the elaboration of the new method of solid structure diagnostic based on PB.

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4. CONCLUSION

Two peculiarities of PB by relativistic electrons moving in a polycrystalline target are observed in this work for the first time: 1. The spectral-angular distribution of PB photons emitted in a polycrystal contains the sharp peaks appearing due to the ordered structure of microcrystals forming the polycrystalline medium. 2. The PB yield from a polycrystal outside the vicinity of coherent peaks is suppressed strongly in comparison with that generated by relativistic particles in amorphous medium

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5. REFERENCES

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