THE EXPERIMENTAL RESEARCH OF BREMSSTRAHLUNG OF HIGH ENERGY ELECTRONS IN X-RAY REGION

B.N.Kalinin, G.A.Naumenko, A.P.Potylitsin, V.A.Verzilov, I.E.Vnukov
Nuclear physics institute, Tomsk, Russia

Abstract

Experimental researches of radiation of electrons with energy up to 900 MeV in thin amorphous targets in the spectral area 20-700 KeV are carried out. Ter-Mikaelan density Effect is registered. Coherent bremssrahlung on macro ununiformity of a target material is found out.

Introduction

In spite of the fact that the bremssrahlung of electrons with energy about 1 GeV in amorphous targets was iuvestigated already for a long time, the area of a. spectrum of bremssrahlung from several KeV up to 1 MeV is experimentally almost not investigated. It is interesting, that in this area of energy an observation of such effects, as a density effect [1], Landau-Pomeranchyuk suppression [2], coherent bremssrahlung on ununiformity of a target material [3] can take place.

First two effects were investigated at energy of accelerated electron eight and 20 GeV [4], and the third effect was not investigated. The theoretical study of this problem was carried out in [5]. Therefore we have carried out experimental research of bremssrahlung spectra in this area of energy in thick (~1 mm) and in thin (~10μ) targets from the aluminium and molybdenium.

Experiment

Tye researches were carried out on the Tomsk synchrotron "Sirius" with energy of accelerated electrons up to 900 MeV. A current of accelerated electrons is of 10 - 20 milliamperes at a duration throwing of electrons on a target of 20 illihisecond, and cycle of acceleration of 200 milliseconds. In experiment spectra of bremssrahlung of the electrons with energy up to 900 MeV in targets from various materials of different thickness in a spectral range from 20 up to 800 KeV were measured. Collimation of bremssrahlung made 0,6 milliradians. The area of energy up to 1 MeV is accessible for measurement by a detector of type NaY(T1).

Scheme of experiment is shown on fig.1. The detector NaJ(T1) sizes 64x64 mm was placed on a direct beam of bremssrahlung. In such mode for exception of the detector overcharge the current of the accelerated electtron was reduced on five - six orders from nominal. Thus the charge of a detector made 20 - 40 events for 20 milliseconds. Moreover, the charge of a spectrometer path was supervised by registration of a spectrum at a random start of a charge-digital converter. With the purpose of removal of the Compton components contribution of the detector response function from high energy γ-quantum, we measured both the main spectra and the spectra, for which on a bremssrahlung beam was placed absorber, consisting from plate of lead by thickness 0,5 mm and plate of copper thickness 1 mm. This information was taken into account then at processing of spectra for removal of Compton components.

We investigated radiation ill targets from the aluminium by thickness of 1,4 mm and four μ, molybdenum by thickness of 0,3 mm and 12 μ and mailar by thickness five μ at energy of accelerated electron 600 and 900 MeV.

For additional check of obtained results we carried out a control measurements in several points of a specified spectral range with use of the diffraction spectrometer. This technique is free from influence of the response function of a detector. The spectrometer is realized on the basis of a pyrolytic graphite crystal of firm «Union Carbide», placed on a precisional goniometer. The scheme of this experiment is shown on fig.2.

Here we measured radiation intensity in targets from tile aluminium by trickness of 1,4 mm and four μ and in targets from molybdenium by thickness of 0,3 mm and 12 μ. Bragg angle corresponded to reflection of the photon with energy 86, 172, 258, ... KeV. The yield of the photon with energy more than 258 KeV had small statistics and is not here considered. The measurements were carried out at energy of accelerated electron 400, 600 and 900 MeV. For normalize of spectra a current of accelerated electron and full energy of radiation from a target was registered.

Results

On fig.3 radiation spectra in a thin and thick target from molybdenum are shown at energy of accelerated electron 600 and 900 MeV. For convenience here critical energy for effect of density and for coherent bremssrahlung in thin targets are specified. Critical energy in effect of density is the size $\gamma\omega_p$, where γ - Lorenz-factor, ω_p - energy of plasmon. For coherent bremssrahlung critical energy is the size $\frac{2\gamma^2}{l}$, where l - thickness of a target.

On fig.4 we see spectra of accelerated electrons radiation with energy of 600 MeV in targets from the aluminium by thickness of 1,4 mm, 25 μ and four μ and in a target from a mailar by thickness five μ. On a drawing as on fig.3 critical energy for density effect and for coherent bremssrahlung are specified.

On fig.5 spectra of radiation in tile same targets, as on fig.4 are shown at energy of accelerated electrons of 900 MeV. Intensity of radiation in different targets depends very strongly on the thickness of the target, therefore for convenience of comparison tile spectra are normalized on intensity of radiation in the region of 700 KeV.

The results of control experiment with use of the diffraction spectrometer are shown in tables 1, 2. For convenience the results of measurements are shown in the relation to appropriate results at the radiation of electrons with energy of 400 MeV in the aluminium by thickness of 1,4 mm (here $\gamma\omega_p$= 26,5 KeV, where γ - Lorenz-factor, ω_p - energy of plasmon, and the influence to radiation of effect of density should be small) and are normalized on intensity of the radiation of photons with energy of 258 KeV.

Table 1: Molibdenium 0,3 mm and 12 μ

Molibdenium 0,3 mm				Molibdenium 12 μ			
	Energy of photon (KeV)				Energy of photon (KeV)		
ω_0 (MeV)	86	172	258	ω_0 (MeV)	86	172	258
400	0,73	1,16	1	400	0,73	1,07	1
600	0,54	1,01	1	600	0,65	0,9	1
900	0,415	0,85	1	900	0,82	1,02	1

Table 2. Aluminium 1,4 mm and 4 μ

Aluminium 1,4 mm				Aluminium 4 μ			
	Energy of photon (KeV)				Energy of photon (KeV)		
ω_0 (MeV)	86	172	258	ω_0 (MeV)	86	172	258
400	1	1	1	400	0,89	1,16	1
600	0,98	1,01	1	600	1,01	1,06	1
900	0,91	1,1	1	900	2,41	1,45	1

Discussion

In first we see, that In all thick targets suppression of radiation in a soft part of a spectrum is observed. The dependence of this suppression on energy of accelerated electrons corresponds to similar dependence of density effect on the electron energy. However, characteristic energy of suppression in experiment more than the theoretical one. It can be connected to presence at observable spectra of effect of a type Landau-Pomeranchuk. It is specified by the form of a spectrum in this area of energy too. However, the estimations show for this purpose effect considerably lower critical energy.

It is possible to pay attention on that (fig.3) there is dependence of suppression effect on a target thickness. The analysis of this fact shows, that this dependence is stipulated by large angle of a multiple scattering of electrons in molybdenum, which gives the significant contribution of radiation at a large angle at small value of the Lorenz-factor. The account of multiple scattering in density effect confirms occurrence of such dependence from thickness. There is not a new effect. It is confirmed by that for light targets (fig.4) such dependence is away.

If at energy of accelerated electrons of 600 MeV (fig.4) we see only effect tit radiation suppression in a soft part of a spectrum, at energy of electrons of 900 MeV (fig.5) the form of the spectrum in thin targets qualitatively varies. If tile thickness of a target decrease, intensity of radiation ill tile region of allergy up to 100 KeV considerably increase. Let's notice, that for this area of energy the thickness of a target (4μ) is considerably less of the formation length of radiation (more than 30μ). Under these conditions the transition radiation is suppressed. For complete reliance that the increase of radiation intensity in the region of energy up to 100 KeV is stipulated by not a transition radiation, we have carried out measurement of radiation spectrum in an aluminium target by thickness four μ at energy of electrons of 900 MeV in conditions of a strong bremssrahlung collimation (0,2 milliradians). Thus, the intensity of transition radiation should decrease in some times. However, the form of experimental spectra at a collimation 0,6 and 0,2 milliradians has appeared identical.

We shall notice, that in a mailar target by thickness five μ the radiation intensity in a soft part of a spectrum considerably exceeds radiation intensity of photons with energy 700 - 800 KeV. It can be only if we observe any coherent radiation. This effect is observed only in thin targets, when the thickness of a target is equal or less formation length of radiation. We believe, that under these conditions there are no other coherent processes, except coherent radiation on macro ununiformity (about several hundreds of angstrom) of a target material. The intensity of this radiation very strongly depends on character and size of ununiformity, therefore it is not represented possible to carry out its account. Estimating carried out by us has shown qualitative conformity of the form of a theoretical and experimental spectrum of coherent radiation and its dependence on energy of accelerated electrons.

Tile results of control experiment with use of tile diffraction spectrometer (tab.1, 2) confirm spectral features, registered by detector on the direct beam of bremssrahlung. In thick all targets and in a thin target from molybdenum we observe the effect of density. In a thin aluminium target the effect of density is not observed. Moreover, at energy of accelerated electrons of 900 MeV it is possible to observe a significant increase of the radiation intensity in a soft part of a spectrum, including 172 KeV.

Conclusions

The researches carried out by us at energy of accelerated electrons less than 1 Gev have confirmed predicted by Ter-Mikaelan density effect in bremssrahlullg of electrons in amorphous targets. It is shown, tllat the suppression of a soft component of radiation in thin amorphous targets (when thickness of a target less formation length of radiation) differs from suppression, counted without account of a target thickness. Coherent bremssrahlung on macro ununiformity of a material of thin amorphous targets is for the first time experimentally registered.

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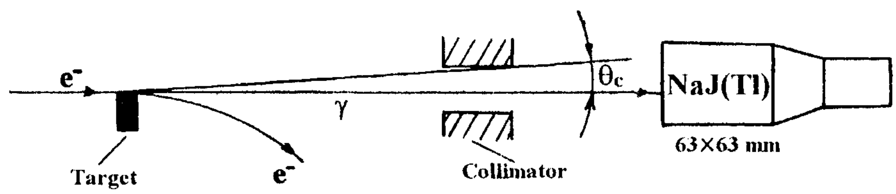

Figure 1: Spectra measurement. Scheme of experiment.

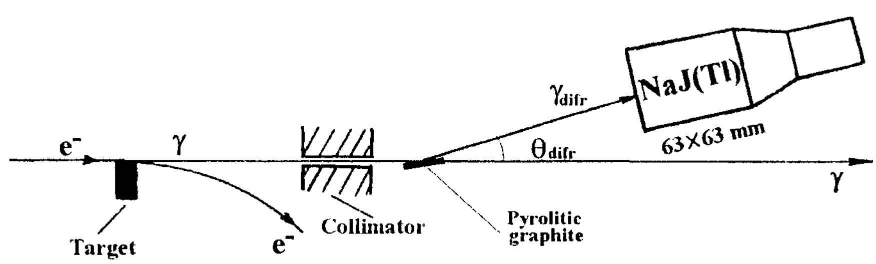

Figure 2: Difractometer. Scheme of experiment.

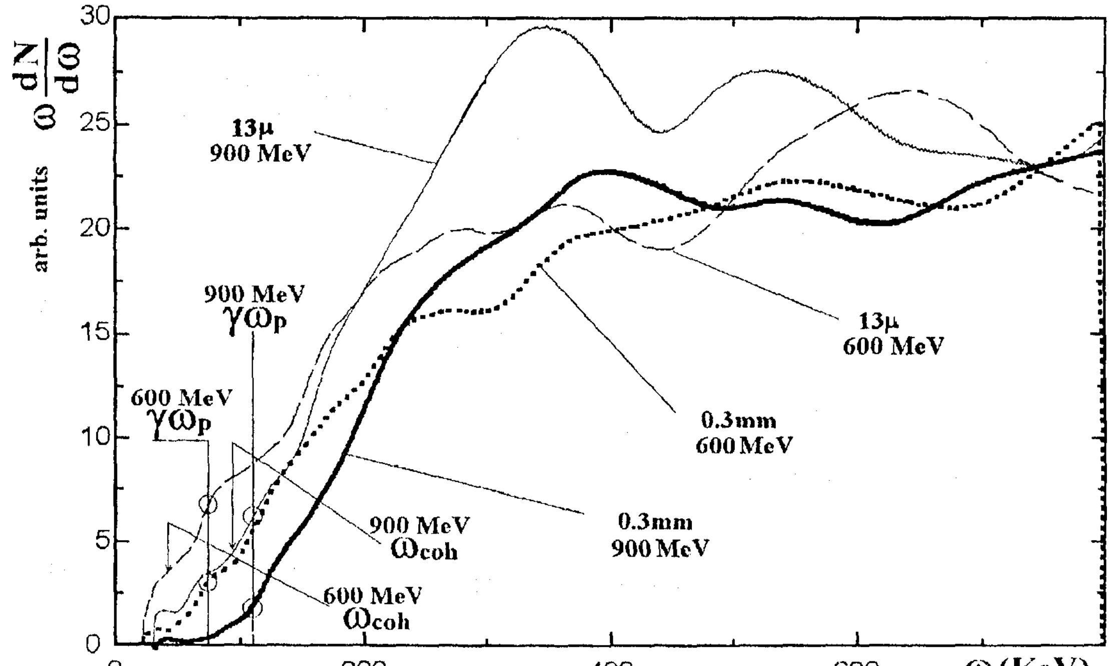

Figure 3: The intensity radiation spectra of 600 and 900 MeV electrons in molibdenium targets of 13μ and $0.3mm$ thickness. $\omega_{coh} = \frac{\gamma^2}{l}$, where l - the thickness of target, γ - *Lorents* factor; ω_p - plasmon frequency.

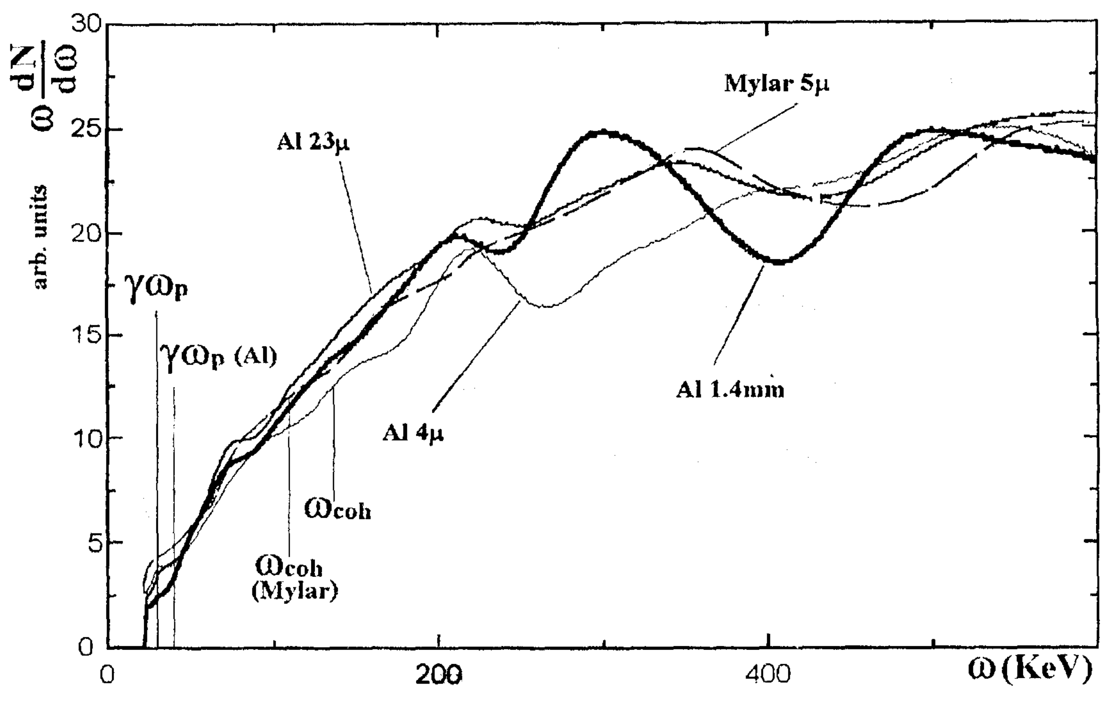

Figure 4: The intensity radiation spectra of 600 MeV electrons in aluminium and mylar targets of different thickness. $\omega_{coh} = \frac{\gamma^2}{l}$, where l - the thickness of target, γ - *Lorents factor*; ω_p - plasmon frequency.

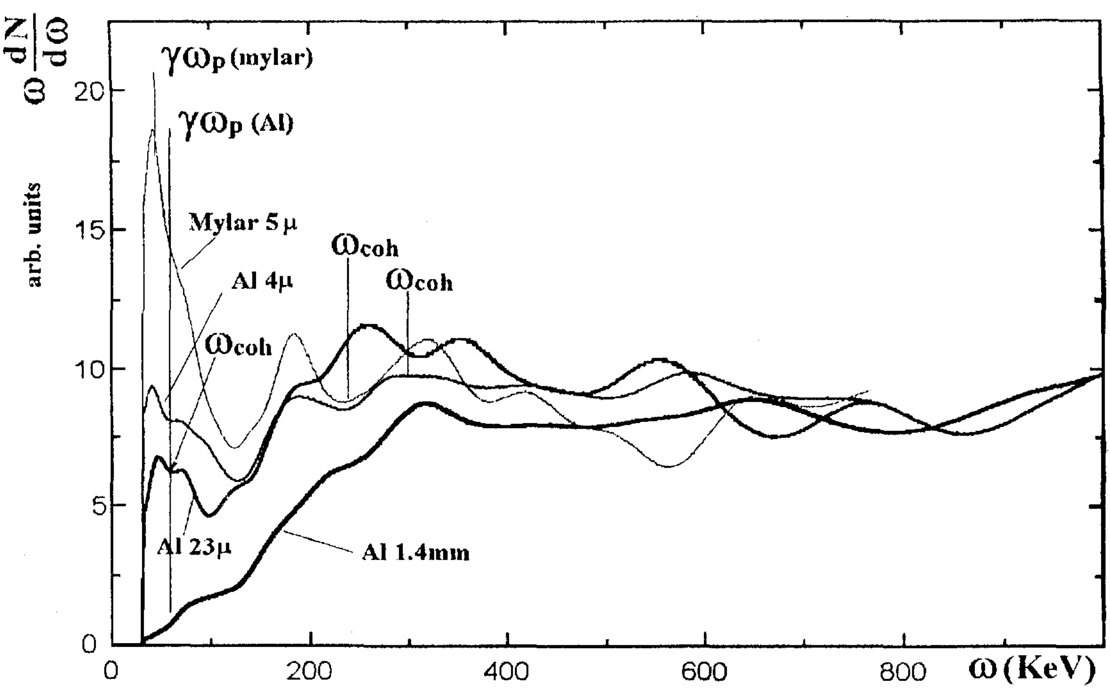

Figure 5: The intensity radiation spectra of 900 MeV electrons in aluminium and mylar targets of different thickness. $\omega_{coh} = \frac{\gamma^2}{l}$, where l - the thickness of target, γ - *Lorents* factor, ω_p - plasmon frequency.