X-RAY RADIATION BY RELATIVISTIC ELECTRONS IN CONDENSED MEDIA ON BASE OF MSU RACE-TRACK MICROTRON

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I. PROGRAM OF STUDY

The development of effective sources of monochromatic sharp-directed X-ray radiation is stimulated by important applications in medicine, Roentgen lithography, crystallography and mikroelement analysis. Possible methods of generating the X-ray radiation are actively studied now. These methods are alternative to the traditional method based on synchrotron radiation. Spectrum and angle features of radiation of fast electrons channelling in crystals, resonance radiation of relativistic electrons in dielectric layerous structures and so on are under insistent theoretical and experimental attention [1]. The essential advantage of mechanisms mentioned above is the possibility to use a low energy beams of electrons (order of 1 - 10 MeV) and to produce also a radiation with the higher spectrum density.

A great number of processes of interaction of fast charged particles and photons with matter leads to new physical effects in the radiation. The effects are for example diffractive radiation of oscillator [2]. Another examples of these effects are the interference of parametric and the Cherenkov radiations [3] and the interference of parametric radiation and coherent bremsstrahlung [4]. Due to this the study of the processes of fast electrons radiation is of interest for fundamental physics and for various applied research.

There is information about the program and the first experimental results of processes of X-ray radiation at the electron accelerator of NPI MSU in this paper.

The electron accelerator of NPI MSU is the first stage of the Race-Track Microtrone with the electron energy up to 180 MeV [5]. The first stage produces the continuous electron beam of 6.6 MeV with maximum current up to 100 mkA. The beam has a little energy spread (about 10^{-3}) and a little transverse emittance (to 5 mm*mrad).

The high quality beam allows to perform different studies of the X-ray radiation of charged particles in amorphous and crystal structures. It is very interesting to investigate the process of radiation which occurs due to scattering of the Coulomb field of fast electrons off atomic shells in substance. This radiation is called polarisation bremsstrahlung (PB). It is mainly studied in rarefied substances where the radiation has a noticeable effect (in the laser discharge in gases ,for example). A number of effects for instance the effect of the suppression of radiation can be observed in dense substances in the low frequency part of the spectrum (in amorphous media) [6]. Another forwarding circumstance is the interference of PB with ordinary bremsstrahlung. The influence of this circumstance becomes conspicuous at not too little observation angles. Besides the dependence of the radiation intensity on the sign of the particle charge is revealed.

Other group of questions is associated with the study of the X-ray radiation in crystall media. Particularly scattering of the Coulomb field of fast particles by the crystall planes leads to the appearance of the parametric radiation (PR). Like the channelled radiation PR is now considered as one of the most perspective effects for creating a tuneable source of the X-ray radiation [7]. The interference of PR with coherent bremsstrahlung and the interference of PR and transition radiation which appears on the crystal surface are the forwarding effects leading to interesting physical law-governed natures. Notice that PR has a high polarisation degree. But the direction of the photon polarisation is an oscillating function of the observation angle. So such and mentioned above effects can be studied only with the high quality beams which are proper for the new generation accelerators with continuous beam.

II. EXPERIMENT AND DISCUSSION

As the first step to accomplish the program presented the study of the features of X-ray radiation of fast electrons in amorphous media was chosen. Notice that the amorphous substances are of certain interest from the point of view of creating materials with new parameters of its structure.

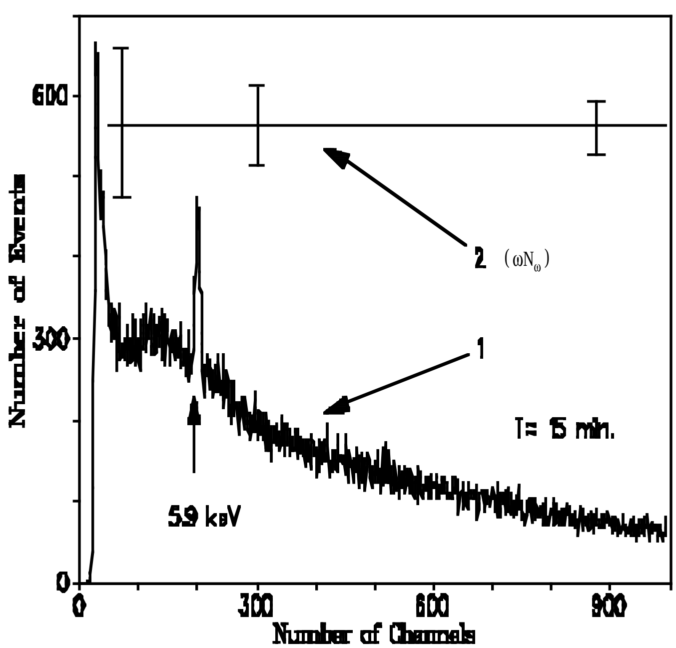
Experimental setup was traditional for such experiments [8]. It included a chamber with windows where the scattering target was placed, input and output beam tubes, the beam focusing system and the beam quality control system, Si(Li) cooling detector, the Faraday cup, monitor, combined protection system and a number of additional equipment. The chamber and the beam control system allowed to measure the photons radiated at the angles 0, 45, 90, 135 degrees respectively to the beam. In the experiments with the target prepared from an amorphous material the observed radiation is the combination of the polarisation bremsstrahlung and the ordinary bremsstrahlung. PB is practically isotropic in difference from bremsstrahlung. As an analytical estimation predicted PB can be 2 or 3 times more than a simple bremsstrahlung at the 45 degrees angle. The last circumstance results in a favourable condition to observe PB.

The first stage of the experiments just finished was devoted to the measurements with a dense foil from amorphous carbon (the foil density 2.4; the foil amorphous structure is confirmed by special measurements). The foil of 10 by 10 square mm, thickness 100 mkm was placed at the 45 degrees angle respectively to the electron beam and perpendicularly to the observation line. Allocating and turning the target were achieved by means of a special holder. To reduce the common radiative background, the target heating and to eliminate the nonlinear errors in the detecting system the measurements were carried out with the beam current of several nA. Even at such a little current due to the continuous character of the beam the information rate was about 1 kHz. This allowed to reduce a real exposition time to 2 h, including a background measurement time (notice that on the pulse accelerators with analogous average current the information rate does not exceed 10 Hz).

High quality of the beam (low emittance) allowed also to decrease a common background level for turning and focusing the particles to the target were brought about without any additional collimation of the beam.

The background created by the beam directly into the chamber was measured in the second position of the target. In this case it scattered the beam but the X-ray radiation did not income to the detector. By the way the background level appeared to be small enough.

Let us state the direct results of the first study. They are unexpected and lessonful. The main results are presented on the Fig.



Curve 1 is the intensity of summary radiation at different energies of the X-ray quanta. The peak with energy 5.9 keV corresponds to the K-line of iron. Its traces are on the surface of the carbon foil. On curve 2 there is a value ωN_ω (in arbitrary units) which is equal to the product of frequency of photons and the radiation spectrum density. This curve is obtained by subtracting the background and correcting the results taking into account the detector spectrum sensitivity ε dependence on the photon energy (in relative units the ε value changes according to special measurements from 0.57 at E_ω=13.92 keV to 0.38 at E_ω=3.3 keV) and the absorption of the X-ray radiation in the target. The confidence intervals take into attention also the discrepancies produced while correction of the results.

The ωN_ω value of the radiation measured is constant with good precision. This shows that the radiation has exclusively bremsstrahlung character, and PB is suppressed completely. The theoretical predictions point out the effect of the suppression in the energy range below 5 keV (the density effect [6]) and fast decrease of the ωN_ω value in the energy range beyond 10 keV. However these predictions are in essence made for very dense gas consisting of separated atoms. Really in carbon in condensed state four electrons of atom are mutual. This results in comparable values of the effective screening radius and the interatomic distance. The latter leads to an amazing effect: the PB suppression in the whole frequency range.

III. CONCLUSION

Thus the first experiment revealed some interesting details and questions. What is an amorphous media (from point of view of the PB experiment)? What is a screening radius ? Obviously we can receive the different answers for the media consisting of the light and heavy atoms. In this case the observations of PB may discover some new features. But this conclusions will be made after the additional processing of both experimental and theoretical studies.

IV. REFERENCES

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