HIGH EFFICIENCY HARD RADIATION SOURCE WITH SLIDING OF CIRCLING ELECTRONS

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Abstract

New scheme of intense hard photon source on base of bremsstrahlung radiation with a thin target and a sliding flow of circulating electrons is considered. Here all flow of bremsstrahlung photons generated by multiple crossing a target electrons is kept , and the total radiation output essentially raises. Due to lateral drift of circulating particles along a target an electronic cloud is "unloading" that also reduces specific thermal loading on a target. Moreover using of special configurations of magnetic fields reduces considerably angular divergence of radiation. Computer modeling with application of package GEANT confirms high efficiency of offered scheme in comparison with traditional bremsstrahlung devices.

1 INTRODUCTION

Hard photons radiated by relativistic electrons are widely used in fundamental researches and industrial applications and it is very important to increase their efficiency.

In present work the new scheme of bremsstrahlung radiation (BR) source, one of most spread sources of hard radiation, is proposed. Traditional BR source, using an ordinary scheme with direct dropping of an electron beam on a target, has two essential defects which decrease device efficiency. Radiation yield in such source is increasing with a magnification of a target thickness. But in the same time an absorption of generated phonons is rising in a target material. The radiation yield reaches to maximum if the thickness is close to 0.3-0.5 part of electron range in a target material. However only about 1/3 part of all radiate losses of electrons makes output of BR energy, and no more than a half of an initial electron energy is used in a traditional "optimized" BR source [1]. Moreover due to a strong dispersion of electrons in the target the radiation of photons happens in a cone with polar angle which is much more than an electrodynamic limit $1/\gamma_e$ where γ_e is the relativistic factor of an electron. So such source loses a sharp direction of its radiation.

A scheme proposed is basing on a circuital principal of an electron radiation with multiple crossing of thin target by electron (this principal was described for the first time in work [2] and then in other works [3,4,5]). Thank to application of a special magnet system the circuital source efficiency is essentially risen, and sharp direction property of BR is restored.

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2 SOURCE SCHEME. MAGNET CONFIGURATION PECULIARITY

The experimental setup proposed is represented in Fig. 1.

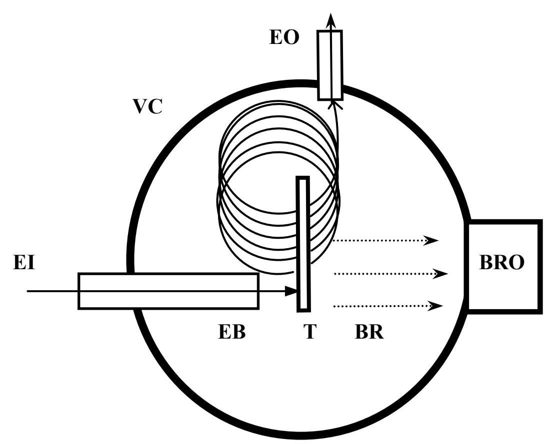

Figure 1. The scheme of experimental setup. VC is a vacuum chamber, T is a target, EB is an electron beam, EI and EO are channels for injection and removal of electrons, BR and BRO are photon flux and photon output channel.

Here in a vacuum chamber VC a target T is installed. The target is immersed in a magnetic field. The electron beam EB is injecting through a special channel EI in a work volume. Electrons circling in the magnet field are hitting the target several times. Then they are been removed through a channel EO. BR generated by electrons is been taken out through a photon channel BRO.

A main point of proposal is to force electrons to do stable multiple crossing of target after preceded ones. For this the special configuration of magnetic field is considered. A magnetic field must carry out some functions. The first one is ensuring a stable circulation of electrons with its properly focused fall on the target. The second one is a necessity to shift the rotating particles along the target. At first approximation a suitable field configuration can be creating by means of magnetic poles of a simple form. These are two parallelepipeds placed over and below the target and stretched along it. The poles are slightly shifted across target plane. In this case the fields dispersed on poles ridges are ensuring spatial focusing of circling particles. Due to a displacement of poles, mean magnitudes of fields are not equal left and right the target, and the latter provides a lateral drift of particles. By results of our previous works devoted researches of efficiency increase of usual bremsstrahlung source, the similar magnetic configurations provides reliable focusing of particles [2]. It is necessary to note a system proposed provides a homogeneity of focusing for particles of different displacement along the target that ensures a continuation of radiation cycle for various particle energies.

More fine magnet system must be applied if we want to reduce the radiation divergence. The latter intends circling electrons go back on the target along trajectories which are close to be parallel to preceding ones. This problem is being resolved in system with special profile of magnet poles optimized for reaching full homogeneity of radiant particle focusing.

3 ANALYSIS METHOD AND RESULTS

For work modeling of an offered source, the method of computer modeling with use of the software package GEANT (CERN) is used in the present work [6]. The library GEANT represents extensive one of the programs for modeling atomic and nuclear experiments. It contains a set of algorithms and given data, including cross-sections of various nuclear physical processes. In GEANT there are means for the description of real experimental installation and generation (by method of Monte-Carlo) all set of events accompanying passage of particles and photons through various substances. For generation of bremsstrahlung radiation in a package GEANT, the manifold experimental data of differential cross-sections of radiation in a range of electron energies from 1 KeV up to 10 GeV are used. Thus the package GEANT allows to carry out a full scale numerical experiment (in area examined by us) at reasonable expenses of computing resources.

Computer testing has been performed for new and traditional schemes for initial energies of radiant electrons at 14, 30 and 70 MeV. Tungsten target thickness was equal to 0.1 and 0.4 part of electron ranges in first and second schemes accordingly.

Testing has confirmed the high efficiency of circuital schemes which are surpass at several times over traditional bremsstrahlung devices in generation of full BR flux.

But the main attention was paid to optimization of magnet system to obtain best focusing of circling electron and to deduce a radiation divergence. Finally we received very perspective and in certain aspects non expected results. So some data describing characteristics of radiation generated in cone with polar angle at 5 ^{o} are presented in fig. 2 and fig. 3. We see distributions of photon number yield along an energetic scale for different energies of incident electron in proposed and traditional schemes. Their comparison indicates that a circuital scheme “right” organized permits to restore BR sharp direction. Of cause the greatest effect is observed in sources with low initial energy electrons. However computer estimates indicate we obtain almost on the order a gain at electron energy of 70 MeV.

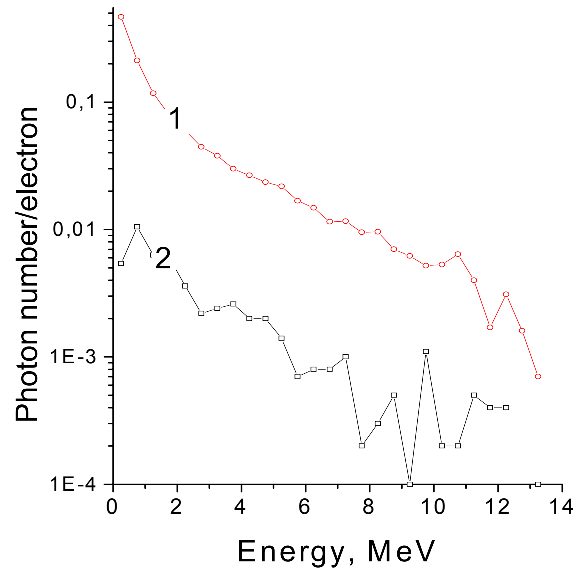

Figure 2. Dependence of specific yield of photon number, irradiated in cone with polar angle at 5 ^{0}, per one incident electron with energy at 14 MeV on photon energy for circuital (curve 1) and traditional schemes (curve 2). Statistic corresponds to number of incident electrons at 10000.

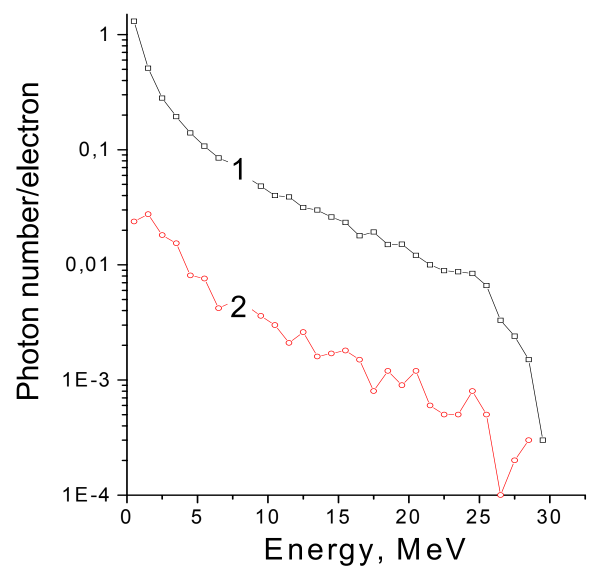

Figure 3. Dependence of specific yield of photon number, irradiated in cone with polar angle at 5 ^{0}, per one incident electron with energy at 30 MeV on photon energy for circuital (curve 1) and traditional schemes (curve 2). Statistic corresponds to number of incident electrons at 10000.

4 CONCLUSION

Thus computer testing confirms very high efficiency of proposed circuital scheme with new magnet system which allows to lift appreciably a total output and to improve considerably angular characteristics of BR radiation

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