EFFECTIVE SOURCE OF SHARP FOCUSED ELECTROMAGNETIC RADIATION OF ELECTRONS WITH MODERATE RELATIVISTIC ENERGY

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Abstract

The new circulation scheme of intense bremsstrahlung source with a sharp directed flow of X-ray and gamma-photons is proposed. In traditional sources the summary output, due to notable self-absorption of generated photon in target, makes no more than 1/3 from all radiative electron losses. Besides because of strong electron scattering in the target material, the photon radiation happens in an angle, which is much more than an inverse electron relativistic factor. In a circulating source the thin target placed in a magnetic field is used, and electrons are radiating, multiple crossing the target. Thereof all flow of generated photons is kept, and the total radiation output essentially raises. The new configuration of magnetic fields improving the electron focusing and simultaneously reducing angular divergence of radiation is considered. Moreover the scheme permits to produce here a lateral drift that displaces circulating particles and to"cleans" a target space. Computer modeling with using of the software package GEANT confirms high efficiency of proposed scheme. So the yield of hard photons in 5-degrees cone rises at order in comparison with traditional devices. Accordingly, the portion of widely dispersed radiation is reduced.

INTRODUCTION

Hard X-ray and gamma-radiation of relativistic electrons are actively employed in different fundamental researches and manifold industrial applications, and it is very important to increase efficiency of their generation. In present work the new scheme of bremsstrahlung radiation source (BRS), one of most spread sources of hard radiation, is proposed.

The traditional BRS have a series of essential defects owing to which the small part of possibilities included in the mechanism of bremsstrahlung radiation (BR) can be utilized only. In the main, it is explained by a certain contradiction of the requirements declared to traditional BRS. In the latter electrons with given energy are directly dropped on the bremsstrahlung target made. The generation of bremsstrahlung photons grows in accordance with thickness of the target. However the photon absorption increases in a material of the target in the same time. An optimum target thickness is equal approximately to 0.3-0.5 part of electron range in the target material when the BR yield reaches a maximum. In total, the noticeable part of initial energy of radiating electrons is "unexpended", and the optimum summary output of BR energy makes no more than 1/3 from all radiative losses of electrons in the target

In reality even this limit is not reached. Due to a strong dispersion of electrons in the target the radiation of photons happens in a cone, a polar angle of which is much more than an electrodynamic limit $1/\gamma_e$ where γ_e is the relativistic factor of an electron. At the same time scattering angle of electrons is $\theta_e \approx \sqrt{t}/\gamma_e$ where t is the target thickness. Therefore the angle of a radiation cone forecasted theoretically can de observed only at rather small thickness about 10 microns (for a tungsten target) that is much less than the optimum value. In the total, the radiating electrons spend no more than third of initial energy.

The marked BRS inconsistencies and defects can be removed in circuital scheme proposed below. In this scheme the thin target immerged in a magnetic field is used, and electrons hitting the target are returning back. In results the electrons are multiple crossing the target and gradually losing all initial energy. In the thin target the soft photons are absorbed rather weakly. Therefore all generated photons are radiated, sharply raising an aggregate photon output.

Notice that the scheme of circuital BRS was offered for the first time in work [2], which reflected different features of such sources. Then similar schemes were considered in other works [3-6] and partly in [7]. Mark that only in the works carried out with author's participation, an attention is paid to an estimate of device efficiency. In the present work the more effective scheme of BRS with a magnetic field with planar symmetry is considered. It is shown by a method of computer simulation that in this case BRS have noticeably higher overall yield and much best angular characteristics of radiation. Thank to applicaion of a special magnet system the circuital source efficiency is essentially risen, and sharp direction property of BR is restored.

SOURCE LAYOUT. MAGNET SYSTEM PROPERTIES

The experimental setup proposed is represented in Fig. 1. 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 operation volume. Electrons circling in the magnet field are hitting the target several times. Then they are been removed

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through a channel EO. BR generated by electrons is been taken out through a photon channel BRO.

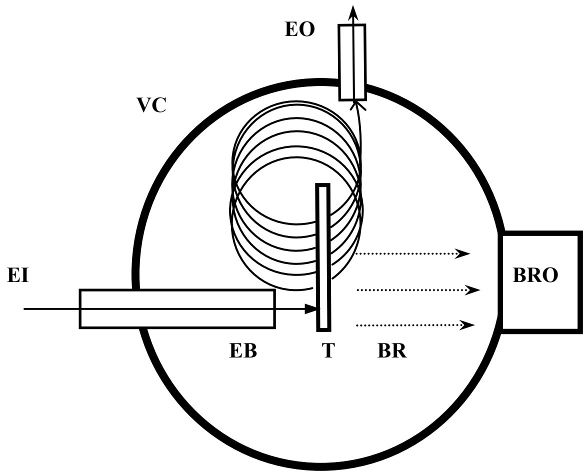

Figure 1. The scheme of experimental setup.

A magnetic field must carry out some functions. The first one is ensuring a stable circulation of electrons with their properly focused back fall on the target. The second one is a necessity to shift the rotating particles along the target. For this the special configuration of magnetic field is considered. At first approximation a suitable field configuration can be creating by means of magnetic poles of a rather 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 "before and after" the target, and the latter provides a lateral drift of particles. By results of our previous works [3], the similar magnetic configurations provides reliable focusing of particles.

However for sharp directed radiation obtaining, a system proposed must provide homogeneity of focusing for particles of various energies during a radiation cycle. Therefore a more fine magnet system must be applied if we want to reduce the radiation divergence. The latter requires circling electrons return on the target along trajectories which are close to be parallel to preceding ones (in this case the divergence angle of electrons is not "accumulated"). The problem is being resolved in system with special profile of magnet poles optimized for reaching full homogeneity of radiant particle focusing.

MODELING AND RESULTS. BACKGROUND FACTOR

In the present work, the method of computer modeling with use of the software package GEANT (CERN) is applied [8]. The software library GEANT represents extensive one of the programs for modeling atomic and nuclear experiments.

As a result 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 with initial energies of radiant electrons at 5, 20 and 50 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 ones are surpass at several times over traditional bremsstrahlung devices in generation of the 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, fig.3, and fig. 4.

Statistic of data illustrated corresponds to number of incident electrons at several hundreds of thousands. We see distributions of photon number yield along an energetic scale for different energies of incident electron in proposed and traditional schemes.

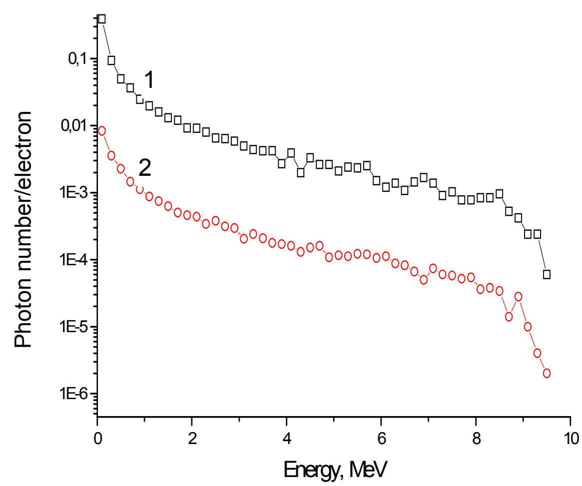

Figure 2. Dependence of specific yield of photon number, irradiated in cone with polar angle at5 ^{0}, per one incident electron with energy at 5 MeV on photon energy for circuital (curve 1) and traditional schemes (curve 2).

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 50 MeV.

Modeling data permit to make the other important conclusion. Introduce a term "background factor" (BF) which is equal to the relation of photon numbers radiated in 5 ^{0} - cone and in the rest space.

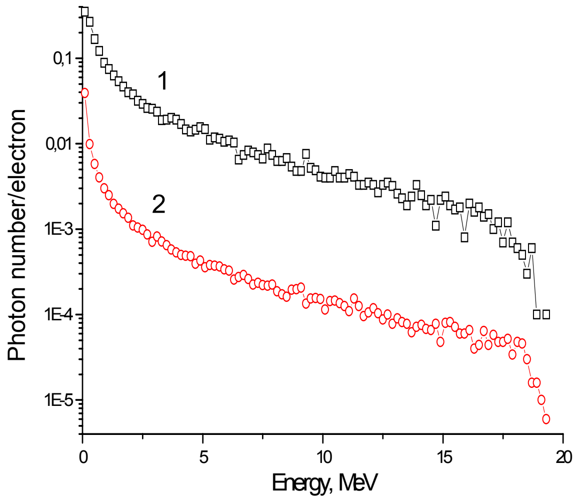

Figure 3. Dependence of photon number yield, irradiated in cone with polar angle at 5 ^{0}, per one incident electron with energy at 20 MeV on photon energy for circuital (curve 1) and traditional schemes (curve 2).

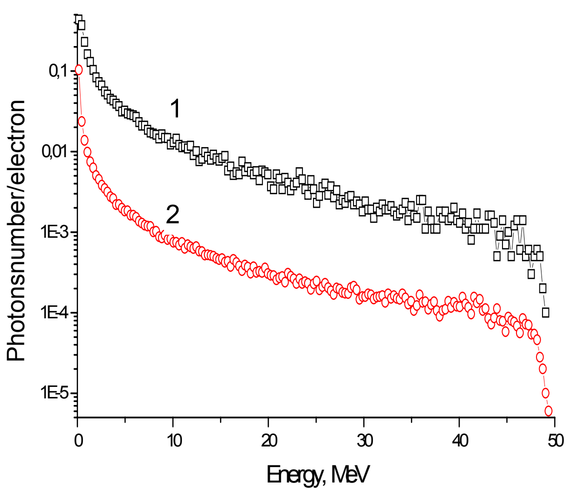

Figure 4. Dependence of photon number yield, irradiated in cone with polar angle at5 ^{0}, per one incident electron with energy at 50 MeV on photon energy for circuital (curve 1) and traditional schemes (curve 2).

This factor allows to estimate "usefulness" and "efficiency" of device usage. So, for traditional and circuital devices with of electron energy 10 MeV we have, accordingly, BR = 0.5 and BR = 0.6 at the registration of photons of all energies, and BR = 0.55 and BR = 1.43 for photons with energy being higher 2 MeV.

So the efficiency of the circuital device at hard photon radiation appears not only higher, but also at three times smaller "background pollution ".

CONCLUSION

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

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