ON THE INFLUENCE OF EXTERNAL MAGNETIC FIELD ON X-RAY TRANSITION RADIATION SPECTRUM

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The work is dedicated to theoretical investigation of the spectrum of x-ray transition radiation (XTR) on a target placed in the external magnetic field. Modification of the spectrum due to interference of the transition radiation with the synchrotron radiation in the magnetic field is investigated. It is shown that both radiation suppression and enhancement can take place under various conditions. The developed theory is applied for the analysis of the experiment on XTR recently conducted at the Test Beam Facility at DESY.

PACS: 41.75.Ht; 41.60.Dk; 41.60.Ap

INTRODUCTION

The processes of electromagnetic radiation during interaction of a high-energy particle with media or external fields can develop within a large distance along the particle trajectory, known as formation length l_F [1]. If the particle experiences further interactions within the distance l_F leading, for instance, to perturbation of its trajectory, the properties of its radiation can be considerably modified. Such a phenomenon has been intensively investigated for bremsstrahlung during electron multiple scattering in amorphous media, which led to discovery of Landau-Pomeranchuk-Migdal and Ternovskii-Shul'ga-Fomin effects of bremsstrahlung suppression [1, 2]. These effects, taking place at different values of the ratio of l_F to the target thickness, are caused by the fact that the particle deflects to a large angle (larger than $1/\gamma$, where γ is the particle Lorentz-factor) within l_F due to multiple scattering. This leads to shortening of the effective path of radiation formation and as a result to its suppression.

In the present work we investigate the analogue of these effects for x-ray transition radiation (XTR) generated by a high-energy electron on a target placed in external magnetic field. In this case the field curves the particle trajectory in such way that under some conditions the particle can deflect to an angle about or exceeding $1/\gamma$ within XTR formation length and it is natural to expect suppression of XTR intensity. Such a suppression can be considered as a result of destructive interference between XTR and synchrotron radiation in the magnetic field. The motivation for this investigation is, particularly, to elaborate a theoretical basis for the analysis of the results of experiment on XTR recently conducted at the Test Beam Facility TB-21 at DESY [3]. In this experiment, in order to decrease the background coming with the incident several GeV electron beam, the XTR target was placed in the magnetic field. Before impinging on the target the beam was deflected by the field. After penetrating through the target it was further deflected not to hit the XTR detector. The obtained results appeared to be somewhat different from the ones expected from the XTR theory for the case of rectilinear particle trajectory taking place in the absence of the external field.

RESULTS OF THEORETICAL INVESTIGATION

Let us briefly discuss the results of analytical consideration of this process. For calculations the geometry presented in Fig.1 was used.

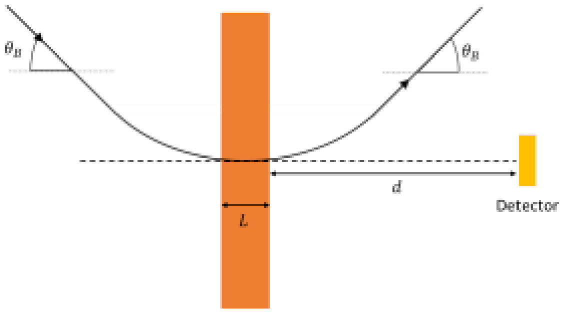

Fig. 1. Geometry of the considered system. Here θ_B is the deflection angle

For calculation of spectral-angular density of the number of emitted photons a method introduced by Garibyan [4] was applied. It was preliminarily adjusted to consideration of radiation in x-ray band. For numerical estimations we applied the values of parameters which took place in the experiment. Particularly, this involves: 2 and 4 GeV electron energies, 17.33 m electron Larmor radius in the magnetic field, 53 μm target thickness, 1.13 mrad as a half of the detector angular size, 1.33 m as a distance from the detector to the target. Radiation attenuation in the target, as well as in the air on its way to the detector, was taken into account.

Applying the mentioned method, the expression for spectral-angular density of the number of photons was derived and further integrated over the detector solid angle. The resulting XTR spectra are presented in Fig. 2. As we can see from this figure, no radiation suppression should take place in the considered case. On the contrary, the spectrum is noticeably intensified. This might seem weird since at 4 GeV the electron deflection angle l_F/R within the XTR formation length is around $1/\gamma$ and one may expect XTR suppression. Further analysis showed that the reason for this is a significant dependence of l_F on the observation angle, due to which the condition $l_F/R > 1/\gamma$ is violated for the most part of the angles, registered by the detector, except for the smallest ones.

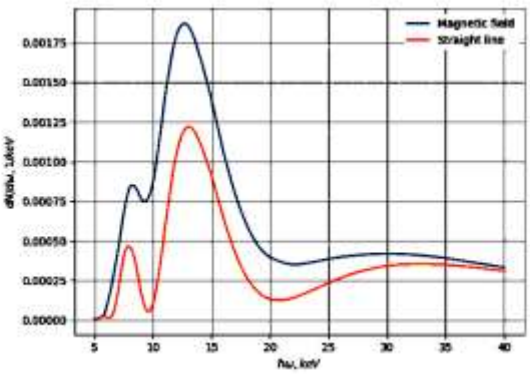

Fig. 2. XTR spectra for the particle motion in the magnetic field (upper curve) and for rectilinear trajectory (lower curve). Electron energy is 4 GeV

In this case the total radiation can be decomposed into an incoherent sum of XTR at rectilinear particle trajectory and synchrotron radiation. The analogous treatment for energy 2 GeV shows that the spectra for the particle motion in the magnetic field and for rectilinear trajectory are almost the same. This fact means that for this energy (and lower) one can neglect the effects of synchrotron radiation and use the conventional formulas for transition radiation at rectilinear particle trajectory.

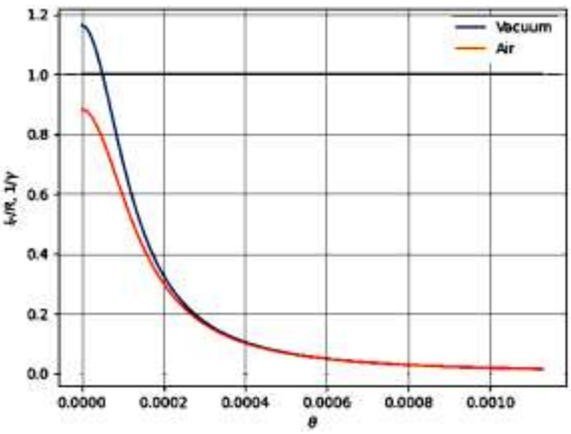

Fig. 3. Dependence of the deflection angle within the formation length on the observation angle for the particle motion in vacuum and air. Electron energy is 4 GeV

Further consideration, performed for smaller radii of curvature of the particle trajectory, higher particle energies and smaller detector acceptance angles showed that XTR suppression indeed takes place in the case when the deflection angle within the radiation formation length $l_F = 2c/[\omega(\gamma^{-2} + \theta^2 + \omega_p^2/\omega^2)]$ is larger than $1/\gamma$ for all or most of the observation angles accepted by the detector. This requirement was not met under the discussed experimental conditions, which follows from Fig. 3, demonstrating the dependence of the electron deflection angle (measured in the units of $1/\gamma$) within l_F, on θ within the range of the detector acceptance angles.

The coincidence between the developed theory and the experimental results is quite nice for 4 GeV electron energies. Such a coincidence appeared to be poorer for smaller particle energies such as 1, 2 and 3 GeV. Further considerations demonstrated that this can be attributed to the beam size, beam divergence and beam shift effects which could have influenced upon the experimental results. Generally, the presented treatment shows that the effect of XTR suppression due to the particle deflection in the magnetic field is expected to take place for higher electron energies and smaller detector acceptance angles.

ACKNOWLEDGEMENTS

The work of S. Trofymenko, A. Potylitsyn and G. Kube was partially supported by the project No. 531314364 of the German Research Foundation (STCU project No. P811). The work of G. Kube and A. Shchagin was partially supported through the MSCA4Ukraine project No. 1233244, which is funded by the European Union.

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