On Synchrotron Radiation from Electrons Moving in Edge Field of a Bending Magnet on the SPring-8 Storage Ring

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1. Introduction

The synchrotron radiation from electrons moving in spatially varying magnetic field at an edge of a bending magnet (edge radiation) has distinctive features as compared to radiation from electrons moving along a circular trajectory in uniform field of a bending magnet (arc radiation) [1].

The edge radiation (ER) having wavelengths longer than the critical wavelength of the arc radiation (AR) has the following characteristics [1].

1) The peak photon flux density of the ER is higher than that of the AR, typically by one order of magnitude or more.

2) The intensity peak of the ER appears at angles $\pm 1/\gamma$ with respect to the straight section axis, where γ is the Lorentz factor. The ER has narrower angular distribution than the AR.

The critical wavelength λ_c of the AR on the SPring-8 storage ring is λ_c = 0.429 Å (28.9 keV). It is expected that intensive ER is observed near the straight section axis in the long wavelength regions such as infrared, visible and ultraviolet.

2. Calculation of Edge Radiation on the SPring-8 Storage Ring

The geometry for calculation of the ER from the storage ring bending magnet (BM) is shown in Fig. 1. The straight section axis is defined as the Z-axis. The horizontal and vertical axes in the plane perpendicular to the Z-axis are defined as the X and Y axes, respectively. In directions near the Z-axis, two sources of the ER are observable. One is the entrance edge of the downstream BM 1 and the other is the exit edge of the upstream BM 2. For simplicity, we ignored the radiation from the BM 2 and calculated only radiation from the BM 1.

The trajectory of an electron was calculated by solving the equation of motion numerically with the Runge-Kutta method. A magnetic field distribution measured in a prototype BM of the SPring-8 storage ring was used [2]. The radiation from an electron beam moving along this trajectory was calculated numerically by changing the observing angle.

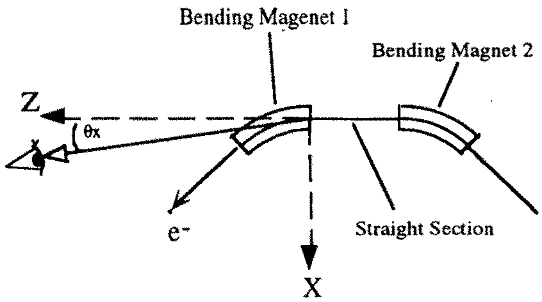

Fig. 1. Geometry for observation of edge radiation.

Angular distribution of synchrotron radiation in the plane of electron trajectory is shown in Fig. 2. The wavelengths are 1 Å, 500 nm, and 1 mm. The ER in the long wavelength region is observed near the straight section axis θ_X = 0. The flux densities converge into constant values as the observing angle θ_X becomes positively large. These constant values correspond to those of the AR. In the case of X-ray having wavelength of 1Å (or photon energy 12.4 keV), the ER is weaker than the AR.

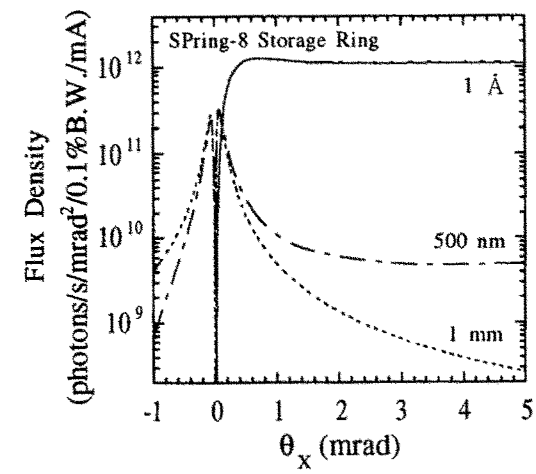

Fig. 2. Angular distribution of synchrotron radiation in the plane of electron trajectory.

On the other hand, in the case of longer wavelength radiation such as visible (λ = 500 nm) and infrared (λ = 1 mm) light, the ER is more intense than the AR. The intensity peaks of long wavelength ER appear at $\theta_X = \pm 1/\gamma = \pm$ 0.06 mrad. These features are the characteristics of long wavelength ER [1].

3. Edge Effect on Radiation in a Bending Magnet Beamline

The implicit assumption in the theoretical calculation of ideal AR is that the length of a BM is infinite. It is assumed that the circular trajectory of an electron is not terminated. On the other hand, the actual BM on the SPring-8 storage ring has finite length, and the source point of BM beamline is located at 147 mm inside from the edge of BM. The finite length between the source point and the magnet edge affects radiation in BM beamlines. Radiation characteristics of BM beamline in long wavelength region is different from that of the ideal AR.

The horizontal angle between the photon beamline from a BM and the straight section axis is $\theta_X = 3.7$ mrad (Fig. 1). As shown in the calculated distribution of Fig. 2, the flux densities of radiation of wavelengths 1 Å and 500 nm are constant at the horizontal observing angle of $\theta_X = 3.7$ mrad. They are consistent with that of the AR. While the flux density of 1 mm radiation is significantly decreasing at $\theta_X = 3.7$ mrad towards larger observing angles. It is larger than that of the AR.

The effect of magnet edge is remarkable in vertical distribution of radiation. Figures 3a and 3b show the distribution of the ideal AR and the actual radiation in beamline, respectively. The wavelength of radiation is 1 mm. The distribution in beamline was numerically calculated for the observing angle $\theta_X = 3.7$ mrad. The actual radiation has more intense peak and narrower distribution than ideal AR.

To find out wavelength region where the edge effect

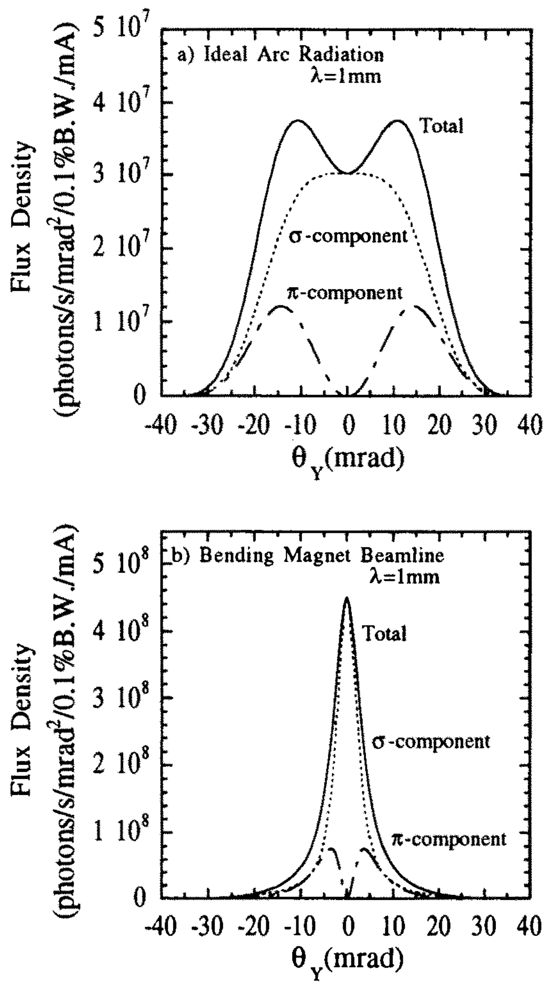

Fig. 3. The edge effect in synchrotron radiation. The wavelength is 1 mm. a) Vertical distribution of ideal arc radiation, wherein the length of bending magnet is infinite. The lower panel b) Vertical distribution of radiation of bending magnet beamlines on the SPring-8 storage ring. The distance of the source point from the magnet edge is 147 mm.

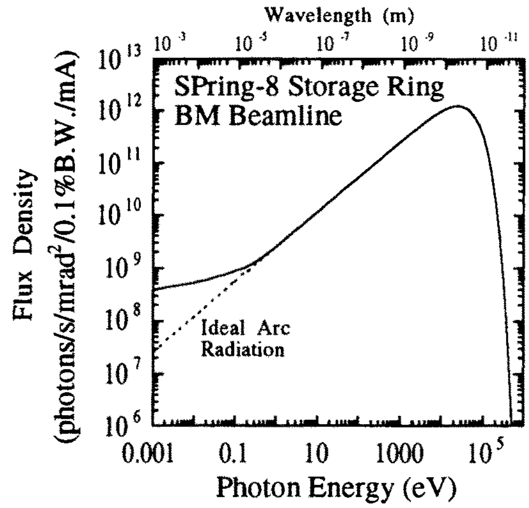

Fig. 4 Spectral flux density on the median plane of the actual bending magnet beamline (solid line) and that of ideal arc radiation (broken line).

is significant, spectral flux density on the median plane was calculated numerically. The solid line in Fig. 4 shows the spectrum in actual beamline and the broken line shows spectrum of the ideal AR. For wavelengths longer than a few μm, deviation from the ideal AR is noticeable.

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References

[1] O. V. Chubbier and N. V. Smolyakov, Proc. IEEE PAC-93, p1626 (1993).

[2] J. Ohnishi, SPring-8 SR Engineering Note MAG-001-92 (1992).