# EDGE RADIATION AND ELECTRON BEAM DIAGNOSTICS.

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*Abstract*

The visible edge radiation generated by a relativistic electron beam at fringe fields of bending magnets in storage rings is substantially different from the well-known standard synchrotron radiation. An intensive peak appears in the angular distribution of the electromagnetic radiation distribution. Its intensity exceeds considerably the intensity of synchrotron radiation. In addition, the radiation generated at two adjacent edges of dipole magnets produces an interference pattern. The real electron beam parameters (its finite transversal sizes and angular spread) have an effect on the radiation intensity distribution. It is possible to find the electron beam parameters from the experimental measured edge radiation distribution. Such electron beam diagnostics as applied to HiSOR storage ring (Hiroshima, Japan) is discussed in the presented paper.

## 1 INTRODUCTION

Electromagnetic edge radiation is generated by a relativistic charged particle when it passes through the region of a rapid change in magnetic field at the edges of the storage ring bending magnets. This radiation was observed in proton [1, 2] and electron [3-6] storage rings.

In a proton storage ring the edge radiation in the short-wavelength spectral region (with wavelength $\lambda << \lambda_c$, where $\lambda_c$ is the critical wavelength of synchrotron radiation) considerably exceeds the intensity of the standard synchrotron radiation. The edge radiation of protons is a dipole one and this allows to obtain relatively simple analytical formulae for its spectral characteristics in the short-wavelength region. A theoretical analysis of the proton edge radiation in the dipole approximation was carried out in [7-10]. By virtue of its specific and attractive properties it was used to determine the transverse profile of the proton beam [2].

Contrary to the edge radiation from proton beam, the edge radiation generated by a relativistic electron beam is not the dipole type. Thus computer simulations are required to obtain the spectral properties of the electron beam edge radiation. Such analysis was carried out by a number of authors [11-15]. In [13-16] some simple and useful analytical formulae were derived, but the long-wavelength limit $\lambda \to \infty$ was used. This assumption restricts considerably the practical usage of the derived formulae.

## 2 DISTINCTIVE FEATURES OF EDGE RADIATION

The simulations made in [13-15], show the following.

In the $\lambda >> \lambda_c$ wavelength range intensive peaks appear in the angular distribution of the edge radiation intensity from a single bending magnet. These peaks exceed considerably the intensity of the standard synchrotron radiation generated in an uniform magnetic field area. Their angular positions do not depend on the radiation wavelength. For the- component of radiation the peaks are located in the storage ring median plane at horizontal angles $\pm\gamma^{-1}$, where $\gamma$ is the electron relativistic factor. For the - component of radiation the peaks are located at angles $\pm\gamma^{-1}$ above and below of the median plane.

In the median plane at horizontal angles $\pm\gamma^{-1}$ the edge radiation spectrum is shifted to the long-wavelength region and shows a slower decrease with increase in $\lambda$.

Since the generation of hard X-rays is suppressed at these angles ($\pm\gamma^{-1}$) because the bending magnetic field is depressed at the fringe region, the undesirable thermal and radioactive synchrotron radiation damage of the optical elements is decreased.

The edge radiation, generated by a relativistic electron is concentrated in a narrow forward cone. The radiation emitted at two adjacent bending magnets bounding a straight section, appears in the same cone. These photons are subsequently synchronized by the electron itself. This leads to the interference of the edge radiation. The interference manifests itself as additional oscillations in the radiation intensity distribution. As this take place, an extra oscillating factor of the $\sin^2(\frac{\pi L}{2\lambda\gamma^2}(1+\gamma^2\theta^2)$ type appears in the formulae of the spectral-angular distributions of radiation intensities (both in - and - components of the radiation, where $L$ is the distance between the near ends of two adjacent bending magnets, $\theta$ is the observation angle). In view of the fact that the spatial distributions of edge radiation, generated at each of the two ends of the bending magnets, are generally not trivial, the resulting radiation pattern on the detecting screen is complicated enough. On the other hand, such fine interference structure of the resulting edge radiation provides considerable opportunity for electron beam diagnostics.

## 3 NUMERICAL SIMULATIONS OF EDGE RADIATION

The computer code has been written for simulations of the different properties of edge radiation. This code uses the experimentally measured (or obtained by other means) fringe magnetic field mesh as the input data. A cubic spline interpolation of the fringe magnetic field has been applied to compute the field in the intermediate points. The program computes the electron trajectory in the edge fields, the one- or two-dimensional distributions of intensities for , and (+) light components, the energy spectra at a given points on the screen, the Stokes parameters and the flux integrated over the screen size. The simulations include the near-field effects and the real electron beam emittance effects too. The last options do not distinctly increase the computation time due to carefully optimized algorithms.

The simulations presented below were made for the HiSOR storage ring [17]. The electron beam energy is 0.7 GeV, the beam current is 300 mA, the bending magnetic field is 2.7 T, the distance between magnets $L$ is 8240 mm, the distance from the screen to the nearest bending magnet edge is 10000 mm, the energy of photons is 2 eV.

Let the y-axis be parallel to the straight section axis and z be the vertical axis. Fig. 1 shows the x-dependence of the edge radiation intensity on the screen at the median plane (z=0). The vertical distributions of - and - components of the edge radiation intensity at x= -0.72 mm are plotted in Figs. 2 and 3 respectively. The electron beam emittance is taken to be zero in this simulations. The difference in the edge radiation intensity magnitudes, emitted at the first and the second edges of the bending magnets (dashed lines in Figs. 1-3), stems from the fact that the distance from the screen to the second fringe field is nearly twice as large as the distance to the first fringe field. This magnitudes tends to be alike when the distance from the screen to the straight section increases. The interfering edge radiation intensity (Fig. 1) is asymmetric about x=0 because of the relatively short distance from the screen to the straight section too.

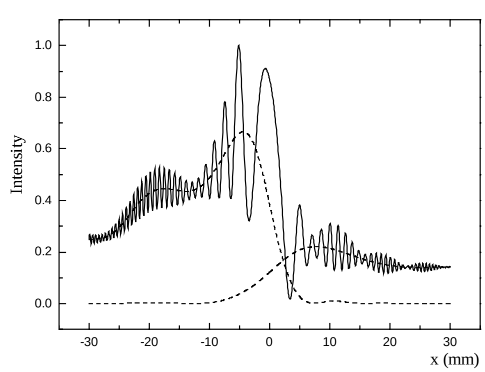


Figure 1: Interfering edge radiation at the screen vs. the horizontal coordinate x (solid line). The dashed lines show the edge radiation intensity for each edge separately.

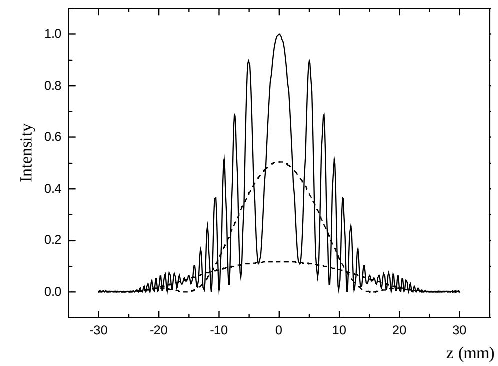


Figure 2: - component of the interfering edge radiation (solid line) and for two edges singly (dashed lines) vs. the vertical coordinate z.

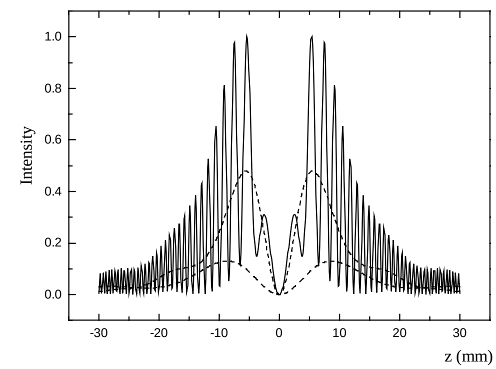


Figure 3: - component of the interfering edge radiation (solid line) and for two edges singly (dashed lines) vs. z.

Figs. 4-6 demonstrate the simulations of the interfering edge radiation for the electron beam with finite emittance. The horizontal electron beam size is 1.49 mm, the vertical beam size is 0.259 mm, the horizontal beam divergence is 0.398 mrad, the vertical beam divergence is 0.130 mrad at the straight section center.

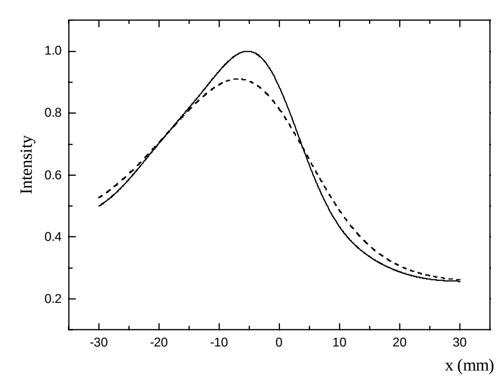


Figure 4: Interfering edge radiation at the screen median plane vs. x for the beam with real emittance, see text (solid line) and for the double emittance magnitude (dashed line).

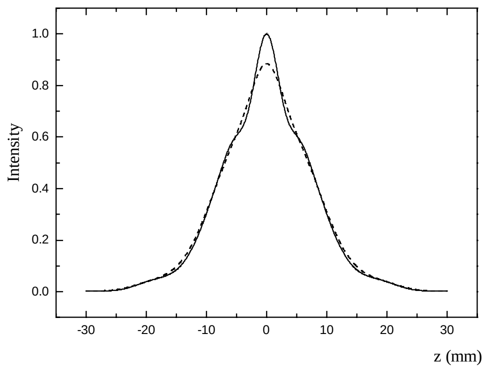


Figure 5: - component of the interfering edge radiation vs. z for the beam with real emittance (solid line) and for the double emittance magnitude (dashed line).

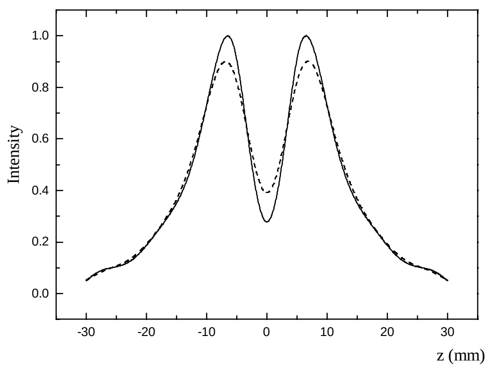


Figure 6: - component of the interfering edge radiation vs. z for the beam with real emittance (solid line) and for the double emittance magnitude (dashed line).

The simulations show that the interference oscillations in the edge radiation pattern will be smoothed out by the electron beam emittance effect. The reason is that the distance between the magnet $L$ = 8240 mm is much larger than $\lambda\gamma^2$ = 1160 mm. It produces the intensity oscillations with too small spatial period (Figs. 1-3). Nevertheless the interference edge radiation intensity still remains irregular. This intensity distribution is reasonably sensitive to the electron beam emittance magnitude. Thus it is possible to use the edge radiation for electron beam parameters measurements.

The preliminary evaluations show that enough intensive visible light will be generated in the quadrupole lenses. It is evident that this radiation will interfere with the edge radiation. This provides us an additional opportunity for electron beam diagnostics. Such investigations are pursued now at our laboratory.

## 4 ACKNOWLEDGMENTS

The authors appreciate valuable discussions with Prof. K. Yoshida.

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