DIFFRACTION RADIATION MONITOR

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Abstract

Diffraction radiation is one of non-destructive electron beam diagnostic techniques. A circular aperture, rectangular slit, and edge are used as a diffraction radiation targets. A transverse size, divergence, bunch charge, position, and bunch length can be measured by analysing a spatial distribution of DR. In the case of that the electron beam energy is low and the bunch length of the electron beam is in the range of few ps to sub-ps, coherently enhanced diffraction radiation with the wavelength of sub-mm to mm range is used. A spatial distribution of coherently enhanced diffraction radiation generated from an edge and slit was measured with a terahertz camera.

INTRODUCTION

Diffraction radiation (DR) is generated when a charged particle moves in the vicinity of a boundary between two media with different dielectric constants. The charged particle does not directly interact with the material. An electric field with an effective electric field radius of $\gamma\lambda/2\pi$ (γ is the Lorentz factor of the charged particle, λ is the observed wavelength of DR) interact with the material. In the condition that the distance between the charged particle and the boundary, d, is larger than the effective electric field radius, no radiation generats. The boundary gets close to the charged particle, DR is generated.

DR is mainly used for the non-destructive electron beam diagnostics. Visible wavelength of DR is usually used for the beam diagnostic of a high energy electron beam. Beam size measurement as small as 14 µm was achieved at KEK-ATF by a rectangular slit [1]. Simultaneous measurement of the beam size, divergence, and position of the electron beam was proposed and experimentally investigated at the FLASH, DESY [2].

On the other hand, long wavelength of DR is used for low energy electron beam diagnostics. If the Lorentz factor and wavelength of DR are 100 and 500 nm, the effective electric field radius is calculated to be 8.0 µm. This value is much smaller than the typical beam size. Thus, long wavelength of DR such as a far-infrared or terahertz radiation have to be measured. When $\gamma = 80$ and $\lambda = 0.2$ mm, the effective electric field radius is calculated to be 2.5 mm. This value is much larger than the typical beam size and a fabrication of the mechanical slit is also easy.

Long wavelength radiation of DR is generated via coherent radiation. Coherent radiation is generated when the electron bunch length is much smaller than the wavelength of DR generated from the electron. Frequency spectrum of coherent radiation is strongly depended on the electron bunch length. Thus the beam diagnostic using the coherent diffraction radiation (CDR) is applied to the bunch length measurement at the low energy electron beam facilities [3-6].

In the previous research [7], feasibility study of beam position measurement using CDR generated from the slit was reported. It was found that an asymmetry distribution of CDR was sensitive to the beam position with respect to the slit center.

In this proceedings, spatial distribution and relative intensity of CDR generated from an edge and slit is reported to make clear the basic properties of CDR.

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EXPERIMENT SETUP

Spatial distribution measurement of CDR was conducted at an S-band compact electron linac at AIST. The electron beam was generated from a photocathode RF gun and accelerated up to 40 MeV by two accelerating tubes. Number of bunch in the macro pulse was 23 and repetition rate of the macro pulse was 25 Hz. The electron beam was then compressed in the longitudinal direction at an achromatic arc section. The compressed electron beam passed through a slit target for generating CDR. The electron beam size was controlled by three quadrupole magnets installed in the upper stream of the slit target. The bunch charge was 0.1 ~ 0.3 nC/bunch.

Schematic illustration of the spatial distribution measurement of CDR is shown in Fig. 1. The slit target was tilted at 45 degree. Thus the backward CDR was emitted toward the perpendicular direction against the electron beam trajectory. Backward CDR was collimated by a 100 mm focal length lens and leaves the vacuum duct through a z-cut crystal quartz window with the thickness of 9 mm. The radiation was then reflected by two silver mirrors, and passes through a wire grid linear polarizer (Specac, GS57203), a lens with the focal length of 50 mm, infrared blocking filter (NEC, IRV-TF030),

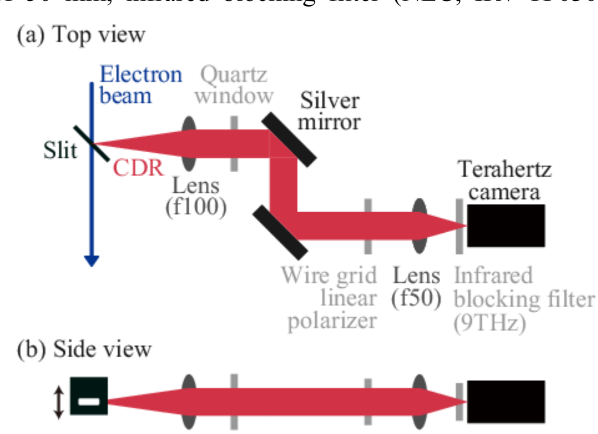

Figure 1: Schematic illustration of the spatial distribution measurement of CDR using a terahertz camera.

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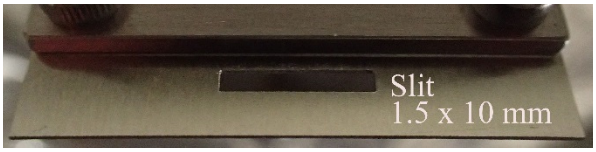

Figure 2: Picture of the rectangular slit target with the dimension of 1.5 mm x 10 mm and edge for generating the CDR.

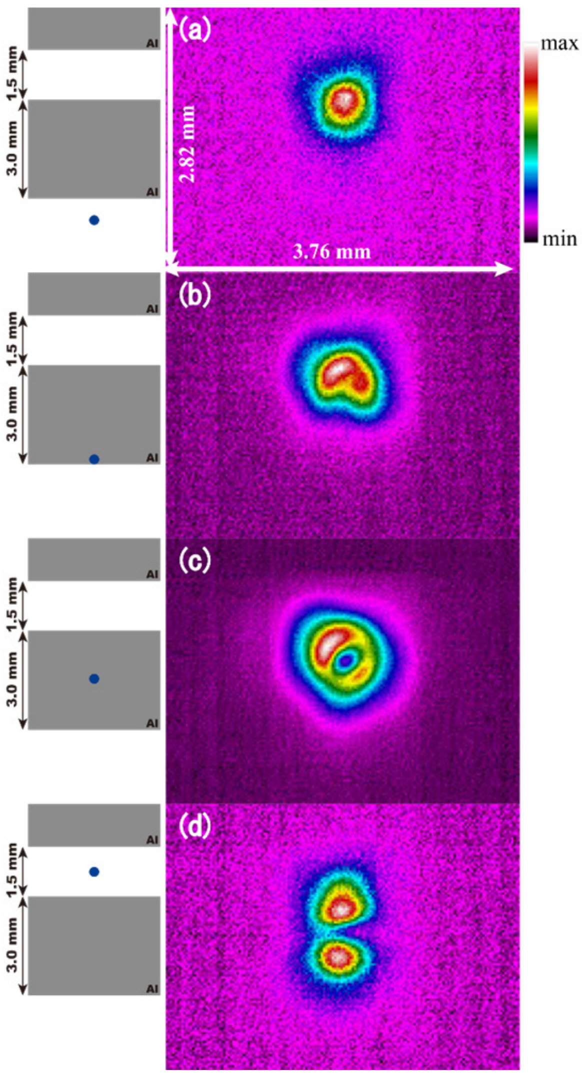

Figure 3: Spatial distribution of the CDR and CTR measured with the terahertz camera. (a) CDR: The electron beam passed in vacuum where 0.7 mm away from the edge. (b) CDR+CTR: The electron beam passed through the aluminium where 0.2 mm inside from the edge. (c) CTR: The electron beam passed through the central of the semi-plane. (d) CDR: The electron beam passed through the central of the rectangular slit.

and finally detected by a terahertz camera (NEC, IRV-T0832). In the experimental condition, the terahertz camera mainly detected the frequency of 1.5 THz. Thus the effective electric field radius is calculated to be 2.5 mm.

An image of the rectangular slit and edge target is shown in Fig. 2. The slit was made a hole with the dimension of 1.5 mm x 10 mm in 0.5 mm thick aluminium. There are semi-plane to generate coherent transition radiation (CTR) with the width of 3 mm under the rectangular slit. We also used the edge of semi-plane to generate the CDR. The slit target was fixed to the holder mounted on a linear manipulator. Thus the slit can be moved in the vertical direction against the beam trajectory. In order to observe the CDR, the beam trajectory and the beam size of the electron beam have to be adjusted. First, the spatial distribution of CTR emitted from the semi-plane was checked. The beam parameters were adjusted to obtain the ring profile of CTR. Then, we measured the spatial distribution of CDR.

RESULTS AND DISCUSSION

Figure 3 shows the spatial distribution of CDR and CTR measured with the terahertz camera.

The spatial distribution of CDR emitted from the edge of the semi-plane is shown in Fig. 3 (a). The electron beam moved in a position where 0.7 mm away from the edge of the semi-plane. The spatial distribution with a single peak was observed.

If the electron passed a position where a lower side of semi-plane, the distribution is changed like a new moon as shown in Fig. 3(b). This is because a low frequency component of CDR is suppressed. The semi-plane is cut at the distance shorter than the wavelength of low frequency CDR. Terahertz camera has a low sensitivity for long wavelength terahertz radiation. Thus the intensity of lower side is decreased.

When the electron passed through the central position in semi-plane, the distribution is almost similar to the CTR (Fig. 3 (c)).

If the electron passed through the center of the slit, main intensity is aligned along the vertical direction (Fig. 3 (d)). This result is similar to the distribution which is measured with the slit width of 1.0 mm [7].

Normalized total counts in area detecting the CDR is shown in Fig. 4. Total counts of background is subtracted. The measurement was carried out at three times. The plus symbol in Fig. 4 shows that the edge of the semi-plane got close to the electron. The target was moved at 80 µm step. The cross symbol in Fig. 4 is the CDR generated from the edge and slit was measured. The target was moved at 200 µm step. The square symbol in Fig. 4 is the vertically polarized CDR generated from the slit by moving the target at 120 µm step. No CDR was observed when the distance between the electron and the edge of the semi-plane was larger than the effective electric field radius. The total counts was increased as the edge of the semi-plane got close. Total counts was maximized at around the center of the semi-plane and was decreased as the edge of slit got close. Once the total counts was minimized at the slit center. It was slightly increased as the upper side edge of the slit got close, however, it was immediately decreased. Originally, the total intensity

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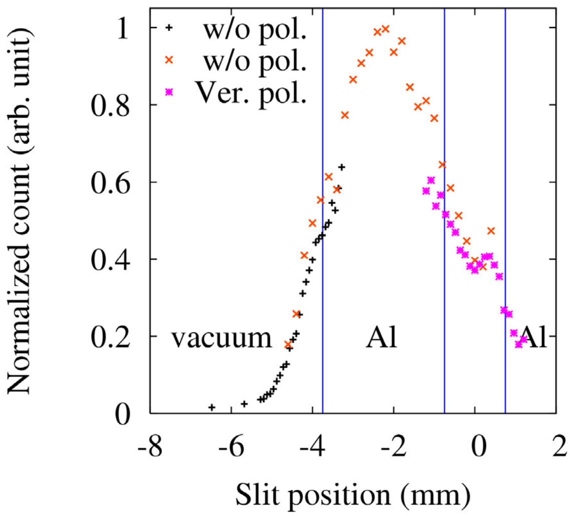

Figure 4: Normalized total counts in area the CDR is detected. The plus and cross symbols are the normalized counts when the polarizer was not used. The square symbol is the normalized counts of the vertically polarized component.

inside the slit describes a parabolic curve as observed in Ref [3]. A decline of the total counts around the upper edge of the slit is due to a structural asymmetry around the slit. There are a material of a holder on the slit.

CONCLUSION

Spatial distribution and relative intensity of CDR generated from the edge and slit target was measured with the terahertz camera. No radiation was observed when the distance is longer than the effective electric field radius of CDR. The spatial distribution of CDR is dramatically changed by the target position. In the near future, spatial distribution of horizontally polarized and vertically polarized CDR generated from the edge and slit will be measured with the polarizer and be compared with a calculation.

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