X-ray Emission from Caesium Sputter Ion Source of 1.7MV Tandetron Accelerator

Nobuyuki SUGIURA, Toshiso KOSAKO and Takeshi IIMOTO
Research Center for Nuclear Science and Technology, The University of Tokyo
2-11-16, Yayoi, Bunkyo-ku, Tokyo 113-0032, Japan

Abstract

The dose rate around 1.7 MV tandetron accelerator was measured. High dose rates of X-ray were detected from a ceasium sputter ion source. The dose rate was the order of 10 μSv/hr. The spectrum of this X-ray has a peak at 25.8 keV. This X-ray showed directivity. This X-ray is considered as the bremsstrahlung, which is generated by the collision of electron to extraction electrode.

This situation was simulated and analysed by EGS4 code. X-ray emission from extraction electrode was found in all directions and the energy spectrum . After passing the wall of ion source, 1 mm thickness of SUS304, the energy spectrum showed a single peak, which range was from 20 to 25keV. It is thought that the generation mechanism of X rays could be confirmed analytically.

1 Introduction

In recent years, the installation of small accelerator is growing for the research field of ion beam science. The 1.7 MV tandetron was installed at Research Center for Nuclear Science and Technology of the University of Tokyo. We have reported the dose rates around the accelerator and the X-ray leakage from the ceasium sputter ion source for providing fundamental information on radiation protection and control [1].

We accumulated further information on the X-ray around the ion source and investigated the mechanism of X-ray generation by using EGS4 simulation.

2 Radiation Dose around 1.7 MV Tandetron

2.1 Measurement method of radiation dose

The ionizing chamber type survey meter (AE-133L, Applied Engineering Inc.) was used for the dose rate measurement. The spectrum measurement around the ion source was done by NaI(Tl) scintillation detector with Be window (Ohyo Koken Kogyo Co.).

The measured ion species were H^{+}, He^{2+}, C^{2+}, N^{2+}, Si^{2+}, Cu^{2+} and Au^{2+}. Terminal voltage was around 1.7 MV.

2.2 Dose distribution and spectrum of X-ray

High dose rates were detected around the ceasium sputter ion source. The dose rates were 35, 15 and 2.7 μSv/hr when ion species were Au^{2+}, Cu^{2+} and N^{2+}, respectively. The spatial dose distribution of X-ray around the ion source in case of accelerating C^{2+} is shown in Fig. 1. This X-ray emission had a directivity.

The spectrum of X-ray around the ion source in case of accelerating Au^{2+} is shown in Fig.2. The peak energy of X-ray was 25.8 keV. The peak energy did not change by the deference of ion species.

This low energy X-ray could be easily shielded by 1 mm thick iron plate. The dose rate decreased from 35 μSv/hr to 0.8 μSv/hr in case of Au^{2+} and from 15 μSv/hr to 0.45 μSv/hr in case of Cu^{2+}.

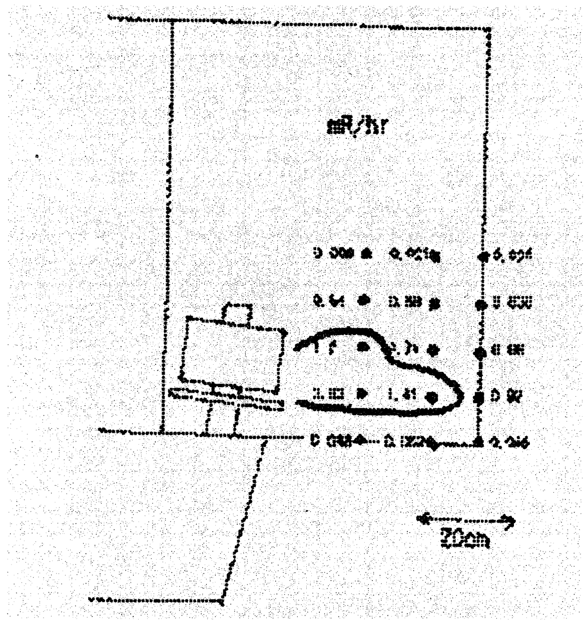

Fig. 1 Dose distribution around ceasium sputter ion source. (ion species: C^{2+})

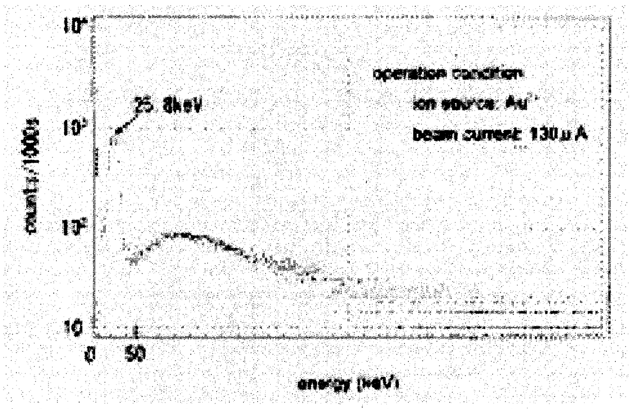

Fig.2 Spectrum of X-ray around ceasium sputter ion source. (ion species: Au^{2+})

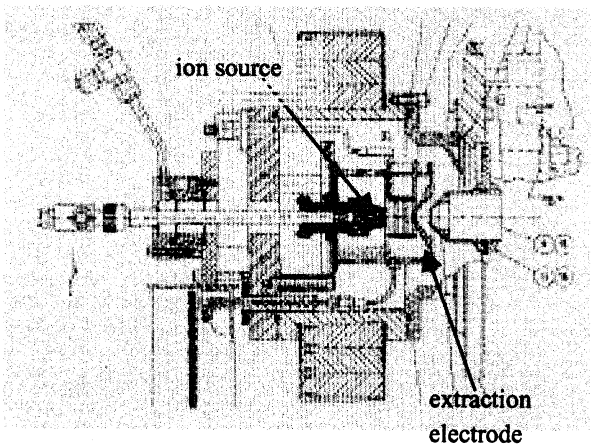

Fig.3 Cross section of ceasium sputter ion source. The potential at the ion source is 0 V (earth), and extraction electrode is -30 kV [2].

The mechanism of the X-ray emission from the ion source was speculated as follows:

1) Free electrons are generated with other anion species in the ceasium atmosphere, especially from the surface of ion source.
2) The free electrons were accelerated by the potential difference between ion source and extraction electrode.
3) The electrons were collided with the extraction electrode and the Bremsstrahlung was generated.

3 Analysis of X-ray Emission by EGS4

3.1 EGS4 Simulation Code

The EGS4 code simulates the electromagnetic cascade and the transport of electrons, positrons, and photons by Monte Calro techniques. The following physical processes are taking into account: 1) bremsstrahlung production, 2) positron annihilation in flight, 3) Moller and Bhabha scattering, pair production, Compton scattering, coherent scattering, photoelectric effect, and continuous energy loss of electrons and positrons with Moliere multiple scattering [3]. The general purpose user's version of the EGS4 code system was developed to make an input files easily by using a CG input [4].

In the present study, this general purpose user's version of the EGS4 was used for the simulation of the generation of Bremsstrahlung from the ion source.

3.2 Calculation conditions for EGS4

EGS4 simulation was done in order to analyse the mechanism of X-ray emission around the ion source. The calculation condition for EGS4 is as follows:

1) source: electron, beam, 30keV (Beam direction was varied from 0° to 75° in every 15°)
2) target: SUS303 (This was represent for material of an extraction electrode)
3) detector: surface crossing detector
   - energy bin: 2.5 keV to 30 keV in every 2.5 keV
   - position: -75° to 75° , every 15°
4) histrory: 10,000,000

3.3 Calculation results of EGS4

Figure 4 shows the deference of directional distribution of Bremsstrahlung by electron beam direction. When the electron collides with the target vertically (0°), the directional distribution seemed almost uniform. On the other hand, when the electron comes slantways (-45°), large amount of Bremsstrahlung was detected in the opposite side.

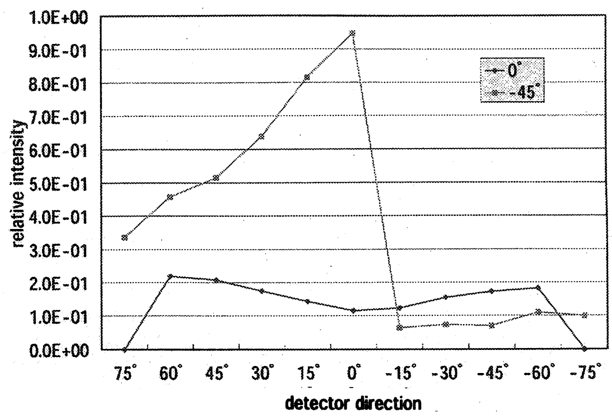

Fig.4 Deference of directional distribution of Bremsstrahlung by electron beam direction

Figure 5 shows the EGS4 simulation results of energy spectrum of Bremsstrahlung generated from extraction electrode. As is shown in Fig.5, the more diagonally the electrons enter, the larger the fraction of low energy X rays is.

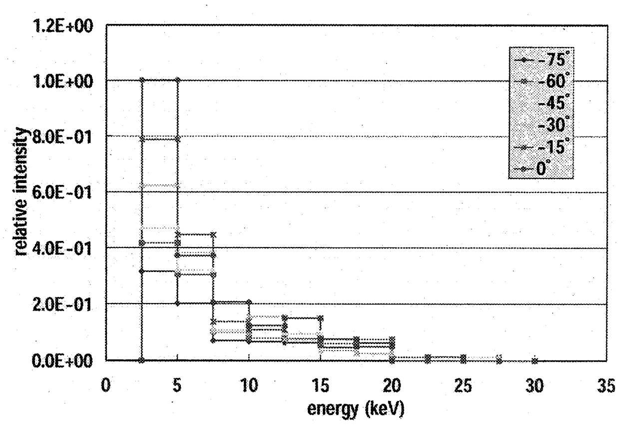

Fig. 5 Energy spectrum of Bremsstrahlung generated from extraction electrode by EGS4.

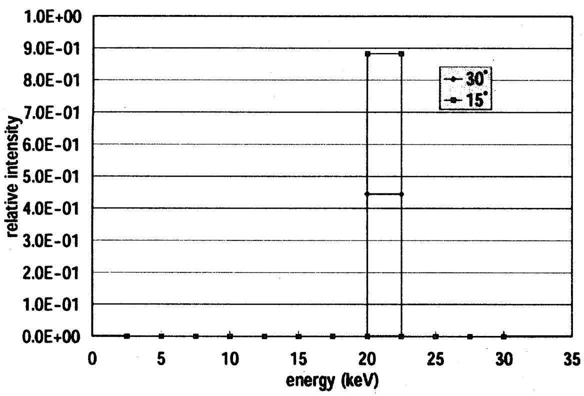

Fig. 6 The spectrum after attenuation of 1 mm thickness SUS304.

Table.1 Linear attenuation coefficient used for estimation of effect of SUS304.

energy (keV)	linear attenuation coefficient (cm^{-1})
5 - 7.5	8.69E+02
7.5 - 10	1.99E+03
10 - 12.5	1.11E+03
12.5 - 15	6.66E+02
15 - 17.5	3.82E+02
17.5 - 20	2.60E+02
20 - 22.5	1.81E+02
22.5 - 25	1.47E+02
25 - 27.5	1.13E+02
27.5 - 30	7.93E+01

Table 1 shows the linear attenuation coefficients for evaluation of the effect of SUS304. As shown in Fig. 6, the energy spectrum showed a single peak which range was from 20 to 25keV after passing the wall of ion source, 1 mm thickness of SUS304. As a result of EGS4 simulation based on the speculation described in the end of section 2.2, the obtained energy spectrum was the almost same as the measured spectrum (Fig.2). Therefore, it is thought that the speculated generation mechanism of X rays could be confirmed analytically.

4 Conclusion

The dose rate around 1.7 MV tandetron accelerator at RCNST, the University of Tokyo was measured. The dose rates around a ceasium sputter ion source was relatively high (the order of 10 μSv/hr).

This X-ray was considered as the bremsstrahlung, which is generated by the collision of electron to extraction electrode. Based on this speculation, EGS4 situation was done. As a result, it is thought that the generation mechanism of X rays could be confirmed analytically.

References

[1] Nobuyuki SUGIURA et al., "X-ray leakage around 1.7 MV Tandetron Accelerator", Proc. 10th Symp. Accelerator Scinece and Technology, JAERI-Conf 95-021 416-418, (1995).
[2] High Voltage Engineering Europe B.V., Instruction Manuals, (1993)
[3] W. R. Nelson et al., "The EGS4 Code System", SLAC-Report 265, (1985).
[4] T. Momose et al., "Improvement in the EGS4 code system - general purpose electron-photon Monte Calro transport code system", 48-73, Proc. EGS4 User's Meeting in Japan, KEK Proc. 91-14 (1991).
[5] J. Ishikawa, Ion source engineering, Ionex Co. (1986)
[6] H. Kumagai., Accelerator, Kyoritu. Pub. (1988).
[7] Roy Middleton., "A Negative-Ion Cookbook", Univ. of Pennsylvania (1990)
[8] R. Middleton, "A Versatile High Intensity Negative Ion Source".