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# X-RAY LEAKAGE AROUND 1.7 MV TANDETRON ACCELERATOR

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## Abstract

For the purpose of offering fundamental information on radiation protection of an accelerator, the dose rates around 1.7 MV tandetron accelerator were measured in various operating condition. The dose rates except around the ion source were generally kept low enough. The peak energy of X-ray detected around the ion source was about 25 keV, which could be easily shielded by 1 mm thick iron.

## 1. Introduction

The installation of small accelerator is expected for the research of ion beam science. The 1.7 MV tandetron accelerator was newly installed at Research Center for Nuclear Science and Technology of the University of Tokyo in 1994. For the purpose of offering fundamental information on radiation protection of an accelerator, the dose rates around the accelerator (ion source, magnetic inflector, high voltage power supply, acceleration tube, switching magnet, and end station) were measured in various operating conditions (ion source, terminal voltage, and beam current).

## 2. Outline of Tandetron Accelerator System

The 1.7 MV tandetron accelerator system is mainly consisted of ion source, magnetic inflector, high voltage power supply, acceleration tube, switching magnet, and end stations. For applications, Particle induced X-ray emission (PIXE), Rutherford backscattering spectroscopy (RBS), and ion implantation system are prepared. The system was named RAPID (Rutherford backscattering spectrometry Analyzer with Particle induced X-ray emission and Ion implantation Devices). The system was supplied by HVEE (High Voltage Engineering Europe B.V.). The system layout is shown in Fig. 1.

(1) Ion source and injector: Two types of ion source are equipped for the system: one is a duoplasmatron (model 358), the other is a Cs spatter ion source (model 860A). They are mounted simultaneously on the dual leg injector system. It provides the flexibility to produce a large variety of ions and the quick changeover from heavy ions to H ions.

(2) Accelerator system: Model 4117-HC is used for an accelerator system. High voltage power supply system is a Cockroft-Walton type one. The terminal voltage range is 0.1 - 1.7 MV. The main specifications of ion source and beam current are shown in Table 1. The control of whole accelerator system is done by the computer control. It allows for unattended start-up and operation of the entire accelerator system.

(3) End station: PIXE, RBS and Ion Implantation system are prepared for the application.

- PIXE: 3 axis and 2 translations sample manipulator, Si(Li) detector with 8192 ch PHA

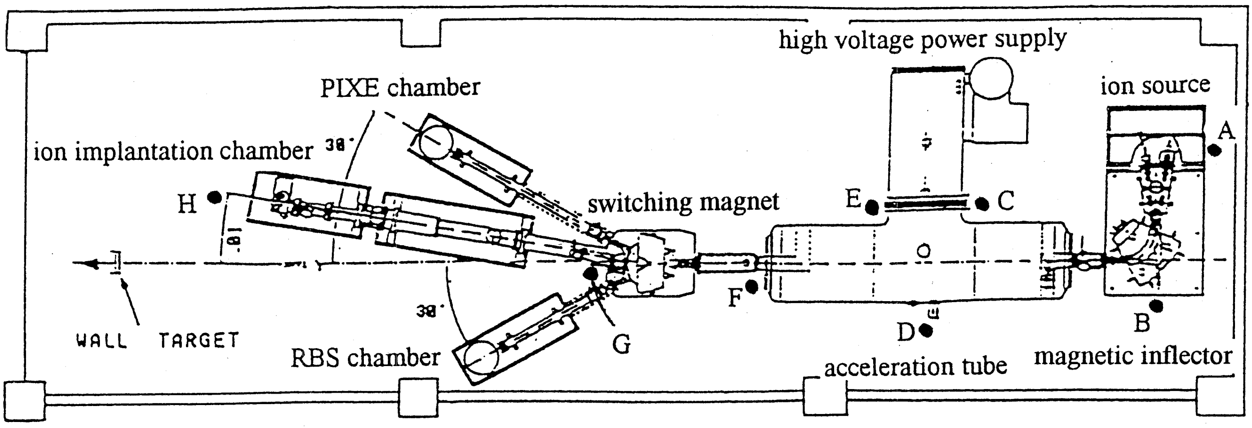

Fig.1 The system layout of 1.7 MV tandetron accelerator system and dose rate measuring points.
A: ion source, B: magnetic inflector, C: low energy acceleration tube, D: center of acceleration tube, E: high energy acceleration tube, F: end of acceleration tube, G: switching magnet, H: ion implantation target

Table 1 Ion species and beam current

| ion species | beam current | |
|---|---|---|
| $H^+$ | 25 μA | (3.4 MeV) |
| $He^{2+}$ | 2.4 μA | (5.1 MeV) |
| $Si^{2+}$ | 140 μA | (5.1 MeV) |
| $Cu^{2+}$ | 20 μA | (5.1 MeV) |
| $N^{2+}$ | 20 μA | (5.1 MeV) |
| $Au^{2+}$ | 80 μA | (5.1 MeV) |

- RBS: 3 axis and 1 translation sample manipulator, silicon surface barrier detector
- Ion implantation: implantation angle 7° , 10 samples within 32 mm $\phi$ , heatable and coolable target holder

(4) Control cabinet

The control cabinet is situated out of the accelerator room. The door interlock system was not prepared for the convenience of access. The data transmission from the accelerator is done by the optical fiber cable for the reduction of electro-magnetic noise.

## 3. Method

### 3.1 Radiation detectors

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 using NaI(Tl) scintillation detector with Be window (Ohyo Koken Kogyo Co.).

### 3.2 Measuring points

Measuring points are 8 as shown in Fig. 1 and, the measuring height was 1215 mm from the floor, which is the same height of beam line.

### 3.3 Measuring operation condition

The ion species of $H^+$, $He^{2+}$, $N^{2+}$, $Si^{2+}$, $Cu^{2+}$, and $Au^{2+}$ were measured. Terminal voltage was around 1.7 MV except $H^+$ (1.5 MV). As for $Si^{2+}$, terminal voltages and beam currents were changed as a standard case.

## 4. Results and Discussions

### 4.1 Dose rate

The results of dose rate measurements were shown in Table 2.

High dose rates were detected around the ion source in case of accelerating $Cu^{2+}$ and $Au^{2+}$ beam. In case of $Si^{2+}$, the high dose appears irregularly. This X-ray generation has no reappearance. This may be caused by the difference of geometry between a sputter electrode and an ion source holder. Further measurements were done for this X-ray generation. The results was described in the paragraph 4.2.

The accelerating energy of H and He per particle is rather high because of those small mass numbers. Therefore, the dose rates around ion implantation target become rather high in case of accelerating $H^+$ and $He^{2+}$.

In spite of the almost same operating condition, the dose rates in case of accelerating $N^+$ were slightly high as a whole. This was caused by the way of accelerating $N^+$. Nitrogen ion source was prepared as $NO^-$. $NO^-$ was accelerated from ion source to stripper canal at the center of acceleration tube. Then, oxygen was stripped with a charge exchange.

Compared with the dose rate around the low energy tube and around the high energy tube, the former were generally high. There were more complex structures in the high energy tube than in

Table 2 Dose rates around 1.7 MV tandetron accelerator system (μ Sv/hr)

| ion source | $H^+$ | $He^{2+}$ | $N^{2+}$ | $Si^{2+}$ | $Cu^{2+}$ | $Au^{2+}$ |
|---|---|---|---|---|---|---|
| terminal voltage (MV) | 1.53 | 1.70 | 1.74 | 1.73 | 1.71 | 1.72 |
| beam current[*1] (μA) | 11 | 2.4 | 26 | 180 | 41 | 130 |
| ion source | 0.06 | 0.14 | 2.7 | 0.33 | 15 (0.45)[*2] | 35 (0.8)[*2] |
| ion injector | 0.11 | 0.15 | 2.3 | 0.17 | 0.75 | 1.6 |
| low energy acceleration tube | 0.10 | 0.26 | 2.0 | 0.46 | 0.85 | 1.7 |
| center of acceleration tube | 0.09 | 0.32 | 1.2 | 0.71 | 0.62 | 1.5 |
| high energy acceleration tube | 0.05 | 0.15 | 1.5 | 0.22 | 0.40 | 0.7 |
| end of acceleration tube | 0.05 | 0.08 | 0.1 | 0.15 | 0.12 | 0.1 |
| inflection magnet | 0.10 | 0.31 | 0.05 | 0.07 | 0.12 | 0.05 |
| ion implantation target | 4.0 | 2.4 | 0.05 | 0.05 | 0.15 | 0.05 |

[*1] at faraday cup of ion implantation, [*2] after shielding of 1 mm thick iron, background dose rate: 0.05 (μ Sv/hr)

the low one. Therefore, the shielding effect from this structure could be expected.

4.2 X-ray around ion source

The spectrum of X-ray around the ion source in case of accelerating $Au^{2+}$ beam was shown in Fig. 2. The photopeak energy was 25.8 keV. The photopeak energies were almost same in case ofaccelerating $Cu^{2+}$ and $Si^{2+}$. This low energy X-ray was easily shielded by 1 mm thick iron. The dose rates were decreased from 15 μ Sv/hr under no shielding condition to 0.45 μ Sv/hr under the 1 mm iron shield ($Cu^{2+}$), from 35 μ Sv/hr to 0.8 μ Sv/hr ($Au^{2+}$).

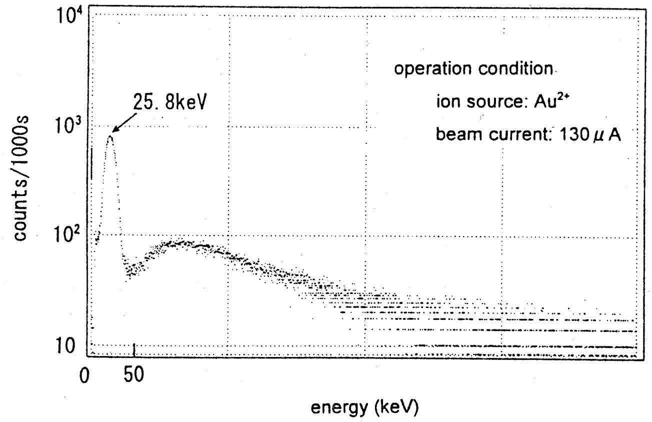

Fig. 2 Pulse height spectrum of X-ray around the ion source

4.3 Relationship of voltage, current and dose rate

In the acceleration tube, the remaining air is ionized by ion beam. In this process, the produced electron is also accelerated. As a result, the bremsstrahlung X-ray is generated. Figure 3 shows the relationship of terminal voltage and dose rate per voltage・current around the acceleration tube in case of accelerating $Si^{2+}$ beam.

No significant tendency was recognized below 1.4 MV. The dose rates were relatively low and the reading error of dose meter might be large. Above 1.4 MV, the X-ray production at the center tube and the high voltage tube increased drastically.

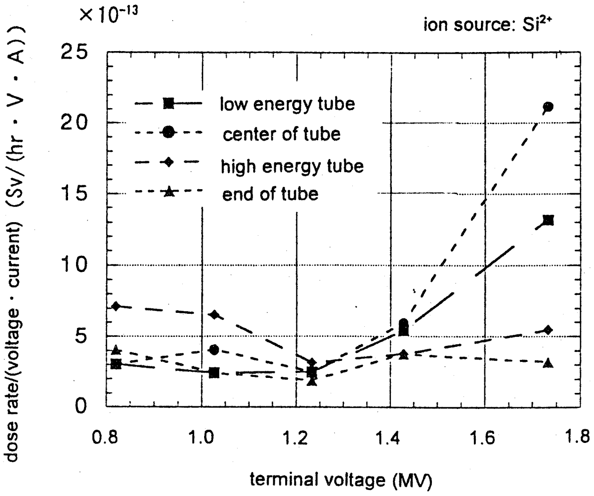

Fig. 3 Relationship of terminal voltage and dose rate per voltage・current

## 5. Conclusion

The measured dose rates around 1.7 MV tandetron accelerator were obtained, which will be useful as a fundamental data for radiation protection of this type accelerator.

## Reference

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2. High Voltage Engineering Europe B.A., Technical Pamphlet of Tandetron Accelerator Systems, Model 4110, 4117, 4125, 4130, (1993).