Design of Single-body Multi-radiation Generator Based on Electron Accelerator

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1. Introduction

Generally, the generation of radiation is most likely to generate one kind of radiation in one device. In this study, we propose a single-body multi-radiation generator that generates more than two types of radiation in one device based on a several MeV class electron accelerator. Using this technology, it requires less space and partial shielding than a large research facility based on a reactor or accelerator that can not be moved and needs a lot of manpower. The main goal is to generate X-rays and neutrons at the same time in one device. It is also possible to use the electron beam itself because it is based on electron accelerator. The X-ray target dose rate is above 30 Gy/min per minute at a distance of 1 m from the target and the target rate of neutrons is above 10^{10} n/s.

2. Design Feature

In this section, we describe the design of a 15 MeV electron accelerator and the design of a target system that generates multiple radiation. The accelerating tube for the 15 MeV electron accelerator was designed by computer simulation using Finite Element Method (FEM), and the multiple radiation generating target was designed using MCNP[1].

2.1 15 MeV Electron LINAC

Table I: Specification of Electron LINAC

Items	*parameters*
Beam Energy	15.27 MeV
Beam Power(peak)	1.2 MW
Beam Current(peak)	87 mA
Resonance Frequency	2.856 MHz
Accelerating Gradient	19.8 MV/m
Gun Type	diode
Gun Gap Voltage	14 kV
Capturing Coeff.	43.6 %
Repetition Rate	210 Hz
Beam Pulse width	4 us
Length of Cavity	1 m

The specifications of the designed 15 MeV electron accelerator are shown in Table 1. As shown in Fig. 1, the electron accelerator consists of a diode E-gun, a side-coupled structure accelerating tube with a resonant frequency of 2.856 MHz, and an S-band klystron as an

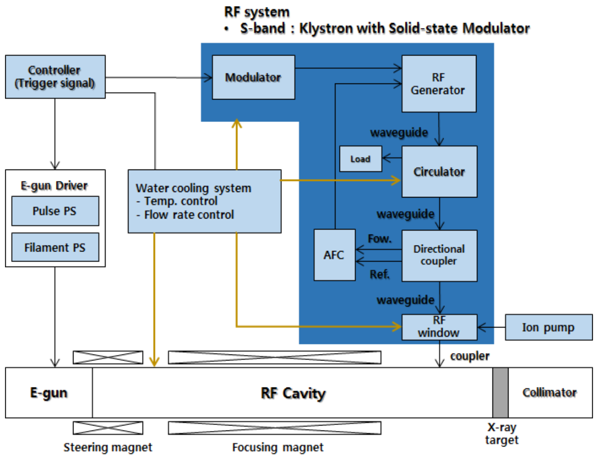


Fig. 1. Configuration and structure of RF electron LINAC

RF generator. The specifications of the RF system are shown in Table 2. With a pulse width of up to 18 us and a repetition rate of up to 660 Hz, the device delivers RF output to the accelerator through an average output of 60 kW Klystron.

Table 2: Specification of RF system

Items	*parameters*
RF generator	Klystron
Radio-frequency	2.856 MHz
RF Average Power	60 kW
RF Peak Power	5 MW
Max. Pulse width	18 us
RF pulse Rep. Rate	1 – 660 Hz
Modulator Average power	164 kW
Modulator Peak power	13 MW
Pulse Flatness(zero to peak)	±1.5%

2.2 Target for Multi-radiation

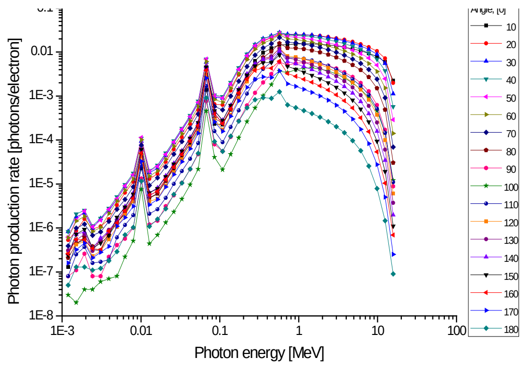
As the energy of the electron beam exceeds 10 MeV, a significant flux of neutrons is generated and neutrons of various distributions can be generated according to the type and thickness of the target material [2]. In this study, we aimed to design an optimized target that simultaneously generates x-rays and neutrons using a single device based on high power electron LINAC. We compare the neutron generation rates of the tungsten and lead thicknesses, which are promising as neutron targets, through the MCNP code, and the results are shown in Table 3.

Table 3: Target Specification for Multi-radiation

Items	***Parameters***
Material	Tungsten
Thickness	2 mm
X-ray dose-rate	>30 Gy/min at 1m
Neutron flux	$>10^{10}$ n/s at spot

2.3 Multi-radiation Analyzing

Fig. 2. The energy spectrum of the photons generated per electron by the 15 MeV electron accelerator



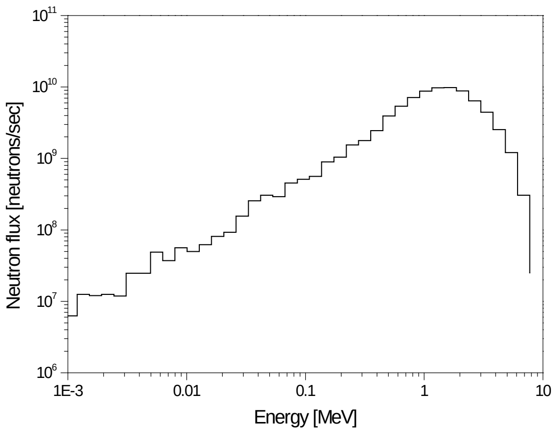


Fig. 3. The energy spectrum of the neutrons generated per second by the 15 MeV electron accelerator

Based on the material and thickness information of the selected target, MCNP analysis for generating multiple radiations was performed. Fig. 2 shows the energy spectrum of photons generated per electron by the 15 MeV electron accelerator, and Fig. 3 shows the energy spectrum of neutrons generated per second. Based on the results shown in Fig. 2, the formula for calculating the X-ray dose-rate at a distance of 1m from the source term is shown in Equation 1.

$$J_x = C \cdot \eta \cdot D \cdot I_p \cdot E^n \quad (1)$$

Jx is the dose rate in Gy / min from the target focus, C is the capture coefficient, η is the photon conversion efficiency, Ip is the peak beam current in mA, D is the duty factor, E is the electron beam in MeV energy, and n are electron energy factors. Based on this equation, it can be confirmed that a maximum dose rate of 100 Gy/min 1m away from target spot point occurs when the electron accelerator specification of Table 1 is applied. Fig. 3 also shows that the number of neutrons per second generated at the spot point of the target material exceeds the target 10^{10} n/s[3].

3. Result and Conclusions

Through the 15 MeV high energy electron accelerator and the target design for generating multiple radiation, two types of radiation, neutron and X-ray, simultaneously acquiring equipments have been designed in one equipment. The multi-beam radiation generator designed in this study can generate X-rays of up to 100 Gy/min at a distance of 1 m from the target and also generates 10^{10} n/s of neutrons at the target spot point.

The future plan is to build the actual electron accelerator and multi - radiation generation target based on the design of the result of this study, and to verify the design value through multi - radiation generation experiment.

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