SIMULATION OF X-BAND LINAC NEUTRON SOURCE

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Abstract

In Tokyo University, there is a plan of development of electron linac neutron source because the research reactor "Yayoi" was decommissioned and a new neutron source is required. This linac will be introduced in the core of the reactor, so measurement of nuclear fuel materials can be expected. The application of this research is to measure more accurate nuclear data of some atomic fuel materials. It is necessary for analysing debris in Fukushima 1st nuclear power plant.

30 MeV X-band linac is used and neutrons are generated by interactions between bremsstrahlung x-rays and materials. In this research, the thermal electron gun, the buncher and the target for the linac are optimized for generating as many neutrons as possible. Uranium can be used as target materials, so high neutron flux was gained from the calculation.

INTRODUCTION

Nuclear data, neutron cross section, is important because it can be applied to development of new reactor and analysis of debris in Fukushima 1st nuclear power plant. However, this data, especially the data of nuclear fuel materials, such as U, Pu, and Am, is not so correct. Figure 1 shows experimental data of total cross section of Pu-239 [1]. You can understand the accuracy of the peak at 1 eV is low. In addition, measurement of this data hasn't been done recently.

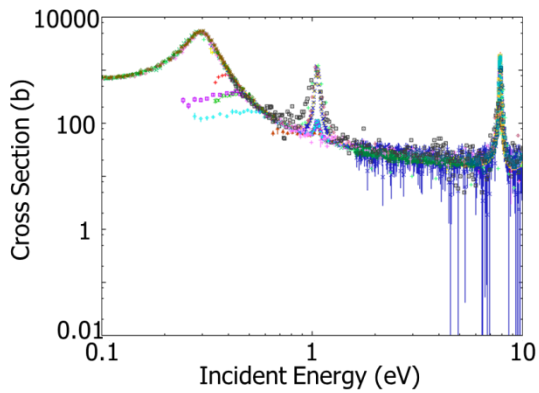

Figure 1: Experimental data of total cross section of Pu-239 [1].

Energy resolution is very important for the measurement of debris. The relation between time and energy is given by the equations

$$T[\mu s] = \frac{72.3L[\mathrm{m}]}{\sqrt{E[\mathrm{eV}]}}, \frac{\Delta E}{E} = -\frac{\Delta T}{T}. \quad (1)$$

For measuring data in 1% energy resolution, 1 μs is necessary when length of beam line is 5 m and beam energy is 10 eV, and 100 ns is necessary when length of beam line is 40 m and beam energy is 100 keV. So short pulse width is necessary for high energy resolution measurement. Pulse width of electron linac is much shorter than that of proton accelerator, so electron linac is suitable for our research.

PURPOSE

The purpose of my research is the development of electron linac driven neutron source for nuclear data measurement. Linac will be installed into the core of the "Yayoi" reactor which is now under decommissioning because in Yayoi, handling nuclear fuel materials are permitted. The reason why X-band linac is used for our neutron source is it enables us to set the accelerator in the core. But the klystron will be set out of the core.

COMPTON SCATTERING X-RAY SOURCE

For preliminary test of neutron source installation, 30 MeV X-band Linac has been tested. The Linac was originally designed for Compton scattering monochromatic X-ray source [2], shown in Figure 2. It is consisted of 3 MeV RF gun, alpha magnet, 30 MeV accelerator tube, and laser.

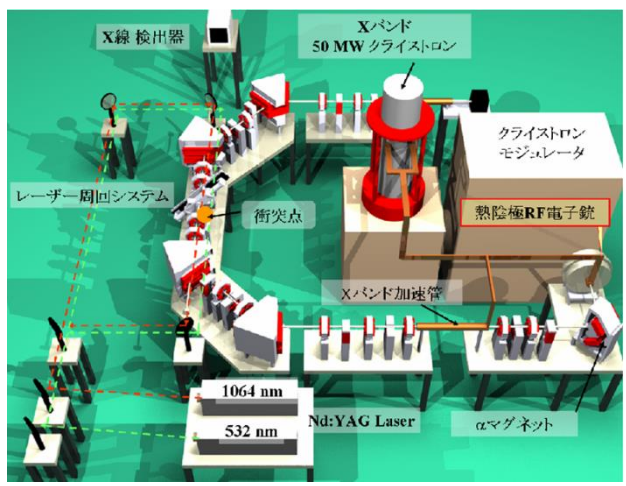

Figure 2: Compton scattering x-ray source.

In December 2012, the experiment of the RF electron gun was done. Figure 3 shows the current of it. The RF gun has is emittance, low current, and stability problem, so it is not suitable for neutron source.

Some part of this system, the RF source, the accelerator tube and the cooling system, will be used in the new neutron source. However, as I explained, RF gun is not suita-

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ble, so thermal DC gun and buncher is designed and will be installed. And neutron target is also designed.

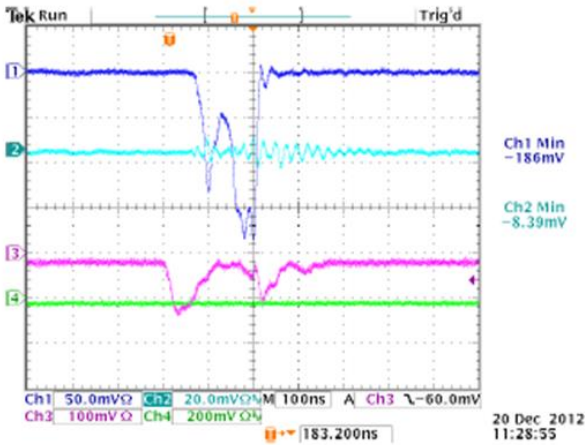

Figure 3: Current of thermal RF gun of Compton scattering x-ray source.

THERMAL ELECTRON GUN AND BUNCHER

Thermal Electron Gun

Stable current is expected to the thermal electron gun so it is suitable for our research. Electric field calculation by POISSON and beam transportation calculation by GPT was done [3-4]. The voltage of the gun was 20 kV. Figure 4 shows the result and Table 1 shows the gained parameters.

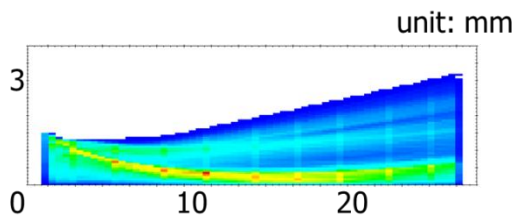

Figure 4: Simulation result of thermal electron gun.

Table 1: Parameters of Thermal Electron Gun

Parameter	Our Thermal Gun
Voltage	20 kV
Cathode Radius	1.5 mm
Beam size (σ) at z = 20 cm	0.224 mm
Emittance at z = 20 cm	0.674 mm-mrad

Buncher

The energy of thermal electron gun is 20 keV, so a buncher is necessary for smooth acceleration. The frequency is 11.424 GHz, the same as the accelerator tube of Compton scattering X-ray source and traveling wave mode is used. Electromagnetic field calculation by SUPERFISH and Beam transportation calculation by GPT was done.

Figure 5 shows the relation between the beam position and the internal diameter of the cavity to keep stable electric field. Figure 6 shows the relation between the electric field and the diameter at the gate of the cavity when the RF power was 5 MW. From this, we decided that the length of the buncher is 20 cm and accelerated energy is 4 MeV.

And from the electron gun and the buncher, the parameter shown in Table 2 can be expected.

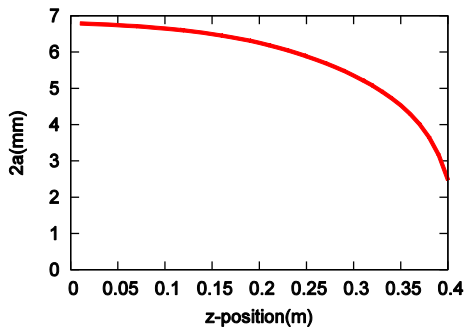

Figure 5: Relation between the beam position and the internal diameter of the cavity.

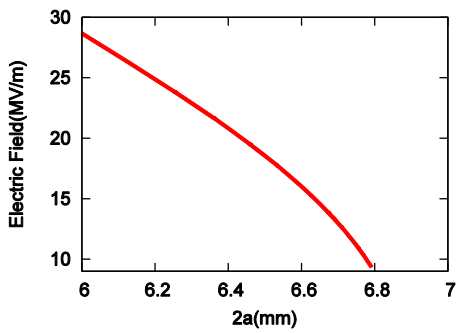

Figure 6: Relation between the electric field and the diameter at the gate of the cavity.

Table 2: Parameters of Electron Beam of Incident System

Parameter	Our Incident System
Energy	30 MeV
Max current	250 mA
Max pulse width	1 μsec
Intensity	50 pps
Max beam power	0.375 kW

NETURON TARGET

Electron linac neutron source has advantage of short pulse, but because of this, power of electron linac is lower than other neutron sources. Therefore, a high efficiency target should be developed for generating neutrons with high flux. Uranium target was simulated because it has photo fission effect and high flux can be expected [5].

Linac will be set in the core of the plant, so nuclear fuel material can be used as the target. Figure 7 shows the neutron flux from various targets, calculated by PHITS, which was developed in JAEA [6]. The electron beam energy was 30 MeV. This shows that uranium target brings about twice as much flux as other target. And when beam energy was 30 MeV, beam power is 0.375 kW and uranium target was used, neutron flux of 3×10^{11} n/s was gained. However, way to treat fission product is important task.

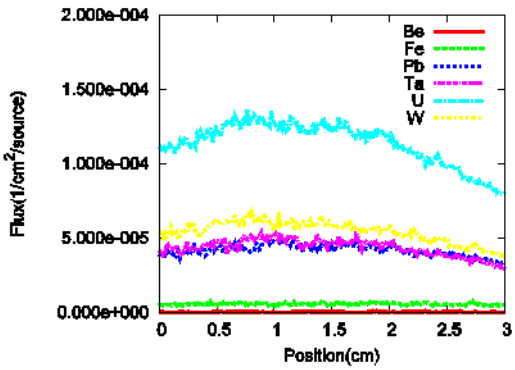

Figure 7: Comparison of neutron flux among several target materials.

CONCULUSION

Neutron source with 30 MeV X-band linac has been developed for measurement of neutron cross section. Thermal neutron gun and buncher were newly designed to combine with the existing accelerator tube. Various neutron target (including Uranium) was designed and neutron flux from target was calculated.In next years, electron beam and neutron beam is going to be measured.

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