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■Technical Paper■

PHOTO-NEUTRON SOURCE USING 2 GEV ELECTRON LINAC FOR RADIATION SHIELDING RESEARCH

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Abstract - The 2 GeV electron linac, the injector of the Pohang Light Source, was used as a photo-neutron source for radiation shielding research. The operational beam parameters are the nominal electron intensity of 0.5 ~ 5 nC/sec, the repetition rate of 10 Hz, and the beam pulse length of 1.0 nsec. One electron beam line was modified in order to install the target systems for producing pulsed photo-neutrons. The neutron spectrum and intensity were investigated by the time-of-flight technique. The reliable maximum energy of the measured neutrons was about 500 MeV. The number of neutrons above 20 MeV produced by one 1 GeV electron in a thick Pb target was about 6.45 x 10^{-4} /sr at 90 degrees to the beam axis. The status of the photo-neutron source and the application research are presented.

INTRODUCTION

Since 1994, the meetings [1] on Shielding Aspects of Accelerators, Targets and Irradiation Facilities (SATIF), organized by OECD/NEA, RSICC, and Reactor Physics Committee of Japan, have been held every 18 months to share the new technology and to discuss the needs for improvement in the aspect of radiation environment and radiological safety. The needs for the advanced knowledge of neutron yields, penetration, skyshine, etc, have been identified and the experimental results for the shielding benchmark have been emphasized on every meeting. The Pohang Light Source, the 3rd generation synchrotron facility, consists of 2 GeV electron linac and 2.5 GeV storage ting. The electron linac is operated as an injector twice a day. During the rest of the operation period, it stays on a standby mode. Therefore, it is available to supply enough beam time for u tilizing as a photo-neutron source. The electron beam line at the end of the linac was modified to set up target systems. Several experiments to get reliable photo-neutron data have been carried out at this beam line since 1998 [2,3]. Other experiments such as an irradiation study have also been conducted [4,5]. In this paper, the characteristics of the electron linac, the photo-neutron measurement, the status of the photo-neutron source, and the application research are presented.

CHRACTERISTICS OF 2 GeV ELECTRON LINAC

The 150 m-long electron linac is placed at the underground tunnel located 6 m below the ground level. The beam extraction points are 80 MeV and 2 GeV. Recently one klystron and two accelerating columns were installed to secure enough beam energy with the provision against the emergency case. At the end of the linac, there are three beam lines as shown in Fig. 1; one is for transport the electron to the storage ring, others are for beam dump. One of latter beam lines was modified to utilize as a neutron source. This is the energy-analyzed beam line with the bending angle of 10 degrees. The energy spread of the electron beam is less than 0.3 %. The beam pulse width and the repetition rate are 1 nsec and 10 Hz, respectively. The nominal intensity is 0.5 ~ 5 nC /sec at the target. The beam intensity was measured by the beam current monitor, which was a type of wall-current monitor and was located at middle of the beam line. The accuracy was verified by the activation analysis using the giant dipole resonance reaction of $^{197}Au(\gamma,n)^{196}Au$ and the error was less than 10 % [2].

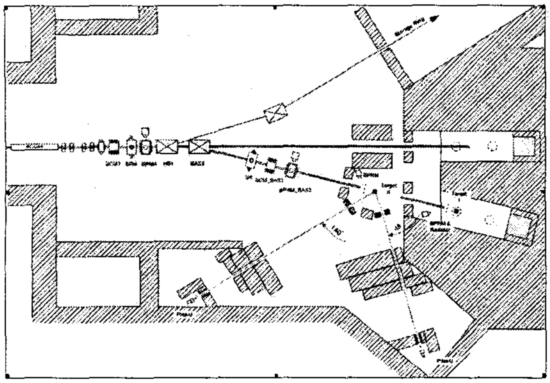

Fig. 1. Overview of the end station of 2 GeV electron linac of the Pohang Light Source for the photo-neutron source.

PHOTONEUTRON SPECTRUM AND INTENSITY

High energy electrons bombarded to the target produce photons via bremsstrahlung, then these photons generate neutrons via photonuclear reactions and secondary interactions. After setting up a target at the position of 'Target I' shown in Fig. 1 and 2, photo-neutron spectra at 90 degrees to the beam axis were measured by using the TOF technique [2,3]. The flight distance between a target and a detector was 10.4 m. The targets are with 5 × 5 cm^2 cross-section and both thin and thick targets were applied. The neutron detector was the Pilot-U plastic scintillator with 2-inch in length and 2-inch in diameter. The fast photo-multiplier, Hamamatsu-R2083, was used. The 2 GHz multi-channel scaler or the Lecroy TDC 3377 was used as the flight time analyzer. The energy threshold of the measured neutrons was 4.2 MeV-electron-equivalent.

The photo-neutron spectra up to 500 MeV were obtained and the differential yields for the Cu, Sn, and Pb targets with 10 Xo in a thickness were shown in Fig. 3. The overall error associated with these measurements was less than 30 % [3]. The neutron yields per one 1 GeV incident electron at the target were compared with Dinter's calculated results and Bathow's experimental results [6] in Table 1. In this comparison, the isotropic emission of neutrons was assumed roughly for the data of this work. Both of these total yields and the differential yields of photo-neutrons above 20 MeV were close to Bathow's. Below 20 MeV, the neutron yields of this work were smaller than other results because neutrons produced by both of giant dipole resonance and high-energy interactions were not measured at this work.

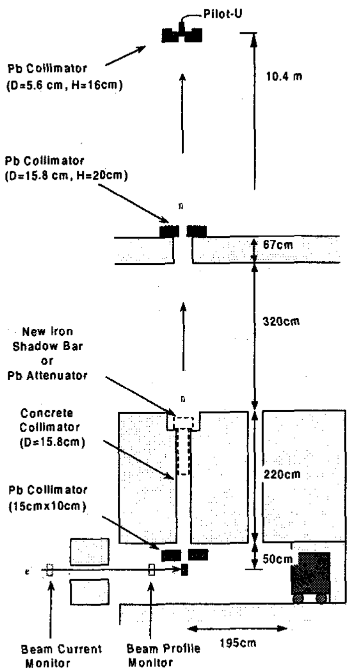

Fig. 2. Experimental arrangement of photo-neutron measurements by using the time-of-flight technique.

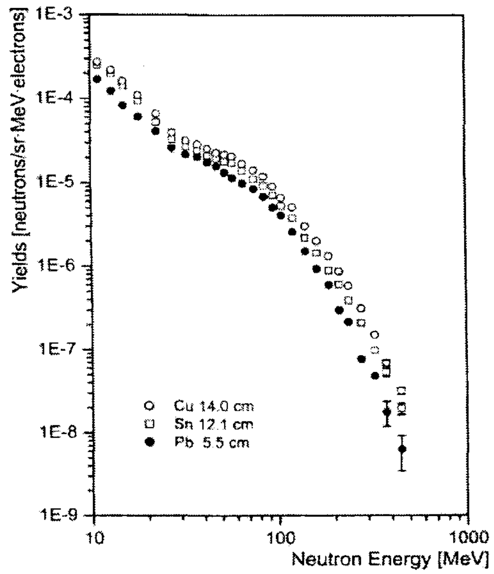

Fig. 3. Differential photo-neutron yields from thick Cu, Sn, and Pb targets at 90 degrees to the beam axis.

Table 1. Number of neutrons produced by one 1 GeV primary electron in thick targets.

Target material	Other authors' works [6]				This work	
	En > 20 MeV		En > 20 MeV		En > 20 MeV	10 < En < 20 MeV
	Dinter et al.	Bathow et al.	Dinter et al.	Bathow et al.	$(dN/d\Omega\|_{90^\circ} \times 4\pi)$	
Cu	0.0063	0.013	0.14	0.19	0.0135	0.0108
Sn					0.0108	0.0096
Pb	0.0045	0.009	0.28	0.34	0.0082	0.0063

STATUS OF PHOTO-NEUTRON SOURCE

The improvement such as reducing a background and a gamma-ray contamination in the photo-neutron measurement at 90 degrees has been done. The structures of the collimators along the neutron path were improved and the counting system based on CAMAC was applied to perform n-γ pulse shape discrimination. The feasibility study to observe the neutron absorption was done at low energy range below 10 MeV [5]. As a next step, the experimental arrangement will be improved in order to produce the practical data of photo-neutron attenuation in a shielding material.

The second target area, 'Target II' shown in Fig. 1, was constructed for the research to require larger space and the photo-neutron measurement at other angle. It is one type of experimental hutch with a thick overhead and side concrete shielding. The irradiation study [4] in order to observe the demagnetization of the in-vacuum undulator magnet was carried out successfully by using the 'Target II' area in 2000 and is scheduled for other type of magnets. Because the undulator have very small gap such as 3 mm, the frequent irradiation by electrons and the damage by produced photo-neutron were expected. The new shielding and the new detection area were also constructed around the 'Target II' in 2000 as shown in Fig. 1 so that the angular characteristics of the photo-neutron production was observed.

SUMMARY

The pulsed photo-neutron source was developed by using 2 GeV electron linac in order to produce the basic data for the radiation shielding of high-energy electron accelerator. The beam intensity is 0.5 ~ 5 nC/sec. The three flight paths were constructed for the TOF experiment. The photo-neutron spectra by the irradiation of a 2 GeV electron beam into thin and thick targets were measured at the 90 degrees. The yields were compared with other authors' results. The irradiation study of the undulator magnet using this neutron source was carried out successfully and the measurement of neutron absorption was tested.

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