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Electron Beam Broadening Effect of Neutron Generation in the Lead Slowing Down Time Spectrometer (LSDTS) Target

Chang Je Park* and Yongdeok Lee
Korea Atomic Energy Research Institute
1045 Daedeok-daero, Yuseong-gu, Daejeon, Republic of Korea, 305-353
[*]Corresponding author: cjpark@kaeri.re.kr

1. Introduction

A lead slowing down time spectrometer (LSDTS) system has been investigated and developed to quantify fissile isotopes in the sensitive materials such as a nuclear fuel or a recycled nuclear materials.[1]-[3] The most concern in LSDTS design is a high resolution and a real time analysis. In order to achieve those goals, a highly intense neutron should be produced in the system and neutron production target should be designed optimally. Thus a thin and plate target was designed using tantalum based on the successive reactions such as a bremmstrahlung conversion (e,γ) and a photoneutron production (γ,n).[4] Based on the electron accelerator, the incident beam energy varies about 20 MeV ~ 40 MeV. However, the beam quality is a main issue to produce neutron source in the target. It is known that there exists some noise in electron beam up to several thousand seconds. Some sensitivity tests are carried out with MCNP5[6] code with time perturbation option (TME card). Energy and time dependent neutron spectrums are obtained and analyzed in this study.

2. Methods and Results

The reference target geometry is cylindrical type and 5 Ta thin plates are composed into with Be multiplier as shown in Fig.1. Several cases are considered in this study in order to estimate the effect of the beryllium multiplier for LSDTS target. Fig. 1 depicts LSDTS target with and without beryllium multiplier. Each thickness of Ta target plate increases from 2 mm to 6 mm with 1 mm increment. The radius of target is also increased from 3 cm to 7 cm. For the target with beryllium multiplier, the thickness is varied from 0.5 cm up to 2.0 cm with 0.5 cm increment. The inner medium is filled with helium gas and the outer medium is covered with lead, which is a main slowing down site of fast neutrons. The neutron flux is scored on the outer surface of a lead cylinder. Incident electron energy is 35 MeV with a forward peaked propagation. Multiple physics mode is used in the MCNP code to account neutron, photon, and electron simultaneously and initial number of simulation particles is given as 1,000,000 to get enough reliable results. To consider the beam perturbation, TME card is used in source definition card (SDEF) with FWHM (full width at half maximum) values. The used cases are tabulated in Table I. The electron beam width varies from 50 ns to 1000 ns.

Figs.2 and 3 show neutron spectra for case 4 (500 ns) and case 0 (0 ns), respectively. The overall shape is similar but a small fluctuation of neutron happens around 50 and 100 shakes (=10 ns) in case 4. The more broadened incident electron beams are, the wider produced neutron spectra become as expected. The neutron spectrum broadening is almost proportional to incident electron beam width. Total neutron intensities at time zero are depicted in Fig. 4. Due to distance to tally surface, there is no neutron flux at time zero in case 0. The peak value is obtained around 10 shake as shown in Fig. 3. But beam broadened cases 2 and 3, it is observed that the peak values lie around 1 MeV. The total neutron flux per one incident electron beam varies are obtained similarly about 2.8E-6 n/cm^{2}s for all cases. As beam width increases, width of the broadened neutron spectrum become large as expected. Thus, it should be controlled the width of incident beam due to provide a certain range of resolution. The broadened neutron source is not preferred in LSDTS due to noise signals. From the neutron spectra results of several cases, the FWHM values are estimated for neutron spectrum with a linear fitting as shown in Table II. The estimated FWHM of neutron spectrum at 10 shake increases from 3.0 MeV to 3.4 MeV. The variation of total neutron spectrum is not so large and the difference is less than about 0.1 MeV.

3. Conclusions

It is found that the beam broadening effect of incident electron gives a proportional influence on production of neutron spectra at the LSDTS target system. The neutron spectra vary as a function of time within a 1000 ns due to pulse propagation in the lead medium. During that period, the spectrum slightly becomes wide and the peak value somewhat decreases but is not significant. From the analysis, it is necessary to control the incident electron beam quality in order to provide the reliable resolution of neutron source**.** As a future work, a detail analysis and an experiment for beam broadening shall be carried out.

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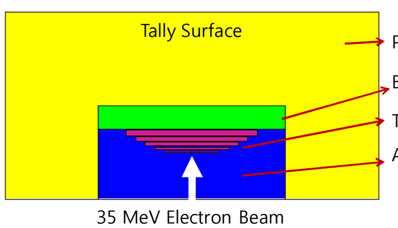

Fig. 1 LSDTS target configuration

Table I. Neutron Flux on the Surface of Lead Medium

Cases	Beam Width, W (ns)	FWHM* (ns)
Case 0	0	0
Case 1	50	118
Case 2	100	235
Case 3	200	471
Case 4	500	1177
Case 5	700	1648
Case 6	900	2119
Case 7	1000	2355

$* \; FWHM = \sqrt{8\ln(2)}W$

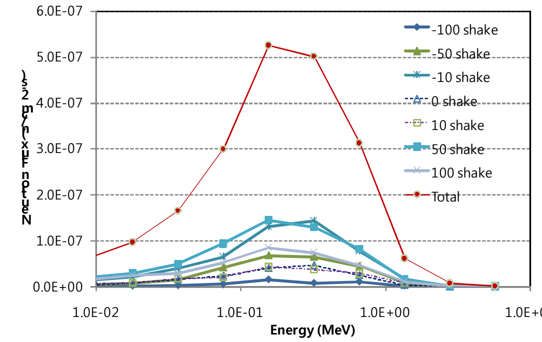

Fig. 2 Neutron spectrum for 500 ns beam broadening (case4)

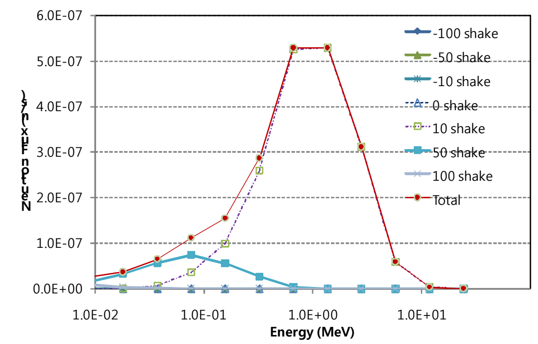

Fig. 3 Neutron spectrum without beam broadening (case0)

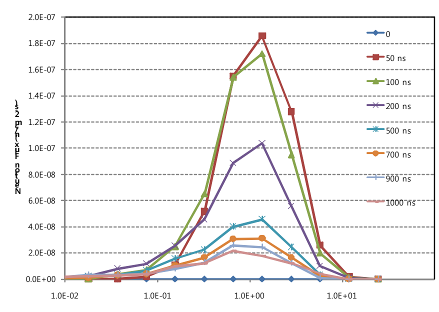

Fig. 4 Neutron flux for various cases at time of 0 shake

Table II. Estimated Width of Neutron Spectrum

Cases	FWHM of neutron (MeV)		
	10 shakes	50 shakes	Total
Case 0	3.02	0.14	3.05
Case 1	2.85	0.92	3.09
Case 2	3.25	2.27	3.09
Case 3	3.35	2.68	3.09
Case 4	3.40	2.86	3.11
Case 5	3.14	3.33	3.15
Case 6	3.44	2.28	3.18
Case 7	3.18	2.28	3.15