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Experimental Performance Analysis of Beam Shaping Assembly for Accelerator-Based BNCT Using 2.5 MeV Mono-Energetic Proton Beam

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1. Introduction

The neutron beams with proper energy and high intensity are required to treat deep-seated tumors using Boron Neutron Capture Therapy (BNCT). The ^{7}Li(p,n)^{7}Be reaction using 2.5 MeV proton is a proper way to get neutron source for BNCT because of high neutron yield and low neutron energy. It was widely recognized that neutrons in epithermal range (4 eV – 40 keV) are suitable for treating cancers without restrictively high skin doses [1]. For this reason, these neutron beams would be generated with an accelerator-based BNCT system that was composed of a neutron source and beam shaping assembly.

In this study, the neutrons from 2.5 MeV mono-energetic proton beam with stable beam current were measured to verify the characteristics of the beam shaping assembly with a He-3 proportional counter, and the results were compared with those from MCNPX. The design of beam shaping assembly for the efficient treatment of deep-seated tumors was based on previous researches at Hanyang University [2].

2. Methods and Materials

The beam shaping assembly was evaluated using 2.5 MeV protons for its applicability to BNCT system [3]. From ^{7}Li(p,n)^{7}Be reaction, generated neutrons were moderated into epithermal range to treat deep-seated tumors. This assembly was composed of two moderators with a surrounding reflector as shown in Figure 1. The moderators are respectively filled with AlF_3 (ρ=2.78 g/cm^3) and Al (ρ=2.78 g/cm^3), and reflector was made of graphite (ρ=1.85 g/cm^3).

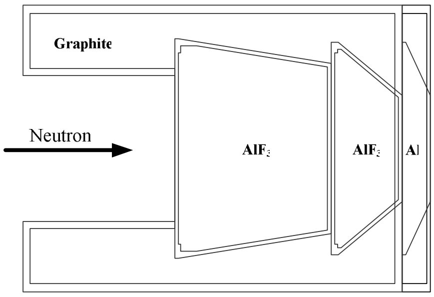

Fig. 1. Design of the Beam Shaping Assembly

Proton beam was generated from NEC 1.7 MV Tandem Accelerator at KIGAM (Korea Institute of Geoscience and Mineral Resource). Experiments were carried out to measure the neutrons from the lithium target and moderated neutrons through the assembly.

Experiment environment for measuring epithermal neutron spectrum is presented in Figure 2. A 100 μm lithium foil and 1 mm aluminum base was used, and the diameter of proton beam was about 1 cm. In order to reduce the pile-up effect, the assembly was located at 255 cm away from the neutron source. And a He-3 counter was arranged to be paralleled with the assembly and covered by 1 mm thick cadmium sheet which is used to greatly reduce the thermal neutrons scattered from surrounding structures

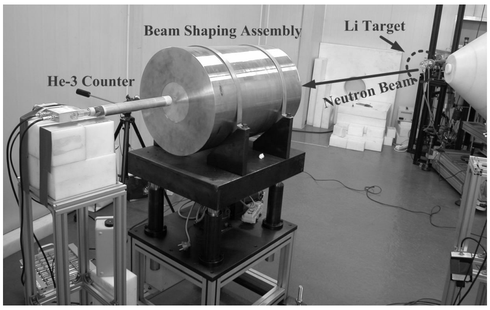

Fig. 2. Experiment Configuration for Epithermal Neutron Detection

3. Results and Discussions

Experiment results are shown in Figure 3. It was recognized that the measured counts in all energy ranges were reduced by the beam shaping assembly. In order to see the efficiency of the beam shaping assembly, total neutron energy range was divided into 21 ranges including epithermal energy range, and the measured counts in each energy range were compared to those with reference to the highest neutron energy range (748.89 – 785.13keV). The ratios of measured counts in each energy bin to those in the highest energy range are presented in Table 1 for both the source and moderated spectra by the assembly. From the result, it is confirmed that the epithermal neutrons generated by the assembly are more than about 3400 times with reference to those in the highest energy range, on the other hand the epithermal neutrons in source spectrum about 730 times.

It is, therefore, found that the beam shaping assembly for accelerator-based BNCT was well designed to get significant epithermal neutrons.

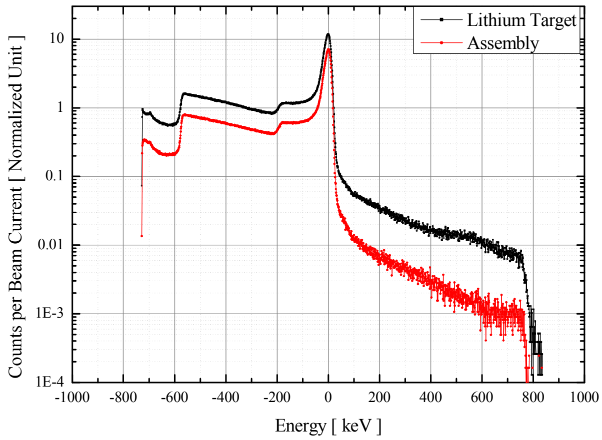

Fig. 3. Neutron Spectra Measured by He-3 Counter

Table 1. Count Ratios in Each Energy Bin for Source and Moderated Spectra

Energy Bin (keV)	Sum of Normalized Count by Charge (Each Energy Bin)		Sum of Normalized Count / High Energy Bin Count	
	Lithium Target	Assembly	Lithium Target	Assembly
0.004 – 40.25*	**1.0476E+02**	**6.1095E+01**	**7.3368E+02**	**3.4575E+03**
41.26 – 77.50	3.2287E+00	8.8620E-01	2.2612E+01	5.0152E+01
78.50 – 114.74	2.1313E+00	4.8996E-01	1.4926E+01	2.7728E+01
115.75 – 151.99	1.7388E+00	3.6317E-01	1.2177E+01	2.0553E+01
152.99 – 189.23	1.4552E+00	2.9119E-01	1.0192E+01	1.6479E+01
190.24 – 226.47	1.2292E+00	2.3997E-01	8.6085E+00	1.3581E+01
227.48 – 263.72	1.0516E+00	2.0089E-01	7.3645E+00	1.1369E+01
264.72 – 300.96	9.0453E-01	1.7800E-01	6.3348E+00	1.0074E+01
301.97 – 338.21	7.7305E-01	1.5056E-01	5.4140E+00	8.5207E+00
339.21 – 375.45	6.8039E-01	1.3566E-01	4.7651E+00	7.6774E+00
376.46 – 412.69	6.1857E-01	1.1050E-01	4.3321E+00	6.2535E+00
413.70 – 449.94	5.5226E-01	9.5761E-02	3.8677E+00	5.4194E+00
450.94 – 487.18	5.3426E-01	7.5566E-02	3.7417E+00	4.2765E+00
488.19 – 524.42	5.1151E-01	6.8482E-02	3.5824E+00	3.8756E+00
525.43 – 561.67	4.8941E-01	6.0258E-02	3.4275E+00	3.4101E+00
562.67 – 598.91	4.4725E-01	5.3418E-02	3.1323E+00	3.0230E+00
599.92 – 636.15	3.7554E-01	4.0633E-02	2.6301E+00	2.2995E+00
637.16 – 673.40	3.2259E-01	3.8190E-02	2.2592E+00	2.1613E+00
674.40 – 710.64	2.8943E-01	3.6806E-02	2.0270E+00	2.0829E+00
711.65 – 747.88	2.6000E-01	3.6806E-02	1.8209E+00	2.0829E+00
748.89 – 785.13 **	**1.4279E-01**	**1.7670E-02**	**1.0000E+00**	**1.0000E+00**

*Note: * and ** respectively represents epithermal and high energy ranges*

The BNCT experiment was simulated with MCNPX [4], and the comparison between the measured and calculated neutron spectra was presented in Figure 4. Appropriate agreement in this comparison can be found in a wide energy range from 0 – 800 keV. The moderated neutrons were focused on thermal and epithermal energy range (0 eV – 40 keV). As a result, the moderated neutron spectra can also be expected with MCNPX simulation.

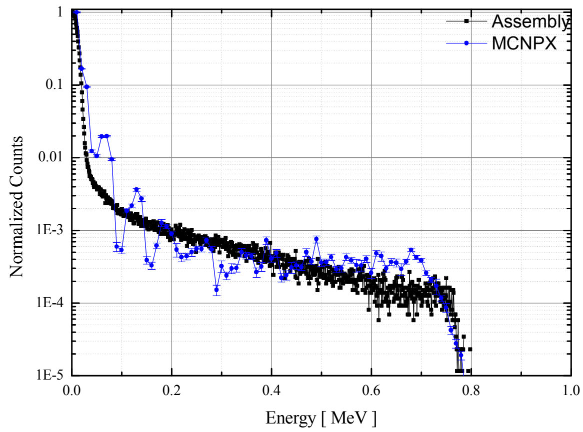

Fig. 4. Comparison between the Theoretical and Experimental Spectrum

3. Conclusions

Beam shaping assembly for accelerator-based BNCT was experimentally analyzed using 2.5 MeV mono-energetic proton beam with a He-3 proportional counter. It is confirmed that the moderated neutrons through the assembly were well focused in epithermal energy range from the experiment. Thus, the design technology of beam shaping assembly is expected to be well applied to the clinical treatment using accelerator-based BNCT.

Acknowledgement

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REFERENCES

[1] M. Y. Paeak, C. Y. Han, and J. K. Kim, "A characteristic analysis of a accelerator-based epithermal neutron beam for boron neutron capture therapy," *Proceedings of the First ITRS International Symposium on Radiation Safety and Detection Technology (ISORD-1)*, Seoul, Korea, July 18-19, 2001, p.292-296 (2001)

[2] Deok-jae Lee, Chi Young Han, Jong Kyung Kim, and Byung-Chan Na, "Spectrum Shaping of Epithermal Neutron Beam for Accelerator-Based BNCT and Dosimetric Evaluation Using a Brain Phantom," *Journal of Nuclear Science and Technology,* **Supplement 4**, 180-183 (2004)

[3] Kyung – O Kim, Sang Hoon Jung, Soon Young Kim, and Jong Kyung Kim, "Evaluation of a Neutron Bram Generation Facility for the Accelerator-Based BNCT," *Proceedings of the Korea Nuclear Society 2006 Autumn Meeting,* November 2-3, (2006)

[4] D.Pelowitz(Ed.), MCNPX User's Manual Version 2.5.0, Los Alamos National Laboratory Report LA-CP-05-0369 April (2005)