Transactions of the Korean Nuclear Society Virtual spring Meeting
May 13-14, 2021

Further study on the photoneutron source for Bragg edge imaging

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1. Introduction

Bragg edge imaging is one of the useful material investigation tools which can be provided using compact accelerator neutron sources (CANS) [1]. The neutron intensity as well as the neutron wavelength resolution are two important factors that need to be considered during designing CANS. In our previous studies [2,3], some preliminary results of the cold neutron source were presented. Here, further investigations are illustrated by focusing on the neutron pulse shape. The neutron pulse shape directly relates to the Bragg edge imaging resolution and the moderator shape and thickness can change the neutron pulse shape. Therefore, it is important to consider this factor in more details beside the neutron intensity maximization.

2. Methods and Results

2.1 Monte Carlo calculations

The geometry shown in Fig. 1 was simulated in our previous work and the moderator and reflector shape and size were optimized with attention to only neutron flux. Using the same geometry, the thickness of the moderator was changed and the neutron time distribution was estimated. The calculations were performed using the PHITS-3.1 code [4]. The JENDL-4.0 [5] nuclear data library was used and thermal scattering low was applied to polyethylene (0.94 g/cm^3). The calculations were performed in two steps to reduce the calculation time. In the first step, the electron beam with the diameter of 5 mm and energy of 40 MeV was irradiated on the neutron production target (tungsten) and the photoneutrons were scored with their position, direction and energies using DUMP option in the PHITS code. In the second step, the scored neutrons were used as the primary particles and the thickness of the PE was changed (Fig. 1). The 40-MeV electron was selected because the neutron production yields did not increase significantly by increasing the electron energy [3]. Time distribution of neutrons emerging from the moderator were then scored using a surface crossing tally. The suitable neutron energy range for Bragg edge imaging is around 5 meV. The calculations were performed to achieve a high cold neutron flux as well as short neutron emission time (neutron pulse).

Figure 2 shows the neutron emission time for different PE thicknesses. By increasing the PE thickness, the neutron flux increases. The full width at half maximum (FWHM) of neutron pulse becomes larger with PE thickness as well. In our previous work [2], optimum thickness of PE was obtained as 8 cm regarding only the neutron flux, while these results show FWHM is larger for 8 cm than 4 or 5 cm thick PE, resulting in lower resolution. Therefore, 4~5 cm is the optimum thickness of PE considering neutron flux and neutron pulse width. The effect of the reflector on time distribution will be also considered to reach a more real target-moderator-reflector design. The desired wavelength resolution is 1 ~ 2%.

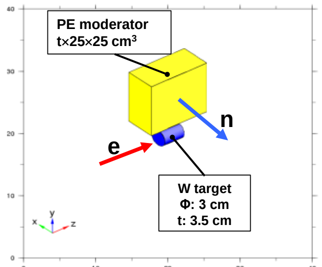

Fig. 1. Simulated geometry to estimate the neutron time distribution after the moderator.

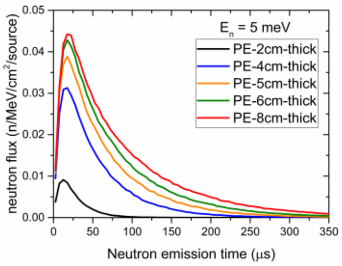

Fig. 2. Cold neutron emission time distribution for different PE thickness.

3. Conclusions

High wavelength resolution of the cold neutron is very important in Bragg edge imaging. To achieve a reasonable resolution the neutron pulse shape needs to be considered. The results in this work show that by taking the neutron pulse shape into account the optimum thickness of the PE is 4 to 5 cm rather than 8 cm.

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