Application of Photofission Reaction to Identify Highly Enriched Uranium by Utilizing Bremsstrahlung Spectrum Photon

*Chin Kim Wei[1], Hiroshi Sagara[1], Chi Young Han[1] and Rei Kimura[1]
[1]Tokyo Institute of Technology.

The principle of photofission reaction ratio (PFRR) method was proposed and validated by an ideal Gaussian photon source simulation previously. In this research, Bremsstrahlung spectrum photon sources were applied to the method to identify high-enrichment uranium. We have investigated the applicability of the Bremsstrahlung photons for PFRR.

Keywords: Photofission, high-enrichment uranium, Bremsstrahlung spectrum.

1. Introduction

The PFRR methodology is one of the active non-destructive assay technologies utilizing photofission reaction of fissionable nuclides [1], and was validated with Gaussian photons. The methodology is based on a characteristic difference of photofission cross sections among heavy metals. Providing Gaussian photon sources will require a high-quality beam and high-cost facility. However, Bremsstrahlung photon sources can be realized in practical scale or portable size. We have investigated the application of Bremsstrahlung photons for PFRR [2], and in the present paper, performed an optimization of energy of electrons injected to create Bremsstrahlung photons.

2. Methodology

The PFRR simulation consists of (1) photon generation by a high energy electron beam from linear accelerator injection to Ta, (2) photofission reaction by photon injection to a heavy metal target, and (3) measurement of photofission reaction rate. In the present paper, the particle transport calculations of (1) and (2) were performed with PHITS3.0 and MCNP6.0 codes with JENDL 4.0 and ENDF VII.1 libraries, respectively.

3. Results

Based on the previous study, the combination of 6 and 11 MeV Gaussian photon energy was chosen to measure uranium enrichment because the difference of photofission cross sections between ^{235}U and ^{238}U at these two energies varies significantly. To achieve the similar photofission reaction rate by Bremsstrahlung photons, a parametric study has been performed by changing the energy of electrons injected into Ta, and finally 7.0 and 13.5 MeV were selected (**Fig. 1**). Then, the created Bremsstrahlung photon sources were injected to a uranium metal target (a mixture of ^{235}U and ^{238}U) with 1 mm parallepipe. In the results shown in **Fig. 2**, it is noted that the PFRR linearly increases with uranium enrichment, and its sensitivity is higher than using the previous Gaussian photons. In conclusion, the Bremsstrahlung photons generated from 7.0 and 13.5 MeV electrons could provide a higher applicability for PFRR than the Gaussian photons. A feasibility study on measurement of photofission reaction will be the next step.

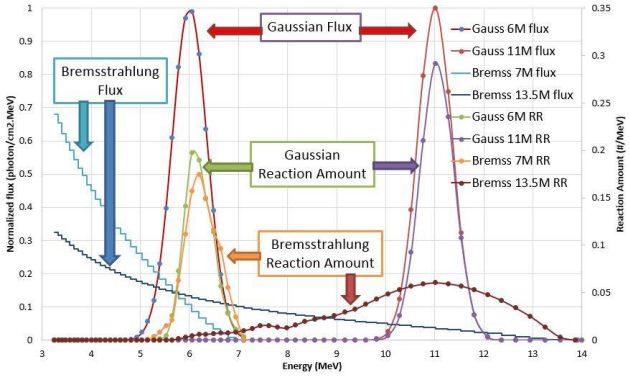

Figure 1 Comparison of flux spectrum and reaction amount

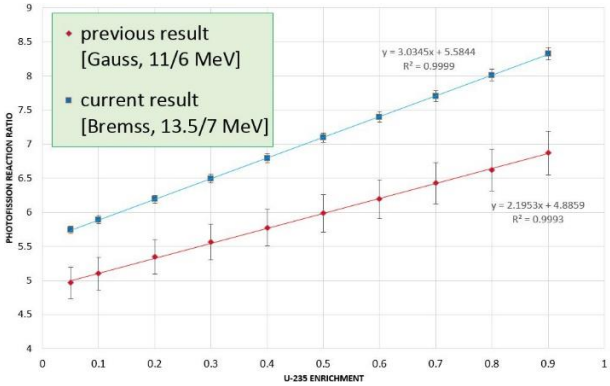

Figure 2 MCNP sensitivity result comparison

References [1] R. Kimura, et al., J. of Nuc. Sci. & Tech., DOI:10.1080/0022313. [2] Chin Kim Wei, et al., AESJ Annual Mtg., 2019.