Neutron spectrum determination and beam characterization at THOR-BNCT by multiple foil activation technique

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Introduction

Boron neutron capture therapy (BNCT) is a targeted radiation cancer therapy based on the nuclear reaction $^{10}B(n,\alpha)^{7}Li$ to kill tumor cells. Selectively concentrating boron compounds in tumor cells and intensive high-quality epithermal neutron beam are the keys to the success of this therapeutic modality. The Tsing Hua Open-Pool Reactor (THOR), a 2 MW research reactor at National Tsing Hua University (NTHU) in Taiwan, has been successfully upgraded and renovated for BNCT application in 2004. The first BNCT clinical trial using the THOR is carried out on August 11, 2010. Up to January 2019, a total of 26 patients, having recurrent head and neck cancers that could be incurable by conventional therapies, was treated by BNCT and significantly improved condition and quality of life were observed. Measurements of dual ionization chambers and two bare activation foils embedded in a phantom irradiated at the beam port of THOR-BNCT are routinely performed before patient treatments for beam quality assurance/control procedures. Accurate determination of the neutron spectrum in a BNCT facility is crucial for precise treatment planning because the physical and biological properties of neutrons vary significantly with neutron energies. This study attempts to conduct a neutron spectrum measurement by multiple foil activation technique and establish a new and efficient device for beam characterization at THOR-BNCT facility.

Materials and Methods

THOR-BNCT is a source from research reactor which shows a mixed neutron and gamma-ray radiation filed. In this study, there are 10 bare foil and 7 spherical-type activation detectors, which are combination of foils, absorbers and moderators, are used to be activated. The reaction rates of different detectors are analyzed by detecting the decayed gamma-rays from residual radionuclides with high-purity Germanium detector (HPGe). To reduce the counting error, the measuring data of different energy peaks are considered in calculation of reaction rates. Maximum Entropy Deconvolution (MAXED), UMG 3.3 packaged unfolding technique, solving the neutron spectrum with the reaction rates and the response functions by simulation. A new supporter made of PMMA and combined with absorbers for multiple foils, is used to conduct foil activation experiment in one time. The design of positioning and activated time are determined by Monte Carlo simulation of MCNP6. With this device, more information about spectrum can be obtained and less time is needed in conduction.

Results

The reaction rates of activated foils show the tendency to be larger than the data of the last QA and the simulated reference spectrum. However, the fast neutron flux of the unfolding result represents opposite to the reaction rates. The neutron flux from 0.2 to 2MeV shifts to lower level, while the thermal and epithermal parts of spectrum meets the result of the last QA procedure.

Conclusion

There is few change in the neutron spectrum compared with the last QA procedure in 2014. Although foil activation analysis provides a relatively reliable measurement of neutron spectrum in large energy range, the procedure is time consuming. Further investigation and examination are needed to establish faster and more accurate procedure. The improving device is in progress, and the latest progress will report and present at conference.