Abstract

The aim of this thesis was to design and optimize neutron beam shaping assemblies (BSA) for adapting neutron beams produced by Deuterium-Deuterium (DD) and Deuterium-Tritium (DT) neutron generators as well as by Cyclotron C18/18 for application in boron neutron capture therapy (BNCT). A series of GEANT4 simulations were performed in order to find a BSA design enabling formation of neutron flux meeting recommendations of the International Atomic Energy Agency (IAEA) for BNCT. Energies of neutrons produced by generators and by protons from cyclotrons are too high, and the neutron flux is too much diffused for the direct applications in BNCT. Therefore, the thermalization, as well as focusing processes need to be performed before the treatment. The design of BSA included optimization of shapes and materials for multipliers, moderators, reflectors and shielding purposes for DT and DD neutron generator were performed using computer simulations applying GEANT4 programming package. The main optimization criterion for BSA design was the maximization of the epithermal neutron flux with respect to the flux of thermal and fast neutrons and with respect to the radiation dose from gamma quanta. The simulations were performed by taking into account 2.5 MeV initial energy and 10^{11} n/s to 10^{13} n/s neutron yield of DD compact neutron generators, as well as 14.1 MeV and up to 10^{14} n/s neutron yield of DT neutron generators. Also, separately cyclotron C18/18 based BSA design and optimization was simulated, by selecting exact thickness and material type for the proton beam of the C18/18 cyclotron installed at A. Alikhanian National Laboratory of Armenia. For the above-mentioned purposes, nat-U, nat-W, and its ^{182}W, ^{184}W, ^{186}W isotopes were discussed as first part of the moderator. It is known, that materials mixed with fluorine, such as AlF_3, MgF_3, AlF_3 mixtures with nat-Al and other materials, can be useful to increase the number of neutrons in the epithermal energetic region from 1 eV to 10 keV and may be placed next to the first part of moderator as the second layer of the thermalization system. Before collimating the flux, filters like hydrogen borate (boric acid), cadmium, lead and other materials were placed in as filters to lower the amount of thermal neutrons. The best established version of the DD based BSA includes moderator consisting of 8 cm thick ^{186}W, 45 cm thick mixture of 5% Fe and 95 % AlF_3, 1.25 cm thick LiF, 0.5 mm Bi and 1 mm thick lead, and the 20 cm thick back and 15 cm thick side Pb reflectors with 15 cm thick lead collimator. As for DT neutron generator based BSA the best design consisted from 27 cm thick Bi, 53 cm thick $FeAlF_3$, 3 cm thick Al, and 1 cm thick LiF moderator with 25 cm thick back and side lead reflectors and 10 cm thick lead collimator. The achieved epithermal over thermal neutron ratio was larger than 100 and comparably lower fast neutrons flux was registered from 10^6 initially simulated neutrons/projectiles. Thermal/epithermal neutron flux of C18/18 based BSA for BNCT as result of the GEANT4 simulation study is $\sim 5\cdot10^8$ n/ (s·cm^2), where the majority of particles are epithermal neutrons in energy range from 1 eV to 10 keV, while DD based BNCT yet needs to be revised as the highest yield of neutrons was less than needed $>10^{13}$ n/s. The system resulting 6 in epithermal neutron current over the epithermal neutron flux which should be > 0.7 is under development.