Studies on (i) Characterization of Bremsstrahlung spectra from high Z elements and (ii) Development of Neutron source using MeV pulsed electron beam and their applications

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Abstract

Particle accelerators which have initially been developed as a tool for basic research now have well known applications in medical, industry and applied sciences. As to electron accelerators, we have now really well developed LINACs and Microtrons (circular and Race-track) for these applications worldwide. Interaction of high energy electrons with high Z target produces a flux of gamma quanta, called bremsstrahlung radiation. Radiotherapy using electron and bremsstrahlung radiation represents the most diffused technique to control and treat tumor diseases. Looking at this important aspect, the problem of the present thesis has been defined and divided into six subparts. The first part of the thesis mainly deals with the design of dual scattering foils for 6 to 20 MeV electron beam accelerators in clinical applications. The thickness and shape of the foils have been optimized using FLUKA code as well as through analytical calculations. The study of bremsstrahlung spectra from 6 to 18 MeV electron beams from different materials (low to high Z elements) as e – γ target have been studied in the second part of the thesis. The simulation using FLUKA involves the fluence determination of neutron, electron and positron along with photon at various angles. The data generated in this part can be used as right hand data for the researchers and medical physicists. In addition, the reliability of FLUKA simulation was confirmed by calculating the spectra for the setup of the experiments performed by other researchers. The third part of the thesis includes the estimation of neutron contamination in clinical photon beam generated from optimized accelerator head assembly through photonuclear reaction. The e – γ target, primary collimator, secondary collimator and filter of accelerator head assembly of 15 MV medical LINAC has been designed through FLUKA simulations. The bremsstrahlung radiation produces neutrons through photonuclear reaction (γ, n) in various targets (γ – n) based on their photonuclear reaction threshold energy and cross-section. These types of accelerator based neutron sources are found to be advantageous over radioactive based neutron sources and have various applications in industries as well as in the medical field. Therefore, in the fourth part of the thesis, emphasis is given to the measurement of angular distribution of neutron flux for the 6 MeV Race-Track Microtron based pulsed neutron source for short lived activation product analysis. In this case, the neutron flux was measured using the activation analysis technique and the same has been modeled in FLUKA for comparison. Moreover, (n, α) reaction with boron has been studied using 6 MeV Race-Track

Microtron based pulsed neutron source. In the fifth part of the thesis, 6 MeV linear accelerator based pulsed thermal neutron source has been designed for elemental analysis. In this design, all the possibilities to get highest neutron flux was checked and the (γ – n) target, moderator, reflector, shielding material have been optimized. A prototype experiment was carried out and corresponding experiential results were compared with simulated ones. In the sixth part of the thesis, the 15 MeV linear accelerator based neutron radiography facility has been designed. The development of the optimized system is in progress at the Society for Applied Microwave Electrical Engineering and Research (SAMEER), Mumbai. In this case, a neutron collimator has been designed along with (γ – n) target, moderator, reflector and shielding. To get the best values of collimator parameters such as collimation ratio, gamma content, neuron flux, cadmium ratio, beam uniformity, etc FLUKA simulation was carried out. Radiography using the developed facility has been kept as a future aim.

Keywords:

Photon and Electron mode Medical LINAC, Bremsstrahlung, Neutron radiotherapy and radiography, Accelerator based neutron source, Photonuclear reactions, FLUKA simulation.

List of Publications related to thesis work

1. ***B. J. Patil,*** S. T. Chavan, S. N. Pethe, R. Krishnan, V. B. Bhoraskar, S. D. Dhole, 2010. Estimation of Neutron Production from Accelerator Head Assembly of 15 MV Medical LINAC using FLUKA Simulations. Article in Press, **NIM-B** (DOI: 10.1016/j.nimb.2011.04.013).
2. ***B. J. Patil,*** A. J Patil, S. T. Chavan, S. N. Pethe, R. Krishnan, V. N. Bhoraskar, S. D. Dhole, 2011. Collimator Design of 15 MeV Linear Accelerator Based Thermal Neutron Source for Radiography. Proc. of Particle Accelerator conference-2011, THP009.
3. ***B. J. Patil,*** S. T. Chavan, S. N. Pethe, R. Krishnan, V. N. Bhoraskar, S. D. Dhole., 2011. Optimization of Dual Scattering Foil for 6 To 20 MeV Electron Beam Radiotherapy. Proc. of Particle Accelerator conference-2011, THP010.
4. ***B. J. Patil,*** S. T. Chavan, S. N. Pethe, R. Krishnan, V. N. Bhoraskar, S. D. Dhole, 2010. Simulation of *e-γ-n* targets by FLUKA and measurement of neutron flux at various angles for accelerator based neutron source. **Annals of Nuclear Energy**, 37(10) 1369-1377.
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8. ***B. J. Patil,*** S. N. Pethe, S. T. Chavan, V. N. Bhoraskar, S. D. Dhole, 2005. Useful Bremsstrahlung spectra from linear and circular accelerators for radiation therapy: calculated and simulated case. **Journal of Medical Physics**, vol 30 (4), 298.
9. ***B. J. Patil,*** S. T. Chavan, S. N. Pethe, R. Krishnan, V. N. Bhoraskar, S. D. Dhole. Design of 6 MeV Linear Accelerator Based Thermal Neutron Source: FLUKA simulation and experiment. Communicated to **Applied Radiation Isotopes**. (ref. no.: ARI-D-11-00246)