MONTE CARLO SIMULATION & DOSIMETRIC MEASUREMENT FOR A 10MeV RF ELECTRON LINEAR ACCELERATOR

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Abstract

A 10 MeV RF Electron Linac at 3 kW power is operational at Electron Beam Centre (EBC), Kharghar, Navi Mumbai to demonstrate various industrial irradiation applications like medical product sterilization, food irradiation, cross-linking of polymers etc. It is required to determine the dose accurately at a given distance from the exit window for a given set of beam parameters. Monte Carlo codes were written in C++ using Geant4 package and simulations were run for a magnetically scanned beam to estimate the dose-rate.

Experiments have also been carried out using radio-chromic films to obtain dose-profile along the scanning length of 1meter. The dose-rate profile shows linear variation with the distance from exit window indicating that the system acts as a directional line-type radiation source of 1meter length. It was also experimentally verified that the output beam energy is 10 MeV by measuring the depth-dose distribution in different materials like perspex and aluminum. The optimum range (or maximum useful range) in perspex and aluminum are about 30 mm and 15 mm respectively.

INTRODUCTION

The 10MeV RF Electron Linac at EBC, Kharghar generates 100 mA, 10 µs current pulses and beam scanning is done over a 1 m long of titanium exit window. The accelerator is operated at a scan frequency of 1 Hz and pulse repetition frequency of 300 Hz so that desired uniformity of radiation can be realized. The energy absorbed by water phantom pixels which gives the dose has been simulated by using GEANT4 software code which is based upon Monte Carlo method. [1] The dose-rate output was experimentally verified by using radio-chromic film dosimeters below the Ti exit window at various distances in both static (no use of conveyor) as well as dynamic mode (at different conveyor speeds).The output energy is verified experimentally by determining depth-dose profile in different materials.

MONTE CARLO SIMULATION

Our RF Linear accelerator generates 300 beam spots per second and operates at a scanning frequency of 1 Hz. So a simulation should be done for 150 steps in magnetic field for the 1 m scan length. For 100 mA peak beam current and 10 µs pulse duration, the number of electrons in one pulse is $6.3X10^{12}$. In the simulation, we have used 2000 electrons per pulse for realistic computation time and then appropriately scaled the absorbed energy for comparison with experimental results. The scaling factor is $3.15X10^9$ ($=6.3X10^{12}/2000$). The simulated dose profile (in terms of absorbed energy per phantom pixel) for electrons at 20cm distance from the Ti-exit window is shown in figure1**.** The graph shows that dose distribution is uniform over scan length of 1m when the scanning magnet field is varied from -0.08 T to 0.08 T for the 10 MeV electron beam.

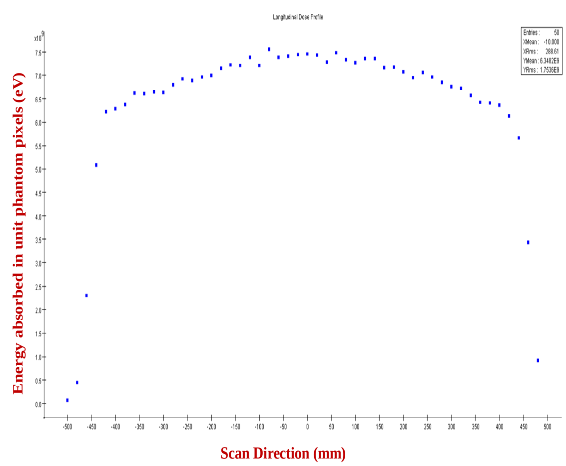

Figure 1: Absorbed dose profile for 10 MeV electron beam over the 1 m scan length. Average energy absorbed in a single pixel phantom $=7X10^{9}$ eV.

The pixel size of water phantom is 20 mm X 100 mm X 5 mm and mass of single pixel is 0.01 kg. The absorbed energy in a pixel was in eV in the simulation which is about $7X10^9$ eV, by taking into account the scaling factor and other parameters, the absorbed energy in a pixel is 7.06 J/s and thus the absorbed dose-rate is 42.4 kGy/min.

DOSIMETRIC EXPERIMENTS

The radio-chromic films of 10 mmX10 mm were arranged at nine locations (-48 cm, -40 cm,-32 cm, -16 cm, 0, 16 cm, 32 cm,40 cm and 48 cm) along the scanning direction. The “0” position corresponds to centre of scan length while -48 cm and 48 cm correspond to its ends. The dose-rate profile is observed at different distances from Ti exit window in static mode. Also the same observations were carried out in dynamic mode at fixed distance from Ti exit window but at different speeds.

For the output energy verification perspex sheets are stacked together and radio chromic films were fixed between two sheets and depth-dose profile has been observed. Similar experiment was repeated in aluminum by taking 1-1.2 mm thick aluminum sheets. The absorbance change of the film was measured by means of a spectrometer.

RESULTS AND DISCUSSIONS

Figure 2 shows the dose- rate variation in static mode at different distances from the Ti exit window. The average dose-rates at 12 cm, 20 cm and 36 cm are found to be 65 kGy/min, 40 kGy/min and 21 kGy/min respectively. The dose rate is uniform within ±8% over the entire scan length.

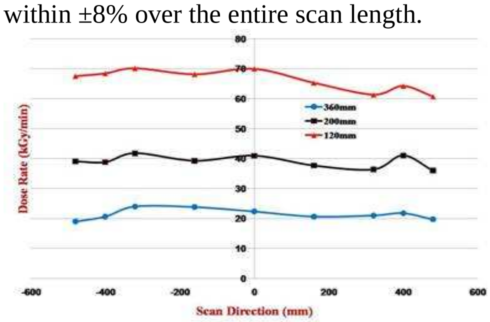

Figure 2: Dose rate distribution over 1 m scan length in static mode at different distances from exit window.

In case of dynamic mode, the uniformity over the whole scan length is comparatively better than that of the static mode. The dose profiles for dynamic mode are shown in figure 3. The output dose is 2 kGy at speed of 1m/min while we switch the speed 10 times lesser that is 0.1 m/min dose becomes 10 times more and it is 21 kGy with ±5% variation.

Depth-dose distributions in perspex and aluminum have been shown in figure 4 and figure 5 respectively. The optimum (or useful) range in perspex is 30 mm and that in aluminum is 15 mm. Also the full penetration depth in perspex and aluminum are 42 mm and 19 mm respectively.

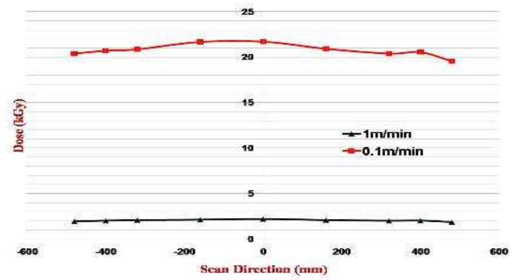

Figure 3: Dose profile over 1 m scan length in dynamic mode at different speeds.

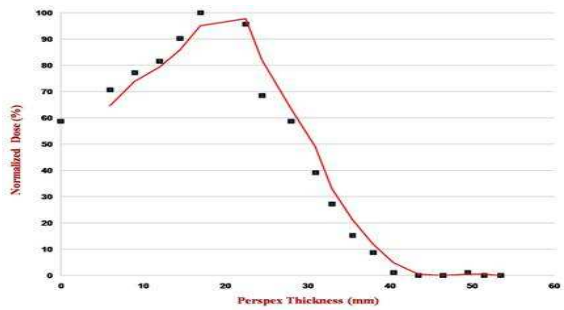

Figure 4: Depth-dose distribution for 10 MeV electron beam in perspex.

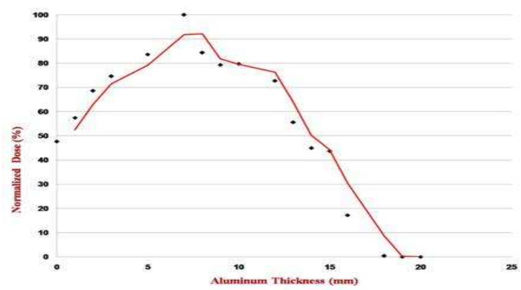

Figure 5: Depth-dose distribution for 10 MeV electron beam in aluminum.

CONCLUSION

The dose-rate varies linearly as the distance from the Ti exit window and it implies that the accelerator acts as a line-type source of length 1m. The simulated dose-rate at 20 cm from Ti exit window is 42.4 kGy/min which agrees with experimental observation of 40 kGy/min at same distance form exit window. The variation in dose uniformity over the full scan length is only ±5% in dynamic mode which is satisfactory for industrial accelerators. The optimum range and full penetration depth obtained from depth-dose distribution experiments verifies that the output beam energy is 10 MeV. [2]

REFERENCES

[1] Book for Application Development of GEANT4.
[2] IAEA “Trends in Radiation Sterilization of Health Care Products” 2008.