Measurements of bremsstrahlung spectra from 4/6 MeV e-LINAC at Electron Beam Centre, Kharghar

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Introduction

The x-ray imaging has application in various fields including national security. Nowadays, x-ray imaging is used in Container Inspection System (CIS) for scanning the cargos for detecting unauthorized objects at ports (airports, seaports etc) [1,2]. A Container Inspection System typically consists of an x-ray source, an array of detectors, image processing software and control systems. An electron LINAC (e-LINAC) is generally used as an x-ray source in the CIS. An RF e-LINAC of dual energy (4 MeV and 6 MeV) has been developed by the APPD, BARC at the Electron Beam Centre (EBC), Kharghar for the Indian Cargo Scanner (ICS).

In this work, measurements of bremsstrahlung spectra for 4 MeV, 6 MeV and dual energy (4 MeV + 6 MeV) electron beam from the e-LINAC at EBC Kharghar is presented. The energy of the electron beam has been estimated from the end point energy of the measured bremsstrahlung spectrum.

Experimental Details

The e-LINAC can be operated either in single energy mode (that is 4 MeV or 6 MeV with uncertainty of ± 100 keV) or dual energy mode (i.e., both 4 MeV and 6 MeV simultaneously). The accelerator provides the electron beam of a pulse width of 3-4 μs and a peak current of 120-190 mA with a repetition rate of 50-200 Hz; and with RF frequency of 2856 ± 2 MHz. The electron beam from LINAC impinges on a 1.2 mm thick Tungsten target and gets stopped within the target and as a result of deceleration of the electrons, the bremsstrahlung photons are produced. These bremsstrahlung photons come out from the Tungsten target. The electron beam spot size at the target was ≤ 2 mm and the Tungsten target was mounted inside a cylindrical collimator with a trapezoidal planar slot to collimate the intense high energy photons produced in a horizontal plane. The exit slit (collimator) size for bremsstrahlung photons is 210 mm (h) x 4 mm (w).

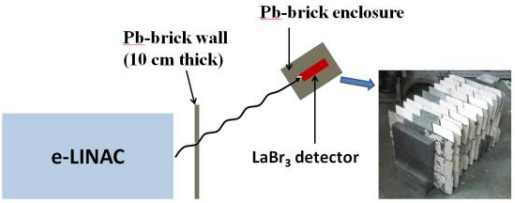

Fig. 1 Schematic of the experimental set-up.

A 1.5 inch x 1.5 inch $LaBr_3$ Scintillation Detector (Energy resolution: ~ 4% at 662 keV and timing resolution: ~ 700 ps) was used for detecting the photons. The detector was operated at -1150 V and the signal from the detector was fed to a NIM based digitizer for processing. The data was processed online and also written to the disk for offline analysis. The pulse structure of the LINAC with a peak current of 120 mA produces approximately 10^{12} electrons in a short time window of 3 μs leading to an intense flux of photons ~10^7 per cm^2 at 1 meter in the same time interval. For 4 MeV and 6 MeV electrons, the current was 190 mA and 120 mA, respectively. For $LaBr_3$ detector, which operates in pulse

mode, aforementioned photon flux must be considerably reduced so that only a single photon should fall within the active time window of the detector i.e. ~200 ns. The electronics and data acquisition system also need to be protected from such a high intensity of photon-flux for their normal operation. During the experiment, the detection system (detector + associated electronics) had to be properly shielded from not only direct photons-flux but also from the scattered-photons from the surrounding materials (e.g. walls). For shielding purpose, a Pb-brick wall [33 cm (L) x 10 cm (w) x 85 cm (H)] was made in front of exit slit of the accelerator (Fig. 1). The $LaBr_3$ detector was kept on the ground at 3.14 meter away from the exit slit and at ~ 32° angle from the direct viewing line the accelerator's exit slit. Further, the $LaBr_3$ detector was covered from all six sides by thick Pb bricks (Fig 1).

Results and Discussions

The detector was energy calibrated using 0.511 MeV and 1.275 MeV photons from ^{22}Na radioisotope before, during and after the experiment; and the energy calibration was found to be stable during the entire period of the experiment. The experimental data for electron beam energy of 4 MeV, 6 MeV, and the dual mode (4 MeV + 6 MeV) were taken for duration of around three hours each. The background spectrum (i.e. without beam - e-LINAC OFF) was also taken for the same duration.

The bremsstrahlung photons spectra for electron beam energy 4 MeV, 6 MeV, and the dual mode (4 MeV + 6 MeV) are presented in fig. 2. The spectra presented in fig. 2 are background- and pile-up- corrected. The presented data has a binning of 20 keV. A threshold of ~500 keV was applied for rejecting the noise in the detector. The introduction of Pb shielding between the photon source and the detector attenuate low-energy photons and slightly alter the shape of the spectrum; however, the end-point energy of the spectrum remains unaffected.

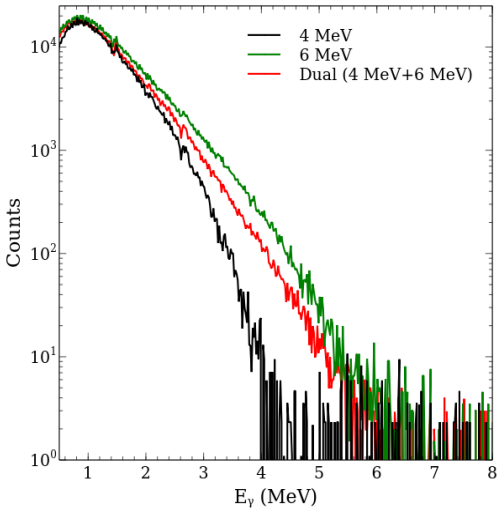

Fig.2 Comparison of the measured bremsstrahlung spectra from electrons of 4 MeV, 6 MeV and in dual mode (4 MeV + 6 MeV).

The end-point energy of both the energies i.e. 4 MeV and 6 MeV is found to be very consistent with the tuned electron energy and also for the dual mode. It is to be mentioned that the detector has ~ 2% energy resolution in the 4 - 6 MeV photon energy region.

Acknowledgments

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