A.8: Linac-3 physics design

A 9.5 MeV, 6 kW electron linac (Linac-2) was earlier designed, developed, tested and installed at RRCAT for industrial irradiation applications, and is now operating at Agricultural Radiation Processing Facility, set up at Devi Ahilya Bai Holkar Subji Mandi, Indore. Here, the accelerating structure is a 2π/3 mode, constant impedance, disk loaded, 2856 MHz traveling wave structure that accelerates the 50 keV beam from electron gun to 9.5 MeV. Considering the new requirements described below, an upgraded design has been evolved to operate in two modes – electron mode (with an average beam energy of 9.5 MeV), and x-ray mode (with an average beam energy of 7.0 MeV). Since it is a sequel in earlier developed two linacs, it is named as Linac-3.

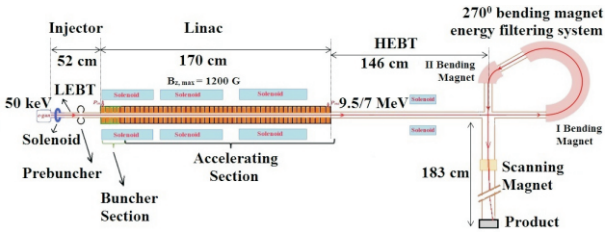

Fig. A.8.1: Schematic of the Linac-3.

Linac-3 design incorporates (i) enhancement in the beam transmission efficiency through the accelerating structure, (ii) reduction in the energy spread of the output beam, (iii) enhancement in the output beam power to 10 kW, and (iv) ability to restrict the maximum energy of electrons in the output beam to 10 MeV (in the case of electron beam mode) and 7.5 MeV (in the case of x-ray mode) as per the regulatory requirements. To achieve (i) and (ii) above, we have incorporated a pre-buncher RF cavity before the linac structure. For improvement (iii), the beam current and input RF power will be increased. For improvement (iv), a 270° bending magnet based energy filtering system is added after the TW linac structure. Figure A.8.1 shows the basic schematic of the Linac-3.

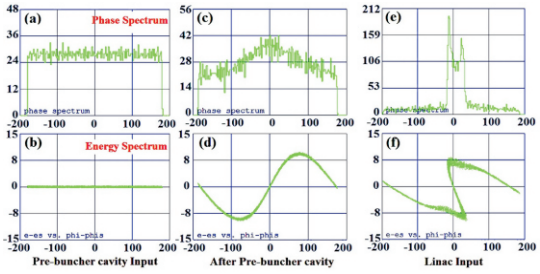

Fig. A.8.2: Energy and phase spectrum at pre-buncher input (a,b), pre-buncher output (c,d), and linac input (e,f).

The pre-buncher is a 2856 MHz, single cell, standing wave, Coupled Cavity Linac (CCL) type cavity. It provides velocity modulation in the input beam. The velocity modulated particles travel in a drift and are bunched at the optimum distance, where they enter the accelerating structure. Figure A.8.2 shows the phase and energy spectrum at the pre-buncher input, pre-buncher output, and the linac input. With pre-buncher cavity, the beam transmission efficiency of accelerating structure shows an increase from 65% to 88%. The energy spread of output beam is obtained as ± 5% for 90% particles. The RF power to beam power conversion efficiency improves from 45% to 66%.

An energy filtering system, comprising of 270° doubly achromatic bending magnet system with beam scrapper, is incorporated in Linac-3 to scrap the particles which have energy higher than 10 MeV for electron mode, and 7.5 MeV for x-ray mode. The physics design studies for the Low Energy Beam Transport (LEBT) Line, pre-buncher cavity, TW electron linac, High Energy Beam Transport (HEBT) Line, followed by the beam transmission studies through the 270° bending magnet system have been performed. The beam is dispersed in the horizontal plane after entering the bending magnet, where the high energy particles are separated from the low energy particles. Figure A.8.3 shows the evolution of beam envelope from the pre-buncher cavity to energy filtering system for 9.5 MeV case. The available vacuum aperture is also shown in the figure. The reference frame here is moving along the central beam trajectory. The distance of beam scrapper edge from the center line was adjusted to scrap the electrons with energy more than 10.0 MeV/7.5 MeV.

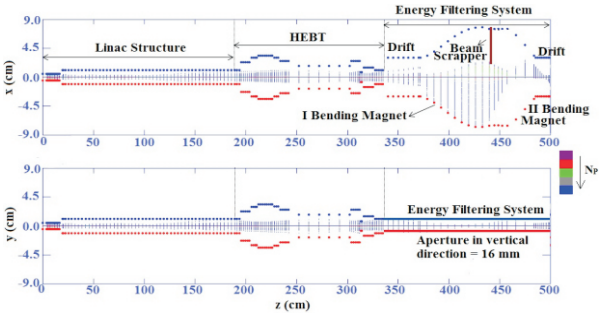

Fig. A.8.3: Evolution of beam envelope from pre-buncher cavity to energy filtering system for 9.5 MeV case in the horizontal plane (top) and the vertical plane (bottom).

Linac-3 is tested up to 5 kW average beam power at 9.3 MeV at linac output, and up to 1 kW at 9.5 MeV at energy filtering system output. With pre-buncher cavity, the beam transmission efficiency of Linac-3 has improved from 65% to 88%. Further details about the hardware development and experimental results are given in report A.9 in this issue of the Newsletter. Currently, beam measurements are being performed for recursive design improvements.

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