NEW GENERATION X-BAND LINACS FOR MEDICAL AND INDUSTRIAL APPLICATIONS

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Abstract

The proposed designs of the new X-band linear accelerators for industrial and medical applications are based on a well-known side-coupled RF structure. The immediate applications envisioned for the new linear accelerators are security screening and intraoperative radiotherapy (IORT). The new design has promising features and presents cost reduction potential for electron beam and X-ray systems used in medical, industrial, and security screening applications.

INTRODUCTION

The side-coupled RF structure has been designed using SUPERFISH and PARMELA computer codes, and was targeted to cover specification requirements for the known medical, industrial, and security screening applications. The new linear accelerators are designed to match the usual specification operating in energy range from 1 MeV to 9 MeV. Most of the produced designs are energy regulated and will operate in dual energy mode, such as (1/3) MeV and (4/6) MeV. We have already built the newly designed cavity prototypes, which allow us to verify and adjust the accelerator cavity design parameters in a broad electron velocity range, collecting data adequate for building an operational linac. Special efforts have been taken to ease cavity and structure tuning and reduce cost of the new designs. The RF structures have shorter lengths, higher gradients, and better capture. Reduced beam losses lead to a decrease in mass of primary shielding and enhanced mobility.

The new RF design of the two-section 4 MeV to 12 MeV linac has been produced by Radmedex LLC “from the drawing board” as an improvement of the originally designed intraoperative linac [1]. The original design has been in operation for nearly 20 years. It is currently employed in a system called Mobetron, which is produced by Intraop Medical Corporation in Sunnyvale, California [2]. The modern Intraoperative Radiotherapy approach requires systems installed and safely run in the operating room (OR) environment, that apply the electron beam directly to the tumor. Therefore, linac performance, mobility, and reduced background radiation during IORT treatment become highly important. Presently, the IORT market may require tens of such systems per year, making production, commissioning, and running cost reduction pivotal factors. IORT has many advantages as a relatively new approach in radiation therapy. It helps improve numerous patients’ quality of life and saves the lives of many others [2, 3]. There are several other players in the industry using electron beam (Italian SIT spa, Tomsk Polytechnic University) and photon beam (Carl Zeiss Meditec, Xoft Inc.) for IORT treatment [4].

NEW LINAC FOR INTRAOPERATIVE RADIOTHERAPY

The X-band accelerators operate at approximately three times higher frequency than the similar S-band linacs. Therefore, the RF linac structure cross section is approximately 10 times smaller than that of the S-band accelerators. While producing less power than their S-band counterparts, the use of X-band RF sources may lead to a substantial reduction in the mass of primary shielding along the linac [5], which is important for some of the applications. On some occasions, the X-band accelerators’ dose rate has approached the S-band linacs’ output [5]. We have made the next step in improving the X-band structure by introducing a new design, new geometrical parameters of the RF cavities. Based on the genuine interest in this initiative and the prototype demonstrated by Intraop Medical Corporation, the outer shape of the parts is similar to the existing linac, and the two-section linac assembly is designed to fit in the existing housing of the Mobetron. The target specifications of the new X-band linac, such as the operational frequency 9290±10 MHz, energy range from 4 MeV to 12 MeV, with peak output current of 10 mA were also selected to match the existing Mobetron design. The total RF structure length is substantially shorter than that of its predecessor. The linac beam centerline structure consists of two sections with two power inputs, respectively. The first shorter section is designed to permit fast bunching and to obtain an acceptable electron beam capture without magnet focusing.

In order to achieve various output beam energy values power and phase can be regulated between the two sections of the linac. The final calculation results are shown in Fig. 1-2.

The new accelerator has 3 output energy modes: “6 MeV”, “9 MeV” and “12 MeV”, while it is capable of operating at 4 MeV as well. It could be seen from Fig. 2 that particle capture approximately equals 12% to 15% at the output end of the RF structure.

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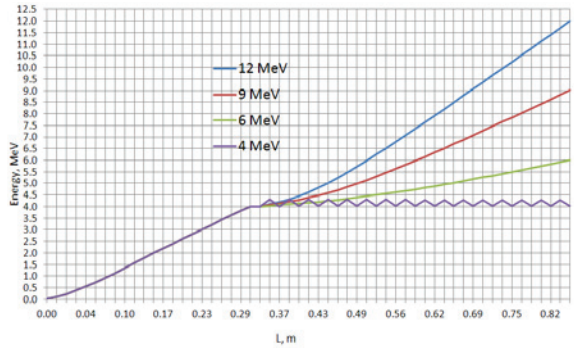

Figure 1: Electron beam energy versus longitudinal coordinate.

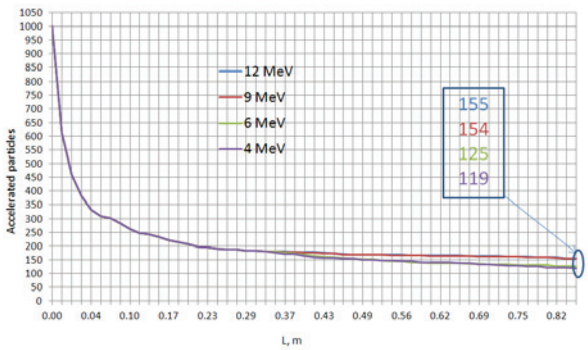

Figure 2: Electron beam capture variation along beam axis.

The new accelerator structure, therefore, is designed to substantially reduce radiation leakage and subsequently, mass of the shielding. In Fig. 3 and Fig. 4, we present the estimated radiation dose rate at 90 degrees to beam axis due to beam losses in copper walls.

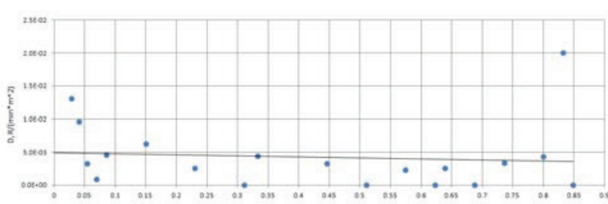

Figure 3: Radiation dose rate at 1 m, at 90° due to beam losses in copper in 12 MeV operational mode.

The similar results with a 1cm thick lead shield are shown in Fig. 4.

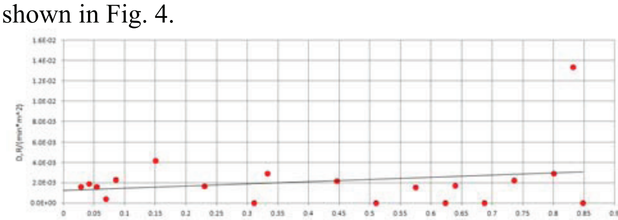

Figure 4: Radiation dose rate at 1 m, at 90° due to beam losses in copper with 1 cm thick lead shield in 12 MeV operational mode.

CONCLUSION

We present some of the results of our more than one-year efforts by RADMEDEX LLC group, which lead us to the new family of the X-band linacs. We have completed design of a new improved 4 MeV to 12 MeV linac, which is substantially similar in output characteristics to the one used on the Mobetron system. Currently, we are in a process of building the above prototype. We have also designed a 1/3 MeV and 4/6 MeV energy switchable linacs for security applications, procured prototype cavities and measured their characteristics in the necessary broad particle velocity range. We have selected side-coupled RF structure for these linacs. The immediate applications envisioned for the new linear accelerators are in NDT, security screening, and intraoperative radiotherapy. The new designs have promising features and present cost reduction potential for electron beam and X-ray systems used in medical, industrial, and security screening applications.

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