# STATUS OF KAERI 6 MeV 9.3 GHz X-BAND ELECTRON LINAC FOR CANCER TREATMENT SYSTEM*

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*Abstract*

The X-band RF linear accelerators (LINAC's) are popular for medical application due to its compactness [1, 2]. To increase the precision of treatment accuracy under circumstance in which the LINAC is mounted on an apparatus such as gantry frame or robot-arm; this is an advantage as the weight and size are more reduced [3]. It is a 9.3 GHz magnetron with the most readily available RF generator in the X-band frequencies from 8 GHz to 12 GHz and the magnetron is mainly used for the source of the RF power in a compact LINAC. The average power of the magnetron at 9.3 GHz is generally a few MW and this amount could provide a sufficient radiation dose-rate for tumour therapy.

KAERI has been developing a new compact 9.3 GHz X-band electron LINAC for a cancer treatment system. The maximum energy of the electron beam is 6 MeV and the average beam power at the tungsten target is about 1 kW. In this paper, we describe the status of development of the 6 MeV X-band LINAC at KAERI.

## INTRODUCTION

The Stereotactic Radiosurgery (SRS) such as Gamma Knife, CyberKnife and proton therapy is a non-invasive technique for the delivery of collimated radiation to the malignant tumour with extreme precision [4]. In 1951, SRS was introduced by neurosurgeon Lars Leksell at Karolinska Hospital in Stockholm, Sweden [5]. The frameless robotic radiosurgery, CyberKnife, has been available to treat tumours since the 1980s after the development of an X-band LINAC and magnetron [6]. Since the size and weight of the accelerator has been reduced, the compact X-band LINAC has become the common treatment machines in most radiation oncology departments [7].

## DESIGN FEATURE

A 6 MeV compact X-band LINAC for medical applications has been developing at KAERI. A schematic flow of the LINAC is shown in Fig. 1, and general parameters of the machine are summarized in Table 1. The electrons are generated from triode type 20 kV electron gun and accelerated up to 6 MeV in the accelerating structure. The 2 MW RF power is fed into the 9.3 GHz RF accelerating structure through the transmission line such as a straight, E & H bend, flexible, and twisted waveguides, and a circulator and RF window. The expected X-ray dose rate is 500 cGy/min at 1 m with a 2 mm RMS spot size at the tungsten target.

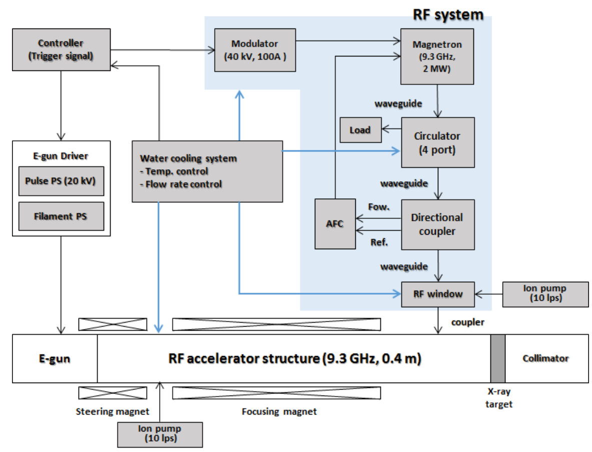


Figure 1: Schematic of 6 MeV compact X-band LINAC.

### *Electron Gun*

An ALTAIR [8] triode 20 kV electron gun is used for the 6~MeV X-band LINAC. The parameters of triode electron gun are summarized in Table 2. The power supply for the triode e-gun has been developing at KAERI.

### *RF Accelerating Structure*

The layout of the RF accelerating structure is shown in Fig. 2 (a) and (b). This 0.4 m long standing wave (SW) on-axis RF structure has 25 cells including 10 bunching cells. Figure 2(c) shows the field flatness of the X-band RF structure and Fig. 2(d) and (e) show the fabricated and brazed RF structure. Each cell of the cavity has a bell shape curvature instead of a nosecone for easy fabrication. This RF accelerating structure has an RF coupling cell at the centre of the structure and the RF power will be fed into the coupling cell through a WR-112 waveguide with a inner size of 28.49 mm × 12.62 mm. The accelerating structure will be operated in π-mode to deliver the electron beam on the tungsten target.

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The mechanical design has been completed, and fabrication is ongoing [9].

Table 1: Parameters of KAERI X-band LINAC

| Parameters | Values | Unit |
|---|---|---|
| Max. energy | 6 | MeV |
| Resonance frequency | 9.3 | GHz |
| E-gun gap voltage | 20 | kV |
| RF generator | Magnetron | |
| RF power (peak) | 2 | MW |
| Length of RF cavity | 0.4 | m |
| Waveguide flange type | WR-112 | |
| RF frequency tuning | AFC with a stepper motor | |

Table 2: Design Characteristics of ALTAIR Triode E-gun

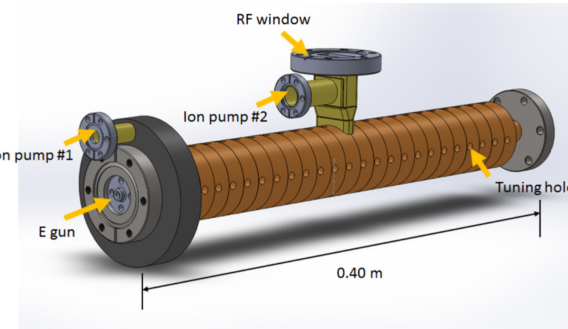
| Parameters | Values | Unit |
|---|---|---|
| Perveance | 0.3 | $\mu A/V^{3/2}$ |
| Gap voltage | 20 | kV |
| Heater power | 15 | W |
| Cathode Type | Dispenser | |

### *RF Generator & Pulsed Modulator*

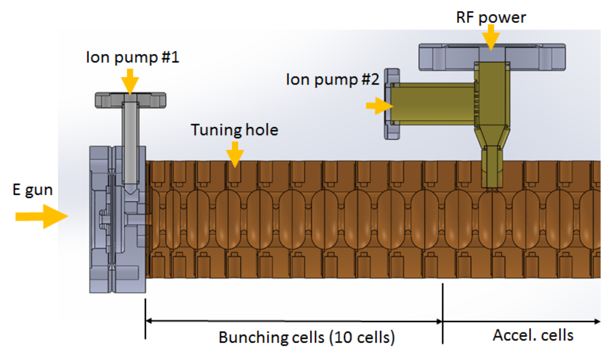
For the RF power source of the LINAC, as shown in Fig. 3(a), an L3 PM1110X X-band magnetron will be used [10]. The PM1110X is a coaxial pulse magnetron that delivers 1.7 MW minimum peak output power at a duty cycle of up to 0.0008 and a pulse width of up to 4.0 µs. For the magnetron modulator, as shown in Fig. 3(b), a customized ScandiNova M1 Mark4 will be used [11]. To reduce the size of the modulator, the ScandiNova uses solid state technology. The modulator can be operated with the maximum macropulse length of 5 µs and maximum repetition rate of 500 Hz.

### *Automatic Frequency Control (AFC) Unit*

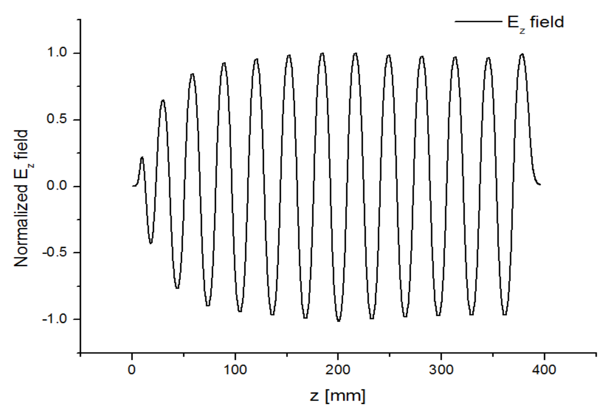
During the operation of a RF LINAC, the resonance frequency of the RF cavity changes because of the power dissipation on the wall inside the cavity. The Automatic Frequency Control (AFC) unit is a device to automatically tune the frequency deviation between the RF source and RF cavity. Consequently, an accelerator obtains a stable electron beam by a function of the AFC [12]. A KAERI designed X- band AFC unit is ready for a compact X-band LINAC. The schematic flow of the AFC is described in Fig. 4. This AFC unit measures and compares the forward and backward RF power from the RF generation system. It then generates and sends signals to the mechanical tuning part which was designed to be driven remotely by an electric motor.




(a)




(b)




(c)

Figure 2: (a) Layout of RF cavity for 6 MeV LINAC, (b) Cross-sectional view of the 6 MeV RF cavity, (c) normalized $E_z$ field along the longitudinal direction, (d) fabricated cells, and (e) brazed RF accelerating structure.

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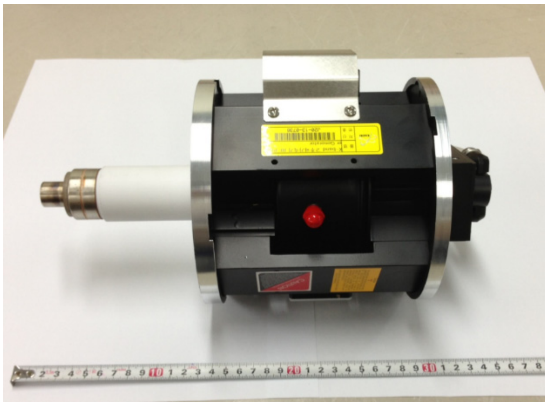
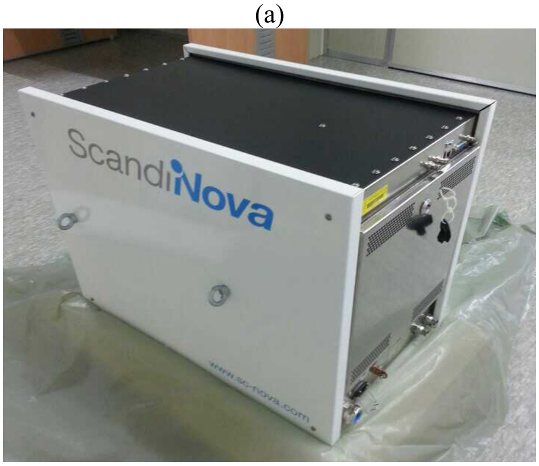


(a)




(b)

Figure 3: (a) X-band Magnetron (L3 PM1110X) for RF generation, and (b) Modulator (Scandinova M1 Mark4) for X-band Magnetron.

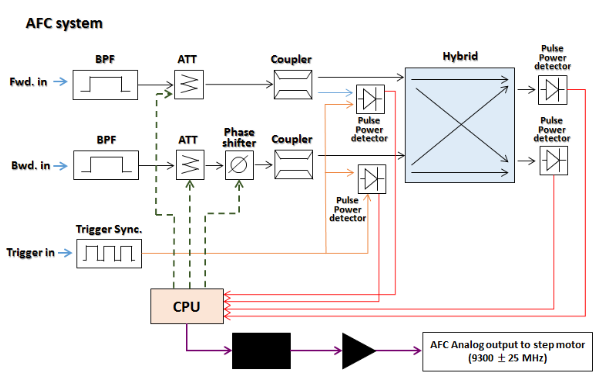



Figure 4: Schematic of AFC for RF tuning of X-band electron LINAC.

## SUMMARY AND FUTURE PLAN

The KAERI designed a compact X-band LINAC for medical application. The layout of the designed LINAC is shown in Fig. 5. The RF cavity is ready for fabrication and RF components including waveguides, a circulator, and an RF window were prepared. After manufacturing the accelerating tube, the beam dynamics will be conduc - ted with information of the ALTAIR e-gun to clarify the performance of the designed LINAC. A water cooling system with a loaded W target is also being designed for X-ray generation. Commissioning is supposed to be conducted in September 2014.

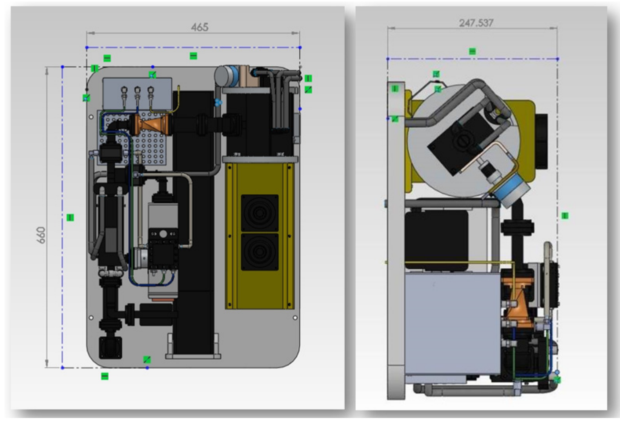



Figure 5: Dimension of 6 MeV compact X-band LINAC for medical application

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