'S' BAND LINAC TUBE DEVELOPMENTAL WORK IN SAMEER*

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Abstract

The development work on linear electron accelerators in SAMEER, India is briefed in this paper. The technology to develop 'S' band compact side coupled standing wave electron linear accelerator is very well established at SAMEER, Mumbai center. 6 MV to 15 MV linac are developed with the desired specifications. Indigenous 6 MV linac machines for radiotherapy applications have been developed successfully and these machines are in use at premier cancer hospitals in the country. SAMEER is presently working on the development of the dual mode-electron and photon and dual energy linear accelerator for radiotherapy application. The 6 MeV linac tube development and its test results are discussed.

INTRODUCTION

SAMEER has developed a 6MeV S band standing wave side coupled compact linear accelerator for cancer treatment. The main parameters of the linac are tabulated in table 1. The design and development work was carried out to achieve 300 Rad at 1 meter per minute (RMM) at 6 MeV energy [1] [2] [3]. Since the machine was designed for patient treatment a compact linac was preferred to accommodate the linac tube in the gantry in vertical position. The electron gun to target length of the linac is 42.25 cm. A 2.6 MW magnetron is used as an RF power source at 3GHz frequency. The linac tube was successfully tested on the test bench and is now working in a hospital. This paper describes the design aspect and development of the linac tube in our laboratory.

Table 1: Machine Parameters

Parameter	Value
Energy	6 MeV
Frequency	2997.98 MHz
Dose Rate (Flattened)	240 RMM
Input Power	2.6MW(peak)

LINAC DESIGN

The basic design parameters of linac tube are given in table 2. The cavity designed for the linac tube is shown in Fig.1 while the SuperFish profile for single cell is shown in Fig.2. The cavities were fabricated in-house. The initial frequency was set at 3017 MHz and subsequently a slot was cut to get a final frequency of 2997 MHz. The cavities were then brazed to side cavities in hydrogen atmosphere. The machining of cavities was done on CNC machine using diamond tips. The surface finish was maintained less than 2 microns and the quality factor, Q were measured to be 15000. Six cells were brazed together to make a 32 cm long linac tube as shown in Fig.3. The linac tube has two buncher cavities and five acceleration cavities. The linac tube is water cooled to maintain the body temperature within 5°C.

Table 2: Linac Parameters

Parameter	Calculated	Measured
π/2 frequency, MHz	2997	2998
Side to main coupling %	0.03	0.0267
Shunt impedance, MΩ/m	120	87
Q (unloaded)	16000	15000
VSWR	1.4	1.56

Figure 1: Linac cavity.

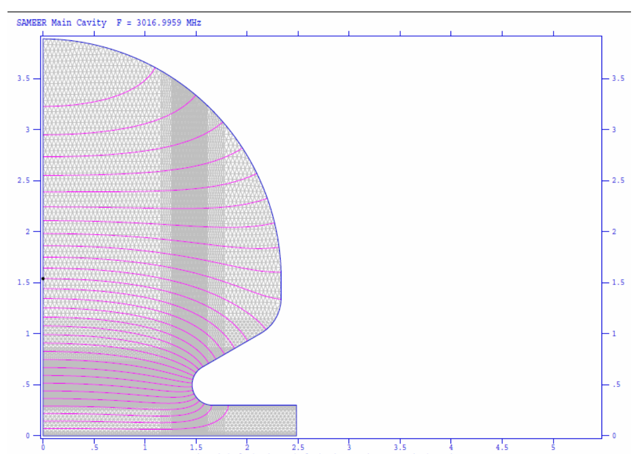

Figure 2: SuperFish plot of a single cell.

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The linac tube made is a side coupled standing wave structure operating at π/2 frequency [4], [5], [6]. The unloaded Q of the structure was found to be nearly 15000 with shunt impedance of 87 MΩ/m measured using bead perturbation technique [7]. The fabrication of such a structure involves extreme accuracy. Some critical and practical observations in process involved are stack brazing and RF feed slot.

Stack Brazing

Cavities are made of OFHC Copper of 99.998% purity of HITACHI make. The profile is done on CNC machine. Slot cutting and dowelling is done on CNC milling machine. The accuracy of dowelling is 0.005 mm. It is important to note that inaccurate dowelling can lead to serious alignment problems and also leaky tubes after first brazing. Our experience shows that when the stack is loaded for stack brazing, no external jig is required if the dowelling is proper. The self-jigging mechanism suits best as it avoids any stress due to external jigs.

RF Feed Slot

The point from where the power will be coupled to the linac tube is very critical. The slot dimensions play a crucial role in coupling the power and a variation in dimension can lead to an under coupled accelerating structure. A larger slot will result in reduction of the frequency of the main cavity at that joint. The VSWR of the final stack was designed to be nearly 1.4 and an elliptical slot of 22.98 x 17.12 mm at depth of 11.35 mm was finalised. The slot cutting was done using DRO based milling machine. The final VSWR of tube was found to be 1.5 and frequency of feed cavity was found to be 2998.6 MHz.

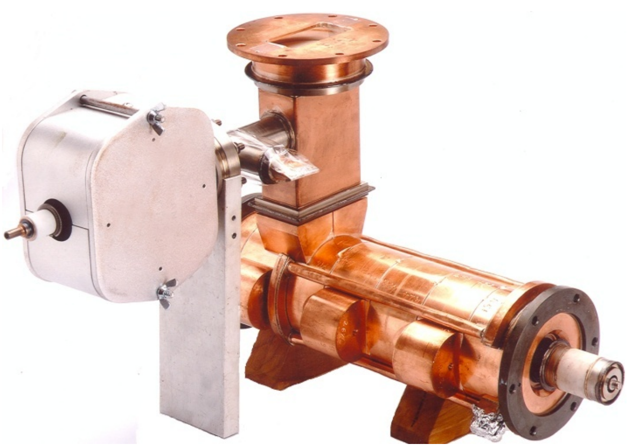

Figure 3: SAMEER made side coupled linac tube.

Other Subassemblies

The electron gun is Pierce type diode gun with 6 mm diameter dispenser cathode. The cathode used is Spectramat make Type M dispenser cathode STD .250 with current density of 2 A/cm^2.

The designed target has a high atomic number, Z target pellet encased in a copper housing. The pellet thickness is 1.5 mm enough to stop all the electrons [8], [9]. Target assembly is water cooled to keep the temperature within 5°C of the set temperature.

RF Window used was SAMEER make with 3 MW power handling capacity. The window is air-cooled. The ceramic disc used in the window was of 3.00 mm thickness.

A sputter ion pump of 8 l/sec capacity was attached to the linac tube to take care of the residual out-gassing during operation after pinch off.

TEST & MEASUREMENT

After attaching all the subassemblies the linac tube was baked at 325 deg. C and the vacuum achieved before cutting off from the online vacuum system was of the order of $4*10^{-9}$ torr. The mode spectrum measured after baking is shown in Fig.4. The measured π/2 frequency was 2998 MHz and VSWR was 1.5.

High power linac tube characterisation was done before integration with the oncology system. The linac was then RF out-gassed. A line type modulator with 2.6 MW e2V magnetron giving 4.5 µs pulse width was used to feed in RF power at 2998 MHz to the linac tube. A 3-port circulator protects the magnetron from reflected power. The linac tube is attached at the second port and S band 30 dB water load is at the third port. The testing was finally done at 200 PRF with a full RF power of 2.6 MW.

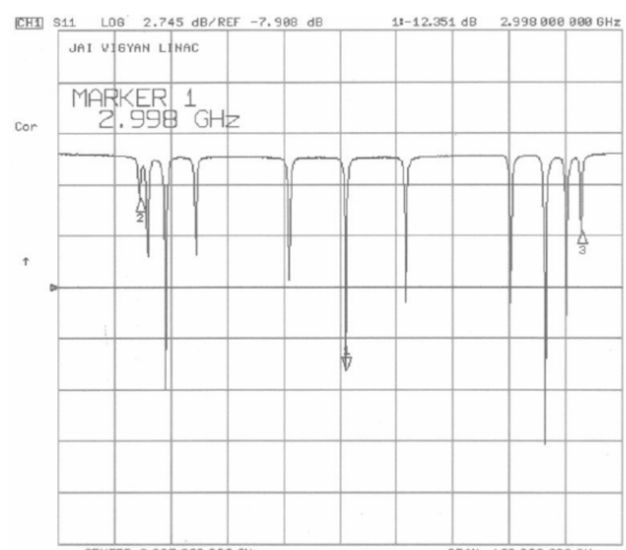

Figure 4: Mode spectrum.

The dose rate was measured using Secondary Standard Dosimeter of Wellhoffer make. The ionisation chamber volume was 0.6cc.The flattened dose rate measured to be 240 RMM. The target current recorded was 130mA (pulse).

RESULTS

The depth dose curve shown in Fig.5 has a maximum build up at 15 mm in 3D water phantom which corresponds to 6 MeV energy. The unflattened dose rate was found to be 300 RMM whereas flattened dose was 240 RMM. The beam symmetry measured was found to be better than 3% of central maxima. The test data is given in table 3.

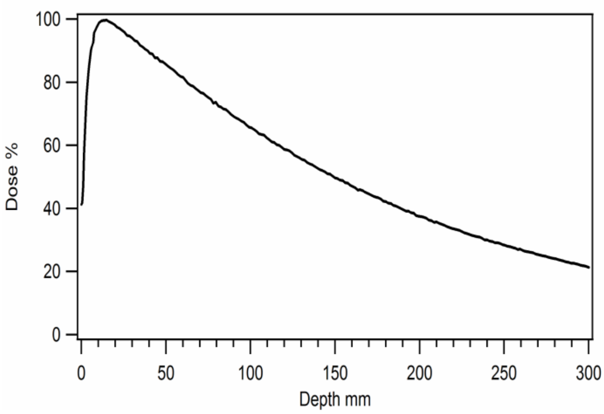

Figure 5: Measured depth dose curve in water.

Table 3: QA Test Data

Parameter	Required	Measured
Energy	6 MeV	>6MeV
Symmetry	<5%	<3%
Dose rate	300 RMM (Unflattened)	240 RMM (Flattened)

CONCLUSION

SAMEER has now successfully proven and established the technology of making Linac tubes of 4, 6 and 15 MV. The dose stability and repeatability with respect to time as well as machine-to-machine repeatability is an important feature of SAMEER linac tubes. Indigenous 6 MV linac machines for radiotherapy applications have been developed successfully and these machines are in use at premier cancer hospitals in the country. SAMEER is presently working on the development of the dual mode-electron and photon and dual energy linear accelerator for radiotherapy application.

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