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CONSTRUCTION OF THE SIDE-COUPLED STANDING-WAVE e-LINAC

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Abstract

Due to Iran's growing need for accelerators in various applications, NSTRI electron linear accelerator project has been defined for medical and inspection applications. This accelerator is a 6 MeV side-coupled standing-wave that operate is π /2 mode in the frequency of 2998.5 MHz.

In this paper the construction and measurement results of the tube of this accelerator are presented. The prototype tube was constructed from aluminum and was clamped with bolts. By using a network analyzer, electric and magnetic probes and a side-coupled cavity tuning method and a bead-pull measurement technique, RF measurements were carried out. The resonant frequency and quality factor have been achieved 2998.5 MHz and 7940 respectively

INTRODUCTION

In Iran, a project has been started in Nuclear Science and Technology Research Institute to build an electron linear accelerator for medical and inspection applications.

For this accelerator, a side-coupled standing-wave accelerating tube was selected that the main specifications of it are given in Table 1 and also a layout of it is given in Fig. 1.

Table 1: The Desirable Tube Specifications

Parameters	Value
RF frequency	2998.5 MHz
Input beam energy	30 keV
Output beam energy	6 MeV
Operating mode	π/2
Maximum RF power	2.6 MW

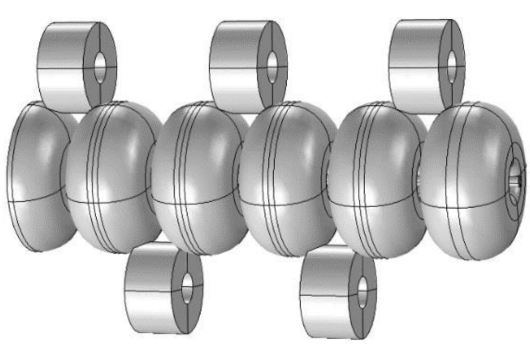

Figure 1: The layout of the entire accelerating tube.

Electromagnetic design, beam dynamics studies and thermal and mechanical simulations of the tube have been carried out by using COMSOL [1], ASTRA [2] and ANSYS [3] respectively [4-6]. After the design was completed, construction and RF measurement of the porotype aluminum tube carried out that the results of them are presented in this paper.

CONSTRUCTION

The design of the tube has been carried out and the mechanical drawings of the tube have been prepared, then each cavity of the tube was machined and polished. The exploded view drawing of the prototype tube is shown in Fig. 2.

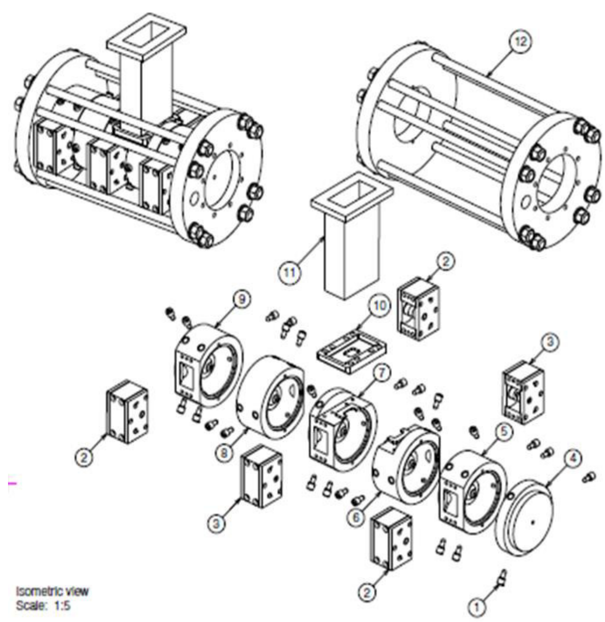

Figure 2: The exploded view drawing of the entire tube.

The first prototype tube was built from aluminium. The cavities were machined and polished and the bolts clamp the cavities in place. We have created six holes on the accelerating cavities wall and one hole on the coupling cavities wall for frequency tuning. The constructed tube is shown in Fig. 3.

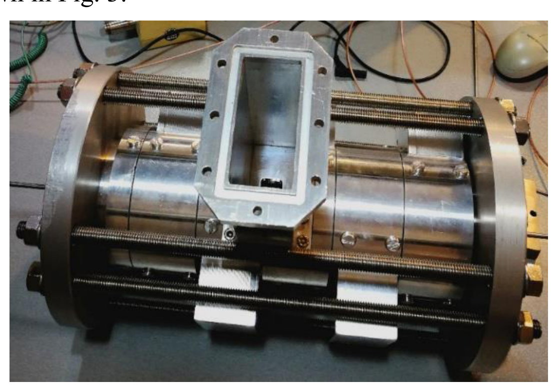

Figure 3: The constructed tube.

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MEASURMENT

After frequency tuning of the tube, the resonant frequency and quality factor of the constructed tube were measured by using a network analyzer (VNA). To tune the frequency of the cavities and measure the RF properties of the tube, methods discussed in reference [7] have been applied. The resonant frequency of the accelerating and coupling cavities after the frequency tuning is shown in Table 2. As shown each accelerating and side cavity individually resonating at 2998.5±0.1 MHz.

The resonant frequency and quality factor of the tube are represented in Table 3. As shown in Table 3 the measured resonant frequency is equal to the predicted value from simulation, but the measured quality factor is about 62 % of the predicted values from simulation.

Table 2: The Accelerating and Coupling Cavities Frequency (MHz)

accelerating	frequency	coupling	frequency
AC1	2998.6	**SC1**	2998.4
AC2	2998.4	**SC2**	2998.5
AC3	2998.4	**SC3**	2998.4
AC4	2998.6	**SC4**	2998.5
AC5	2998.4	**SC5**	2998.5
AC6	2998.5		

Table 3: RF Properties by Measurement and Simulation

Parameters	simulation	measurement
Frequency	2998.5 MHz	2998.5 MHz
Quality factor	12930	7940

In RF test, S11 reflection spectrum results of VNA for the entire tube for two frequency ranges were obtained that are shown in Fig. 4.

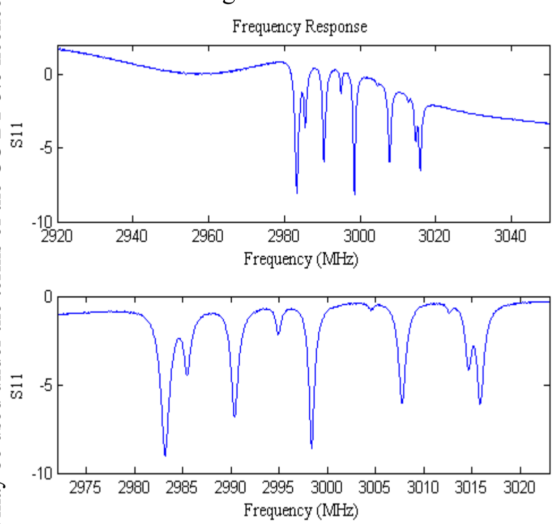

Figure 4: S11 reflection spectrum of the tube.

The bead-pull measurement system is a device that determining the relative amplitude of the electric field generated inside the tube by measuring the magnitude of change in the resonant frequency while a small bead moves through the tube [8].

The axial field profile by bead pull measurement results of VNA before and after frequency tuning and the simulated electric field profile along the tube axis are represented in Fig. 5, Fig. 6 and Fig. 7 respectively. As shown in Fig. 6 and Fig. 7, the RF field peak in the first half accelerating cavity (buncher cavity) is smaller than in the other accelerating cavities and we obtain a good agreement between the simulated and the measured electric field. But as shown in Fig. 5 axial electric field before tuning is not suitable and frequency tuning is required.

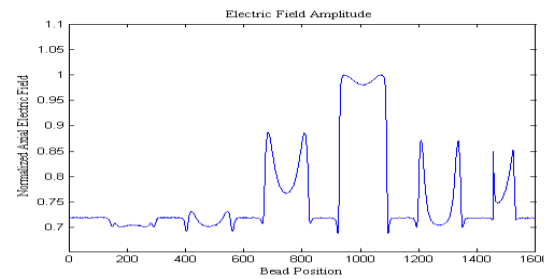

Figure 5: The measured axial electric field profile before frequency tuning.

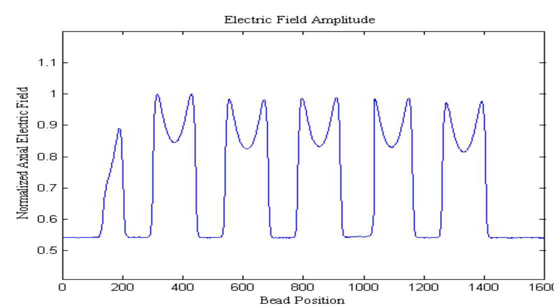

Figure 6: The measured axial electric field profile after frequency tuning.

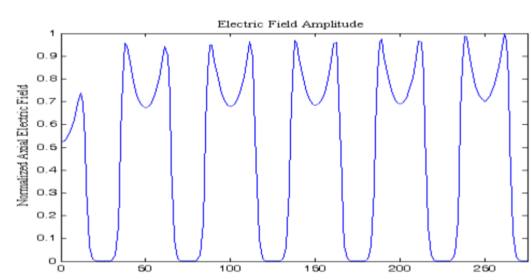

Figure 7: The simulated axial electric field profile.

The resonant frequencies plotted against the phase shifts per cavity produce a dispersion curve (Fig. 9) that was compared to the simulated curve from COMSOL (Fig. 8). Although the center frequency of both curves is equal to 2998.5 MHz, but Fig. 8 shows 11 frequencies against the phase shifts per cavity and Fig. 9 shows 10 frequencies against the phase shifts per cavity. This difference is due to that "0" mode has great loss and the

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peak of this mode disappears in the measurement reflection spectrum.

Because the "0" mode is not the designed operation mode of the tube, this imperfection does not affect the $\pi/2$ mode operation.

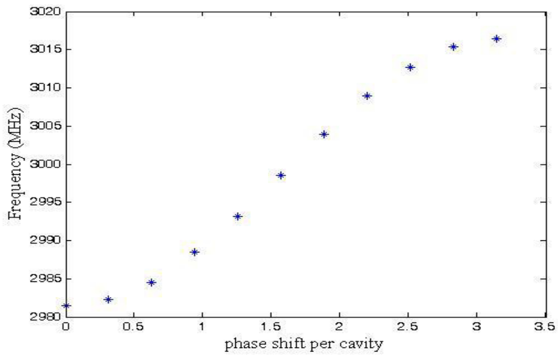

Figure 8: The simulated dispersion curves.

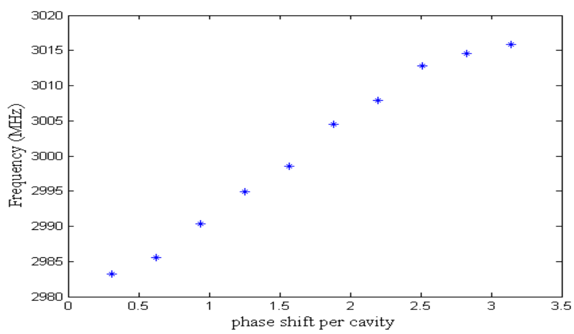

Figure 9: The measured dispersion curves.

CONCLUSION

Because of Iran's need to develop the application of accelerators in medicine, environment, cargo inspection, physics researches and industries, the design and construction of low and medium energy accelerators was started. In this regard, the project of design and construction of the 6 MeV e-linac for medical and cargo inspection application was defined. For the desired accelerator, a side coupled standing wave tube was selected to resonate at the frequency of 2998.5 MHz in $\pi/2$ mode.

The design stage of the accelerating tube was done and the prototype tube was constructed from aluminium and RF measurement was carried out. The constructed tube resonated at the frequency of 2998.5 MHz in $\pi/2$ mode and a good agreement between the measured and the predicted field distribution (by simulation) was obtained.

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