DEVELOPING OF A C-BAND 9 MeV / 6 MeV SW ELECTRON LINEAR ACCELERATING TUBE

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Abstract

In this paper, the design of a C-band SW accelerating tube is presented and its high power test set is shown. The tube can accelerate electrons to 9 MeV or 6 MeV. Its length is about 620mm, and a Pierce electron gun is used. A 2.5MW pulsed magnetron at 5712 MHz is served as the tube's RF power source. Two energy modes are performed by changing the input RF power and the injecting voltage of electron gun.

INTRODUCTION

Electron linacs are widely used in non-destructive testing, electron beam sterilization and radiotherapy etc. Most of linacs are operated at S-band frequency in the world. Owing to developing of the new applications, some lighter and smaller accelerators are required. Recently, a domestic C-band pulsed magnetron has been developed by Beijing Institute of Electron & Vacuum Technology, so we can develop a kind of C band electron linacs to meet the above demand.

The accelerator laboratory of Tsinghu University, which has extensive experience with S-band and X band eleratron linacs, has started to study C band electron linac since 2004. However, without appropriate RF power, this work can not perform too fast. In recent years we pushed Beijing Institute of Electron & Vacuum Technology to develop a C band coaxial magnetron. In last year a C band magnetron was produced and its high power test had been finished. Its operation frequency is at 5172MHz, its output pulse power and average power can reach 2.5MW and 2.5kW respectively. Using the magnetron, a C-band on axis-coupled SW accelerating tube which operated in the $\pi/2$ mode has been developed by Accelerator Laboratory of Tsinghua University. The tube can provide two X-ray energy modes, 9MeV and 6MeV. Its length is about 620mm, and a Pierce electron gun is used.

PHYSICS DESIGN

The design parameters of the C band accelerating tube was established the same as the domestic 9MeV S-band linacs for non-destructive test.

To begin with, the cavity configuration must be carefully optimized to obtain two modes energy, 9MeV and 6MeV. The theoretical value of the optimized shunt impedance can reach 180 MΩ/m, but based on our experience, its practical value can only take about 85% of the theoretical one, namely 153MΩ/m. Otherwise, the mechanical structure of the cavity must be carefully considered for the advantages of mechanical and the final assembly. Finally, it is important that to calculate the beam dynamics using simulation code. The tube design results are as follows. The accelerating structure is a 620mm long, which consists of 25 cavities concluding 4 cavities of buncher, operated in the $\pi/2$ mode at 5712MHz. To obtain small size and less weight of the structure, the phase-focusing technique was used without any external magnetic focusing device. As a result, the beam spot size of the accelerating structure is less than 1.5mm in diameters. The accelerating tube parameter characteristics are listed in table1. Figure 1 shows a schematic illustration of the accelerating tube.

Table 1: The accelerating tube parameter characteristics

Beam Energy	9MeV	6 MeV
Beam Current Peak	100mA,	148mA
Spot Size	<1.5mm	<1.5mm
Frequency	5712MHz	5712MHz
RF Peak Power	2.2MW	1.9MW
Input Coupling	1.7	1.7
Shunt Impedance	153MΩ/m	153MΩ/m
Injection Voltage	9.5kV	16kV

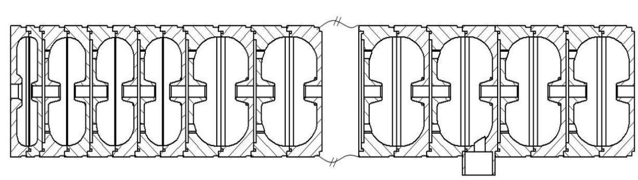

Figure1: Schematic illustration for on-axis structure.

Table 2 is the comparison of operating parameters of C band accelerating tube with the S band one. From table 2, we can get the conclusions that to adopt C band frequency has following advantages:

- Accelerating tube of lighter weight or smaller size;
- Because of higher shunt impedance, the accelerated electron beam energy is increased at same input RF power;
- More efficient.

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Table 2: Comparison of operating parameters

Name	C-band	S-band
Beam Energy	9MeV	9MeV
length	620mm	1020 mm
Shunt Impedance	153MΩ/m	110 MΩ/m
RF Frequency	5712MHz	2998MHz
Input Peak Power	2.2MW	2.3MW
Beam Current Peak	0.1A	0.1A
Spot Size	< 1.5mm	< 1.5mm

The simulation results of the longitudinal and transverse beam dynamics without any external magnetic focusing solenoid with a homemade code are shown in Figure 2 ~5.

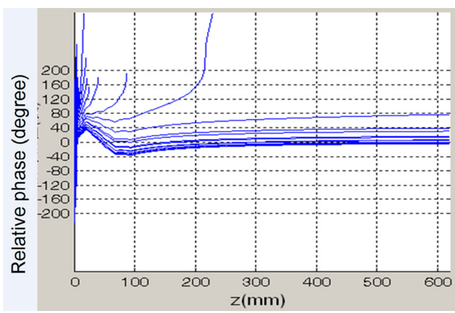

Figure 2: Relative phases curve at 9MeV.

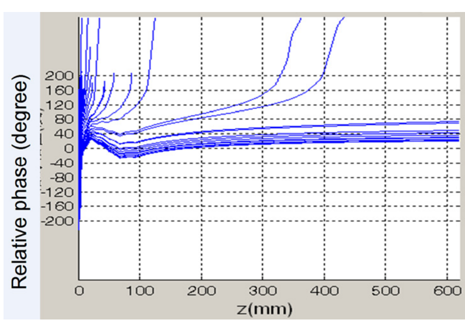

Figure 3: Relative phases curve at 6MeV.

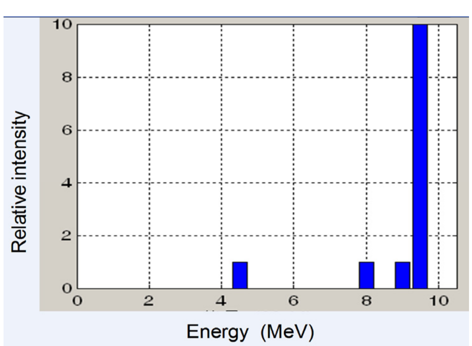

Figure 4: Electron beam energy spectra at 9MeV.

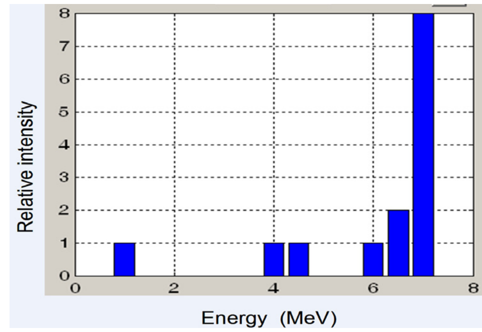

Figure 5: Electron beam energy spectra at 6MeV.

HIGH-POWER TEST SET

Last year a C band high-power test set has been set up by accelerator laboratory of Tsinghua University and Beijing Institute of Electron & Vacuum Technology. Figure 6 is the experiment block diagram of the set. It is composed of Line-type pulse modulator, magnetron, four ports circulator and a pulse power RF meter etc.

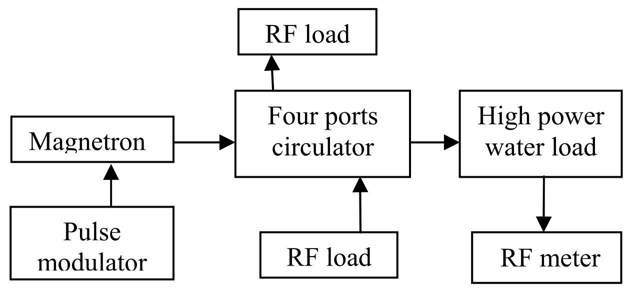

Figure 6: Experiment block diagram of high-power set.

Figure 7 is the photograph of the set. A Line-type pulse modulator provides a pulse power to the magnetron, and then the generated RF power by magnetron passes waveguide into four ports circulator. The output of four ports circulator is connected by waveguide to a high power water load. The displayed data by RF meter will be the input power of accelerating tube in the future. Table 3 is the operation parameters of the high-power test set.

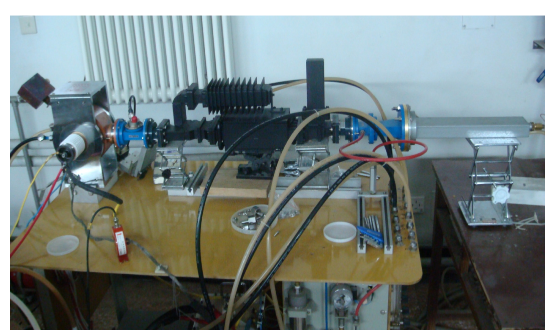
Figure 7: High power test device.

From these results, we know the function of this high power test set satisfies the demand of the designed accelerating tube totally.

Table 3: The operation parameters of the set

Parameter	Value
Operation frequency	5712MHz
Modulator output pulse power	48.4MW
Duty cycle	0.08%
RF power envelop width(at 50% power level)	~4.0μs
Magnetron output pulse power	2.56MW
Insertion loss of the whole RF system	0.23

CONCLUSION

The design of a 9MeV, C-band SW accelerating tube and the high power test set has been completed. At present, the experimental cavities are been machined and cold measured. Commissioning tests of the accelerating tube are expected to begin in this year.

ACKNOWLEDGMENT

The authors express their acknowledgments to Beijing Institute of Electron & Vacuum Technology, they not only supplied magnetron but also helped us to complete the high-power experiments without any pay back. The authors also express their acknowledgments to professor Yuzheng Lin for the beneficial discussion.

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