FABRICATION AND HIGH POWER RF TEST OF A C-BAND 6MeV STANDING-WAVE LINEAR ACCELERATING STRUCTURE*

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Abstract

We have designed a C-band standing-wave bi-periodic on-axis coupled linear accelerating structure for industrial and medical applications [1]. The output electron energy is 6 MeV and the pulse current intensity is 100 mA. The structure has been fabricated and measured in cold test. The cold test results show a good agreement between the simulation and actual measurement. At present, it's under high power RF test. In this paper, we illustrate the fabrication, the results of cold test and newly high power RF test.

INTRODUCTION

Compared with S-band and X-band linear accelerators, C-band linear accelerator has the merits of compact volume, high accelerating efficiency as well as moderate difficulty of manufacture. Considering these merits, many research organizations around the world have shown great interest in C-band linear accelerators [2-4]. The accelerator laboratory of Tsinghua University is also doing research in this domain. Last year, we designed a C-band 6 MeV standing-wave bi-periodic on-axis coupled accelerating structure. With 2.2 MW input RF power, it can accelerate electron to 6 MeV and the pulsed beam current intensity is about 100 mA.

This accelerating structure has been fabricated in our laboratory. In cold test, the characteristics of the cavities, the distribution of on-axis electric field intensity and coupling factor have been measured. These results show a good agreement with our previous simulation. Now, the structure is under high power RF test. We have measured the capture coefficient and the dose rate. We will continue the high power test to measure of the output energy spectrum, the size of the output beam spot, the breakdown rate and other useful data later.

DESIGN REVIEW

In our design process, we implement 2D cavities geometry optimization by SUPERFISH, beam dynamics study by PARMELA and full scale 3D simulations by MAFIA codes. To improve working efficiency, we also write several MATLAB codes to call SUPERFISH and PARMELA and read the output files to extract useful information automatically.

The length of the accelerating structure is less than 30cm. The structure is consists of three bunching cavities and nine normal cavities. The seventh normal cavity is also the RF coupler with a taper waveguide welded with it. The coupling factor between the accelerating structure and ports is designed to be 1.6~1.7, providing maximum input power with beam loading.

The pulse RF power source is a domestic C-band magnetron whose output power can reach 2.5 MW. The magnetron and the accelerating structure are separated by a four-pole circulator and the maximum input RF power for the accelerating structure is about 2.2 MW. These components are connected together by waveguide filled with high pressure SF6 gas.

Some of the design parameter is shown in Table 1. We can see that this structure has high capture coefficient, small beam spot size and compact length.

Table 1: Some Design Parameters of the Structure

Parameter	Value
Operation frequency	5712 MHz
Structure type	Bi-periodic, on-axis coupled
Operation mode	Standing-wave $\pi/2$ mode
Length	28.8 cm
Input pulse RF power	2.2 MW
E-gun voltage	10 kV
E-gun emittance	36 mm•mrad
Accelerating Gradient*	27 MV/m
Efficient shunt impedance*	130 MΩ/m
Quality factor*	10500
Inter coupling factor*	2.4%
Capture coefficient#	46%
Output beam transverse radius#	0.7 mm (rms)

*Values for the normal cavity
#Values for 2.2MW input power

FABRICATION

All the copper cavities have been manufactured with high precision turning machine and milling machine in our laboratory.

The accelerating structure is designed to be cooled by water jacket instead of circumvolute water tubes and there is no tuner on the structure.

The electron gun is a pierce type gun and we can change the injecting current intensity by adjusting the voltage of the gun. In order to measure the energy

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spectrum of the output beam, we welded 0.05 mm thickness titanium window instead of a target at the end of the accelerating structure. A titanium getter pump is welded to the taper waveguide to maintain the vacuum degree of the accelerating structure. The whole structure after fabrication is shown in Figure 1.

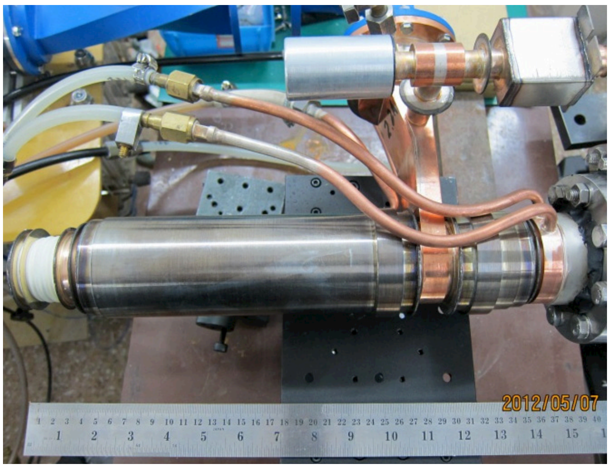

Figure 1: The fabricated accelerating structure.

COLD TEST

We have done the RF cold test at each step of the fabrication. The results [1] show a good accuracy of our previous simulation.

After the cavities were final turned to the operation frequency, we assembled them together and measured the distribution of on-axis electric field intensity, as Figure 2 shows. The blue line is the design distribution and the red one is the distribution measured in cold test. They agree well with each other.

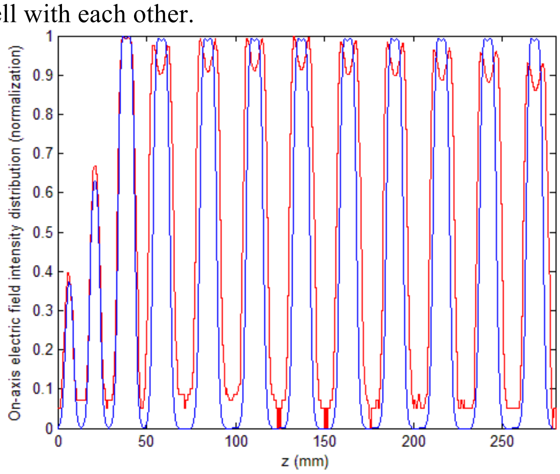

Figure 2: The distribution of on-axis electron field.

After the whole structure was brazed and welded with electron gun, the cooling water jacket, the titanium window and the ceramic window, we measured the frequency of $\pi/2$ mode, the quality factor and the coupling factor between the accelerating structure and ports, as Table 2 shows. The quality can reach nearly 95% of the simulation values. The coupling factor β is little higher than that in simulation. The reasons may be the error of ports calibration and unsatisfactory electric contact of the ceramic window in cold test.

Table 2: Cold Test Results of the Structure After Brazing

Parameter	Design	Cold test
f (MHz)	5712	5712.20
Q_0	10296	9775
β	1.6-1.7	1.95

HIGH POWER RF TEST

We are carrying out high power RF test in our laboratory. At present, we have measured the capture coefficient and the dose rate.

In high power RF test, the pulse width of the magnetron is 5.2 μs and the repetition rate is set to be 60 Hz. The vacuum degree of the accelerating structure is kept to be 10^{-6} Pa [5].

In measurement of capture coefficient, we attached a Faraday Cup to the accelerating structure and the output beam intensity could be measured. We have measured the capture coefficient with different input power for the accelerating structure, as Table 3 shows. The simulation was done by PARMELA and it agrees well with the test.

Table 3: The Capture Coefficient

Input power (MW)	Capture coefficient (%)	
	Simulation	High power test
1.82	41.11	40.6
2.00	43.04	43.3

Because there is no target welded to the structure, we put a 2.5mm thickness tungsten target right in front of the titanium window. The distance from the target to the window was 1m. The input power for the accelerating structure was about 2.1MW and the dose rate we measured was 900 rad / (min•100μA).

We will measure of the output energy spectrum, the size of the output beam spot, the breakdown rate and other data later.

CONCLUSION

We have fabricated a 6 MeV C-band standing-wave bi-periodic on-axis coupled linear accelerating structure. The cold test results show a good agreement between the simulation and actual measurement. In the on-going high power RF test, we have measured the capture coefficient and the dose rate. More measurements will be carried out later.

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