THE RESEARCH OF ELECTRON RF GUN BASED ON X-BAND DAW (DISK-AND-WASHER) ACCELERATING STRUCTURE

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Abstract

A thermionic electron rf gun which is used as an injector for a dielectric linac has been designed and manufactured for the AWA project in ANL. The x-band DAW (disk-and-washer) standing wave accelerating structure, which has very high coupling coefficient (~50%), is adopted in the accelerating tube of the electron gun. The design and manufacture work of the electron gun have finished. The accelerating tube is designed to work at 11.430GHz and the tuning work has nearly been finished. The simulation results of beam dynamics of this rf gun and its DAW structures are given in this paper. Some results of tuning and cold measurements will also be presented.

INTRODUCTION

A thermionic electron rf gun is used for AWA project in ANL as an injector for a dielectric linac(DLA). The experiment setup is shown in figure 1. According to the requirement for the injector, the x-band DAW(disk-and-washer) standing wave accelerating structure is adopted in the accelerating tube of the electron gun.

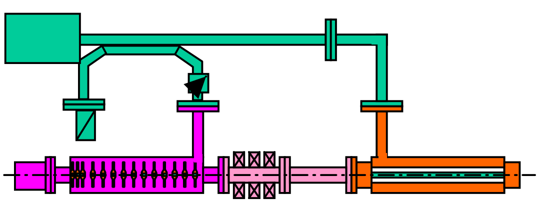

Figure 1: Experiment setup of the injector and DLA

The DAW standing wave accelerating structure has very high coupling coefficient (~50%), which allows a larger fabrication tolerance, which reduces the manufacturing cost[1]. But on the other hand, high coupling coefficient make it not easy to measure the resonant frequency of a single cavity and the tuning is made rather difficult. Mode overlap is anther serious problem. Disperse curves of several HOM are near the working frequency, which will cause BBU effect when beam current is large[2][3].

By now, resonant frequency of the whole tube has been adjusted to 11.428GHz±2MHz and the field distribution of the tube has matched designed target (except the first cavity). Simulation and measurment result will be presented afterwards.

OVERIEW OF THE INJECTOR

Requirement for the injector

According to the requirement of DLA experiment, the parameter of the injector is listed below:

Energy	~5MeV
Pulse repetition frequency	10pps
Pulse length	~200ns
Peak current	~10mA
Working frequency	11.430GHz
Q_L	<2000

Duty ratio of the tube is very little(less than 10^{-5}) and as the cathode is put in the tube directly, the electron energy near the cathode is also very low, so back-bombardment problem will not be considered serious.

Because of the character of power supply, Q_L of the tube is required being less than 2000. As Q_0 of the cavity is about 9000, coupling coefficient β of the whole tube has to be adjusted to about 3.

The average power and current is not large, which can reduce the influence of HOM. It is a good condition to test x-band DAW structure.

Assemblies

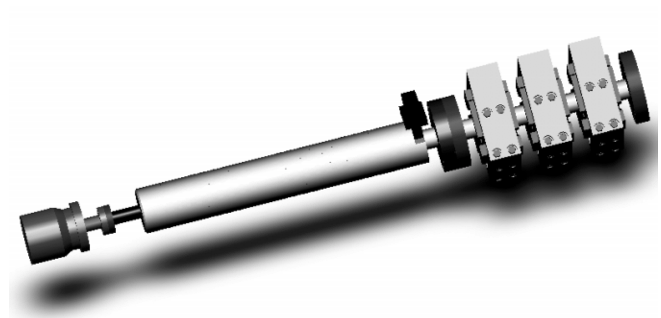

Figure 2: injector for DLA

The injector contained several assemblies: thermal cathode, accelerating tube(DAW structure), quadrupole magnets and some connection elements. All the assemblies have been manufactured and the accelerating tube is being tuned.

LaB_6 cathode is put in the tube directly. This type of cathode has good thermal stability, chemical stability and strong ability against intoxication. It can be put in the air for any long time and work in vacuum after a short time of heating. It is very convenient to use this type of cathode in experiment.

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DAW standing wave accelerating structure is adopted in the accelerating tube. The tube contains 24 cavities (19 cavities in regular segment), the first cavity is a half cavity. Coupler is in the end of the tube. Some dynamic simulation has been taken before manufacturing and the tuning work has nearly finished by now. The simulation and measurement result will be presented in the next section in detail.

There are three magnets on the electron channel to make the electron bunch match the requirement.

SIMULATION AND MEASUREMENT RESULT OF THE ACCELERATING TUBE

The tube contains 24 cavities and 19 cavities are contained in regular segment (shown in figure 3). The couple is in the end of the tube. By now, the tuning work is nearly finished, only the field distribution in the first cavity and the couple degree of the whole tube should be adjusted. The frequency of the tube has matched requirement. In the process of adjusting field distribution and couple degree, resonant frequency of the tube is also shifted, so the tuning of frequency and adjusting of field distribution have to be proceeded alternately.

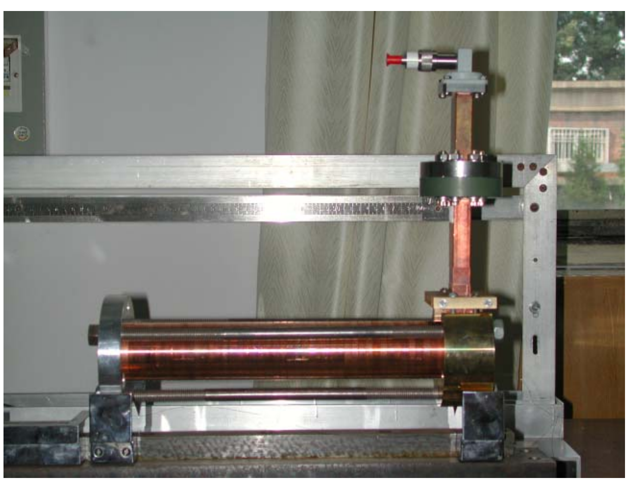

Figure 3: accelerating tube (with waveguide)

Tuning of frequency

The frequency of accelerating mode(TM02-like mode) and coupling mode(TM01-like mode) should be all adjusted to working frequency. In considering the influence of temperature and the frequency difference in air and vacuum, frequency of the two modes should be adjusted to 11.427~11.430GHz. Figure 4 shows the basic half-cavity and the geometrical parameters used in tuning.

Change of one dimension can only change the frequency of one mode and change the other mode very little. So frequency of coupling mode and accelerating mode can be adjusted separately. But the change direction in table 1 are all concluded when the change of parameter is slight, if the change of dimension is very large, the frequency of the other mode will also be changed.

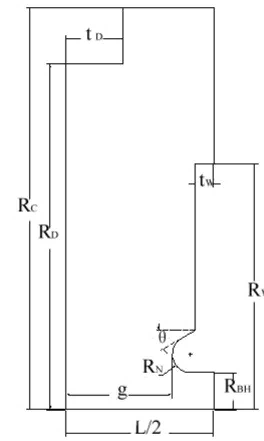

Figure 4: Geometrical parameters of a half-cell DAW cavity

The directions and rate of the frequency changes with respect to the specific parameter are shown in table 1, which is concluded from experiment.

Table 1: directions and rates of frequency changes with parameter changes

	f_c(TM01-like)		f_a(TM02-like)	
	direction	Rate (MHz/mm)	direction	Rate (MHz/mm)
R_c↑	↑↑	~100	—	—
R_d ↑	↓↓	~100	—	—
g ↑	—	—	↑↑	70~80
t_W↓	—	—	↓	40~50

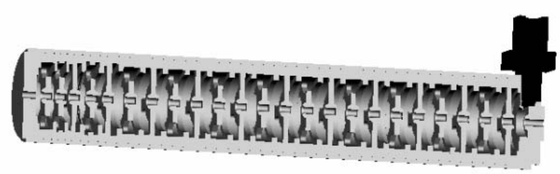

Figure 5: cutaway view of accelerating tube

Adjusting of field distribution

Adjusting work of regular segment is not difficult, for every cavity in this segment is the same and it is easy to get the field in each cavity nearly equal. But adjusting of bunching segment is difficult and some adjust on cavity had been taken. The cutaway view of the whole tube is shown in Figure 5.

Adjusting of field distribution in DAW structure is not as easy as normal diperiodic accelerating structure because the couple between adjacent cavities can't be altered easily. From the experiment some method had been found. If R_c is increased a lot, the ratio of the field in this cavity to the cavity next to R_c-increased side will be changed. Field in R_c-increased cavity will be relatively higher than before changed. These changes can be seen in figure 5. As the change of R_c will be rather large, the frequency of the cavity will be largely altered and the field distribution maybe also changed for the frequency shift. It is difficult to adjust the frequency and field distribution in the same time.

In the process of adjusting, the field distribution is also redesigned to meet the measurement result and dynamic simulation is taken according to the redesigned field distribution. The newest designed field distribution and measurement result are shown in figure 6.

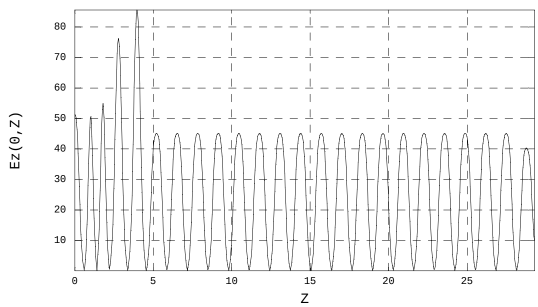

Figure 6(a): designed field distribution

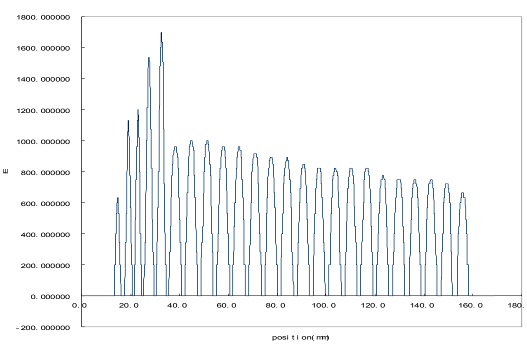

Figure 6(b): measurement result

The adjusting of field distribution is almost finished except the first cavity.

There is a slope of the field distribution in regular segment, perhaps this is come from the frequency difference between the coupler and regular cavities. Further experiment will examine it.

Parmela is used for dynamic simulation. The result given by it shows that nearly 25% of the injecting particle is emitted out of the tube and 95% of the emission electron is above 5MeV. The geography distribution and phase-space distribution of the output electrons are shown in figure 7.

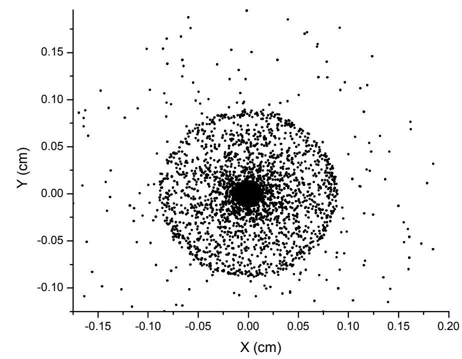

Figure 7(a): geography distribution of emission electron

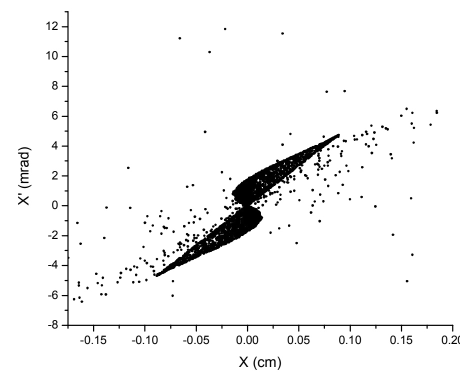

Figure 7(b): phase space distribution of emission electron

Measured coupling coefficient β of the whole tube is about 0.85 and the coupled will be adjusted later to enlarge it.

SUMMARY

The tuning work of injector has nearly finished and some cold measure is proceeding. Some characters of DAW structure appeared during the tuning work and the further research will be taken. The injector will finally complete in two or three month and will be sent to ANL to do the DLA experiment.

REFERENCES

[1] Y. Iwashita, “Disk-and-washer structure with biperiodic support”, N.I.M. A 348(1994) 15-33.

[2] Yuan Hu, Chuanxiang Tang and Yuzheng Lin “Dynamic Analysis of X-band DAW(Disk-and-washer) Accelerating Structure”, Proc. of Apac'01 162-164.

[3] T. Tanaka, et al, “Test of a 1m Long Disk-and-washer Accelerating Tube”, Proc. of Linac’84, 229