ISBN: 978-3-95450-194-6 ISSN: 2226-0366 doi:10.18429/JACoW-LINAC2018-MOPO087

COLD TEST OF HYBRID RFQ PROTOTYPE

P.Y. Yu †, B. Zhang, C.X. Li, F.F. Wang, Z.J. Wang, Y. He
Institute of Modern Physics, Chinese Academy of Sciences, Lan Zhou 730000, China

Abstract

Hybrid RFQ is proposed as a potential good choice at the low-energy range of linear accelerator, which is combined by four-vane RFQ structure and CH-DTL structure. It has higher energy gain rate compared to conventional RFQ, and it is more compact than traditional DTL. In order to research on the RF performance and process exploration of this structure, an aluminium prototype is developed. The cold test of Hybrid RFQ prototype is completed. This paper will present the results and analysis of the test.

INTRODUCTION

Hybrid RFQ is a spatially periodic structure with RF quadrupoles [1, 2], which is combined by alternating CH-DTL sections and four-vane RFQ sections. It has higher accelerating efficiency than traditional RFQ, and shows stronger focusing strength than magnetic focusing DTL, especially when accelerating low r/q ions [3]. The results of beam dynamics and RF simulation of the Hybrid RFQ operated at 81.25 MHz show that the structure has a good performance to accelerate $^{238}U^{34+}$ from 0.38 MeV/u to 1.33 MeV/u [4].

In order to verify the RF performance and the mechanical structure (see Fig. 1) of Hybrid RFQ, as well as to explore the machine processing, an aluminium prototype is developed. The frequency is chosen as 325 MHz to reduce the size of cavity. The length is 1m, and the diameter is approximately 0.3m. The mechanical structure of Hybrid RFQ is complicated. Thus on the one hand, it requires high precision for machining. On the other hand, it is difficult to assemble [5]. The manufacture and cold test of Hybrid RFQ are completed; the results and analysis will be presented.

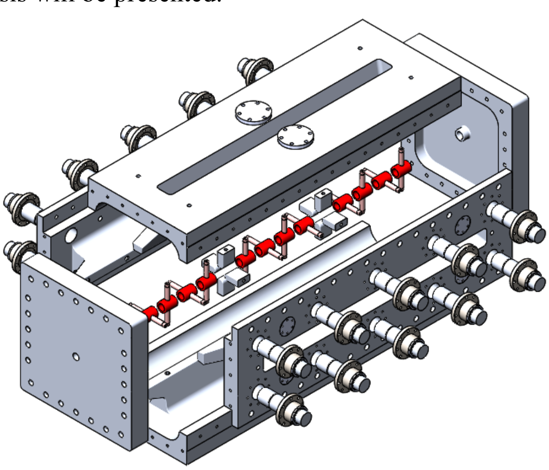

Figure 1: The overall mechanical model of Hybrid RFQ.

† email address: peiyanyu@impcas.ac.cn

RF MEASUREMENT

Measurement Instrument

According to the resonator perturbation theory, the cold test of Hybrid RFQ is conducted using the bead-pull measurement system. During the progress of the C-ADS project, a motion control and data acquisition system for bead-pull measurement has been fabricated [6]. The system including equipment is shown in Fig. 2. The computer controls the motor to drive the wire to move the bead through the cavity, and records the motion steps of the motor. The Vector Network Analyzer transports the frequency or phase signal to the computer.

Figure 2: Bead-pull measurement system.

Measurement of Frequency and Q Value

The frequency and Q value are measured at first after processing. The measured frequency is 326.72 MHz with each penetration depth of 20 tuners is 20 mm. It's 1.72 MHz higher than designed frequency, which is in the adjustable range of tuners. In consideration of the measured size of the parts of cavity, it shows that the main reason of this frequency deviation is the lack of constant temperature condition while processing. The ambient temperature is high when machining, while the measurement is conducted in low temperature. The shrinkage of size leads to the increase of frequency. Furthermore, this point needs verification by simulation. The measured unloaded Q value is 7198. Compared with the calculated value 9083, the measurement value reaches 79.2% of it. Considering there is no RF sealing in the aluminium cavity, this result is acceptable.

The RF measurement of Hybrid RFQ is performed to verify the accuracy of processing and assembly. It includes two parts, one is the measurement of the accelerating field of central axis, and the other is the measurement of the quadrupole field at the RFQ section. The measurement results are compared with the theoretical results which are simulated using CST software. The perturbation body is chosen as a plastic sphere bead with a diame-

29th Linear Accelerator Conf. LINAC2018, Beijing, China JACoW Publishing
ISBN: 978-3-95450-194-6 ISSN: 2226-0366 doi:10.18429/JACoW-LINAC2018-MOPO087

ter of 6 mm, and the largest frequency perturbation arisen by this bead is about 6 kHz.

Measurement of Field of Central Axis

Fig. 3 shows the measured Ez of central axis. In the graph, the electric field intensity is normalized for more intuitive, and the largest electric field intensity is normalized to 1. At the both ends of the cavity, the field intensity at the gap reaches 0.58 as designed. It can be seen that the measured result has nearly consistent tendency with the simulation except for the quadrupole section.

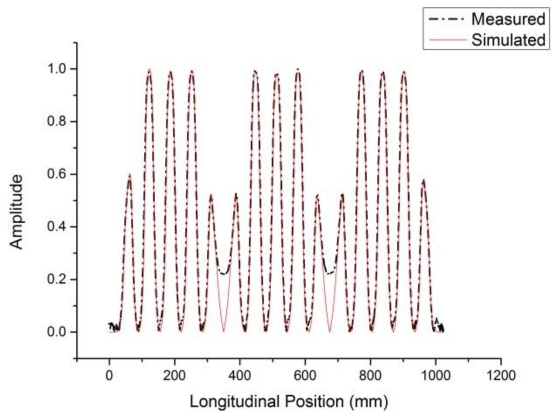

Figure 3: Ez distribution along Z direction.

According to the simulation, the electric field intensity at the longitudinal center of the quadrupole is 0, however it is measured to be 0.2. That is because the perturbation bead is 6 mm, not ideal as a particle. The electric field distribution along the angle bisector of quadrant at the longitudinal center of the RFQ section is presented in Fig.4. It can be seen the electric field intensity at center is 0, and it gets larger as the location is farther away from center. When the 6 mm bead goes through the RFQ section, the bead covers the area where high electric field distributes. Fig. 5 shows the peak value of each gap between drift tubes. The unevenness is below 1.3%.

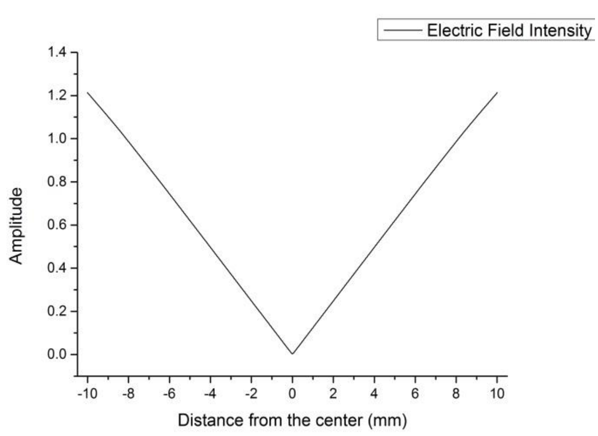

Figure 4: Electric field distribution along the angle bisector of quadrant at the RFQ section.

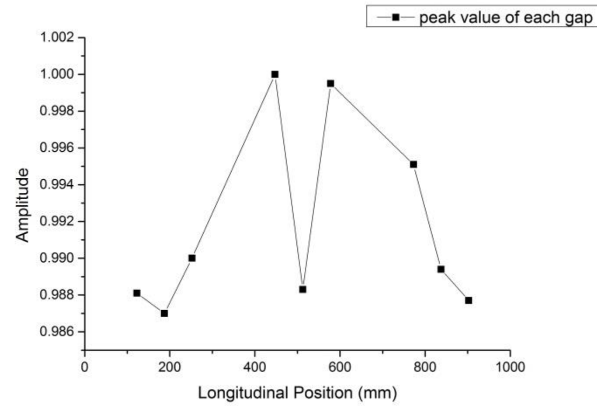

Figure 5: The peak value of 9 drift tube gaps.

Measurement of Quadrupole Field

The inner diameter of drift tube is 20 mm, so the location to measure quadrupole field is chosen as the point 5 mm away from the center along the angle bisector of quadrant. The results are shown in Fig. 6. The measurement is through the whole cavity, but the figure only shows the RFQ sections. The normalization method is the same as above. The field intensity of the longitudinal center of quadrupoles reaches 0.6 as designed. There are two sets of RFQ sections in this prototype. In the first set of quadrupole, the maximum deviation between four quadrants is 5.6%, while it's 6.9% in the second set of quadrupole. We think there are two main reasons caused this unsatisfactory result. One is the positioning accuracy is not high enough, another is the gravity affection of the bead.

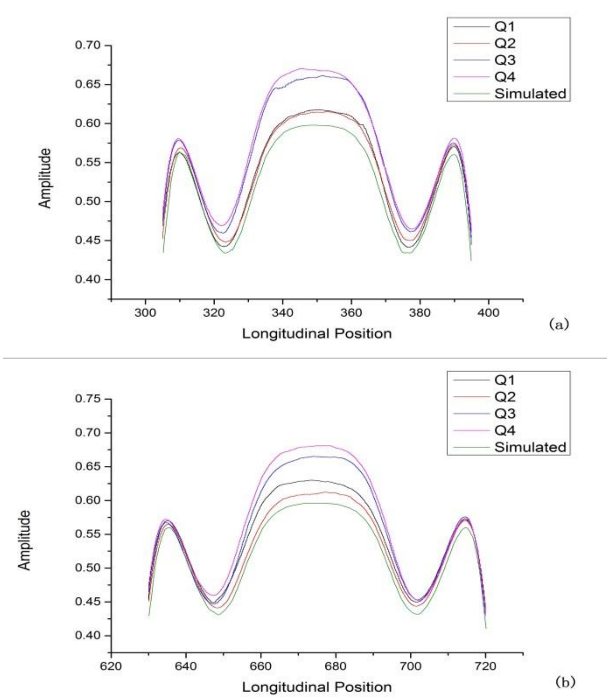

Figure 6: Quadrupole field distribution. (a) shows the first set of quadrupole. (b) shows the second set of quadrupole.

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CONCLUSION

The cold test of Hybrid RFQ prototype is performed. The frequency is 1.72 MHz higher than designed value. The reason needs to be analysed by simulation. Unloaded Q value reaches 79.2% of the calculated value. The filed distribution of accelerating field of central axis and the quadrupole filed are measured. The unevenness of accelerating field is below 1.3%. The deviation between four quadrants of first set of quadrupole is 5.6%, while that of second set of quadrupole is 6.9%.

There is still some problems need to be solved, like improving the positioning accuracy and diminishing the gravity affection of the bead. The tuning and further research on the RF parameters of Hybrid RFQ will be performed soon.

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