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THE DESIGN, CONSTRUCTION AND EXPERIMENTS OF A RFQ COLD MODEL AT TSINGHUA UNIVERSITY *

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Abstract

The design, construction and experiments of a cold model of one high-current CW RFQ with ramped inter-vane voltage at Tsinghua University are presented in this paper. The 1-meter-long aluminum cold model is chosen to be the same as the low-energy part of the 3-meter-long RFQ. This cold model will be used mainly for the RFQ field study and education.

INTRODUCTION

The beam dynamics and structure design of a ramped-voltage CW Radio Frequency Quadrupole (RFQ) accelerator for a National Natural Science Foundation of China (NSFC) Project at Tsinghua University had been finished one year ago [1]. The basic parameters of the RFQ are shown in Table 1.

Table 1: Basic Parameters of the RFQ

Parameters	Value	Unit
Particle	Proton	
Type	Four-vane	
Duty factor	CW	
Frequency	325	MHz
Input beam energy	50	keV
Output beam energy	3.0	MeV
Beam current	50	mA
Maximum surface field	32.12	MV/m
Length	2.86	m

Right after that, the cold model of this RFQ was designed and constructed. The design and construction of the cold model will be shown in this paper. The experiments of this cold model such as RF measurement and tuning of the field distribution is presented in detail in this paper.

DESIGN OF THE COLD MODEL

The length of the cold model was chosen to be exactly one meter (excluding the flanges), which is suitable for RF experiments in the laboratory room. The main structure of the cold model, including the cavity cross section and vane-tip geometry, is the same as the low-energy part of a 3-meter-long ramped-voltage CW RFQ accelerator for one NSFC Project at Tsinghua University. The undercuts and the dipole-mode stabilizer rods are redesigned using CST MWS because of the change of the cavity length. The cavity using for simulation in CST is shown in Fig. 1. The design methods of the undercuts and the dipole-mode stabilizer rods are described in detail in our previous papers [2] [3]. A trapezoid-shape-like undercut is adopted for the RFQ in consideration of its cooling convenience, as shown in Fig. 2. The final undercuts parameters are: at the low-energy end, H_1=H_2=40 mm; at the high-energy end, H_1=44 mm, H_2=29 mm. The diameter and length of the dipole-mode stabilizer rods are respectively 10 mm and 145 mm.

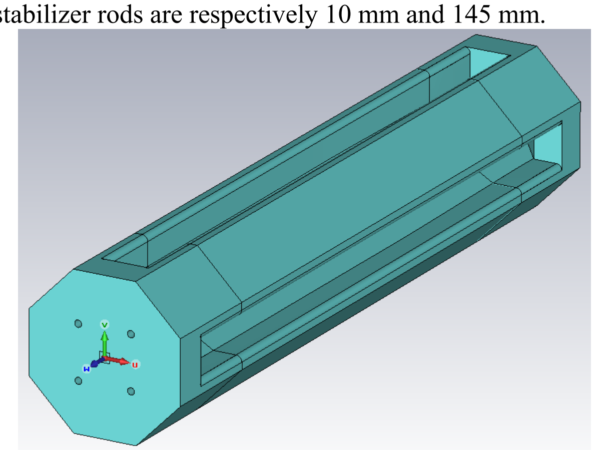

Figure 1: The RFQ cavity in CST MWS used for simulation.

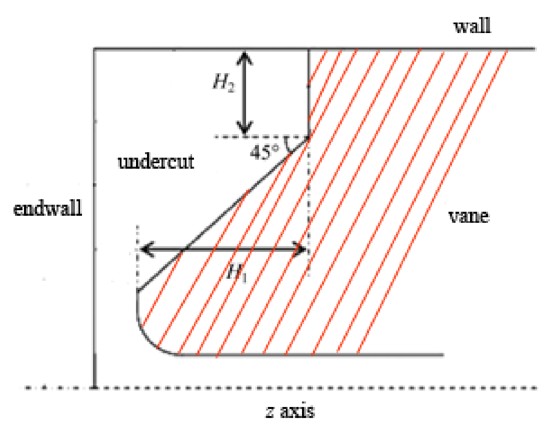

Figure 2: Undercuts schematic.

CONSTRUCTION OF THE COLD MODEL

The machining and assembly of the vanes were accomplished at Kelin Tech Co. Ltd in Shanghai.

To facilitate the machining, the whole RFQ cavity was separated into four segments: two horizontal vanes and two vertical vanes. The machining of the vanes was carried out in three steps: rough machining, semifinishing and fine machining. A CNC machine with a ball-end mill was used to machine the vane tip. A numerical three-coordinate measuring machine named CMM was used to

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verify the accuracy of the longitudinal and transverse curvature of the vane-tip after the fine machining of each vane.

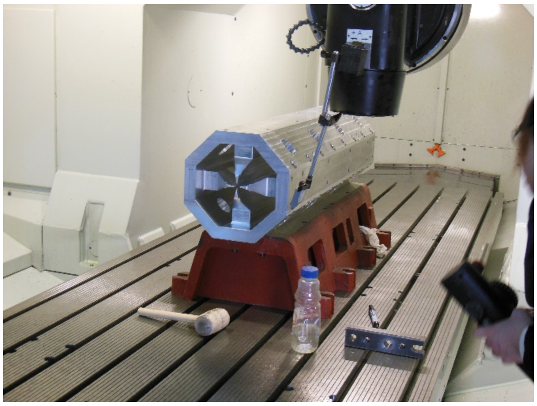

Figure 3: Assembly of the cold model.

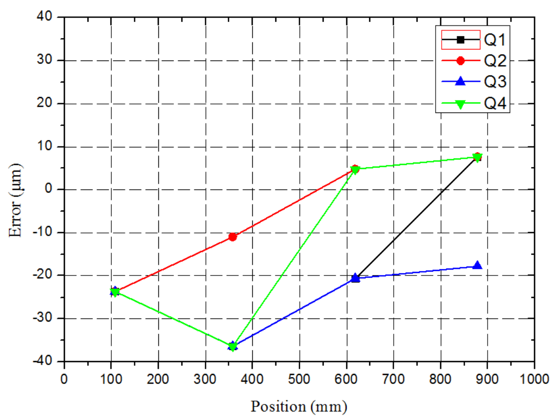

Figure 4: Measurement result of the vane-tip gaps at the longitudinal position of the tuners.

After fine machining and chemical cleaning, the four vanes were assembled together by threaded rods. Fig. 3 shows that the cold model is being assembled. The assembly is inspected by measuring the vane-tip gaps with pin gauges. Generally, all the vane-tip gap errors within ±50 μm comparing to the design value are required. Fig. 4 shows the vane-tip gap errors at the longitudinal position of the tuners in each quadrant after final assembly. All the errors of vane-tip gap are within ±37 μm.

FIELD MEASUREMENT AND CAVITY TUNING EXPERIMENTS

After assembly of vanes, flanges were mounted at both ends, and a total number of 16 tuners were inserted into the cavity (4 in each quadrant). Finally, an experiment platform was set up, as shown in Fig. 5, including the cold model, a network analyzer, a computer, a cavity thermometer, a depth gauge, a stepper motor and its driver, a pulley and a metal bead. The schematic of field distribution measurement system is shown in Fig. 6.

There are four objectives in the RFQ tuning: (1) make sure the frequency gap between the operating quadrupole mode and the nearest dipole mode large enough; (2) make sure the frequency of the operating quadrupole mode achieve the designed value; (3) make sure the relative error of the operating quadrupole mode between the measured distribution and the designed curve is smaller than 1%; (4) make sure the dipole component is below 1% of the operating quadrupole mode.

Figure 5: Experiment platform of the RFQ cold model.

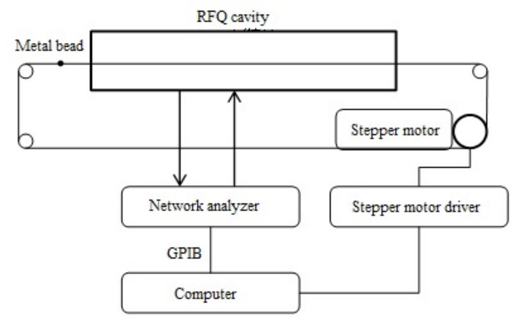

Figure 6: The schematic of field distribution measurement system.

Generally, the first goal is easy to achieve by adjusting the insertion length of the dipole-mode stabilizer rods, and the last three goals are achieve by adjusting the insertion depths of tuners [4]. The insertion depths of tuners are calculated by our program THURT [5], which is based on the perturbation theory and matrix operations. The interface of THURT is shown in Fig. 7.

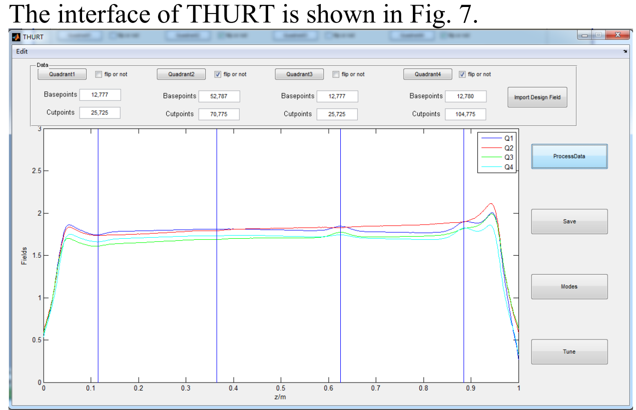

Figure 7: Interface of the program THURT.

To limit the measurement error caused by temperature variation, the experiments were carried out at late night in an air-conditioned room.

The experiments were carried out with two different initial conditions. In situation 1, the initial positions of all the tuners are flush with the cavity wall. In situation 2, all the tuners are initially with random insertion depth.

In situation 1, the initial magnetic field distribution near the outer wall was obtained by the bead-pull method, as

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shown in Fig. 8. The relative quadrupole error is 0.8% and the dipole component is 0.2%. The field distribution was good enough, so the cavity was tuned well after only one iteration tuning the frequency of the operating quadrupole mode to the designed value. The insertion depths of all the tuners are shown in Table 2, where the negative represents the corresponding tuner is concave in proportion to the interior wall of the RFQ.

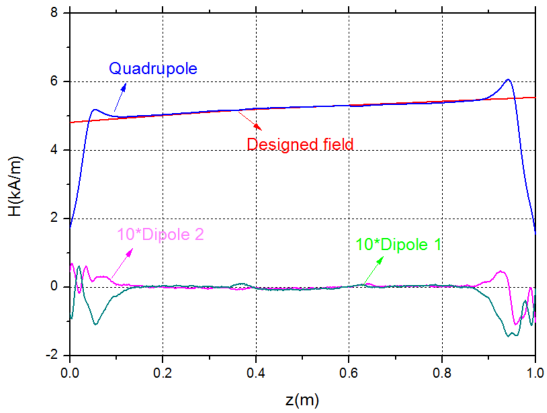

Figure 8: Field distribution before tuning in situation 1.

Table 2: The Insertion Depths of All the Tuners after Tuning From Situation 1

Depth/mm	Q1	Q2	Q3	Q4
Position 1	3.68	3.73	3.17	3.12
Position 2	0.84	0.87	1.83	1.84
Position 3	-0.36	-1.10	-2.02	-1.28
Position 4	2.33	2.95	3.44	2.81

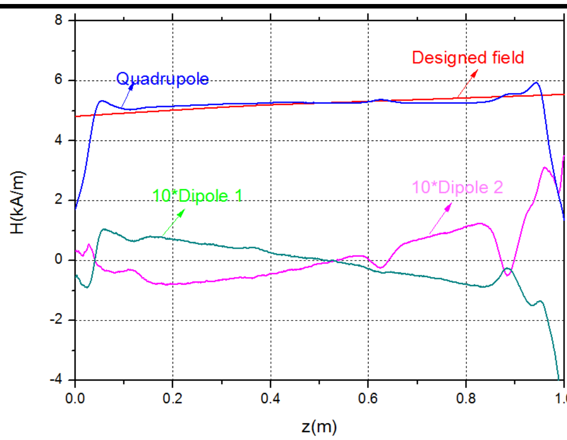

Figure 9: Field distribution before tuning in situation 2.

In situation 2, the magnetic field distribution is shown in Fig. 9. The relative quadrupole error is 3.2% and the dipole component is 4.0%. The cavity was tuned well after two iterations. The field distribution is shown in Fig. 10 and the insertion depths of all the tuners are shown in Table 3, where the negative represents the corresponding tuner is concave in proportion to the interior wall of the RFQ. The relative quadrupole error is 0.9% and the dipole component is 0.9%.

Combining Table 2 of situation 1 and Table 3 of situation 2, it can be seen that the tuning objectives can be achieved with different solutions of the insertion depths of the tuners.

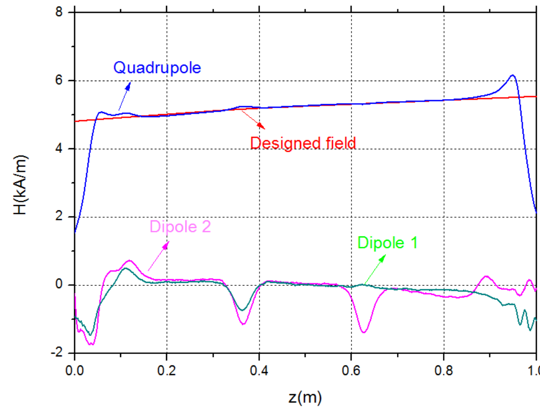

Figure 10: Field distribution after tuning in situation 2.

Table 3: The Insertion Depths of All the Tuners after Tuning From Situation 2

Depth/mm	Q1	Q2	Q3	Q4
Position 1	2.22	5.98	0.50	-0.26
Position 2	1.99	-2.71	1.12	5.82
Position 3	0.38	-4.91	0.70	-0.01
Position 4	2.67	1.48	4.83	3.03

CONCLUSSION

A cold model of a ramped-voltage CW RFQ have been designed and constructed at Tsinghua University. RF measurement and tuning have been accomplished and the results agree well with the design.

ACKNOWLEDGMENT

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