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FIELD TUNING OF THE 1 MeV/n RFQ AT KOMAC*

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Abstract

A 1 MeV/n radio-frequency quadrupole (RFQ) is under development at Korea Multi-purpose Accelerator Complex (KOMAC). The purposes are swift ion beam irradiation and compact neutron source. The RFQ was designed to accelerate ions with mass to charge ratio (A/q) up to 2.5. The designed peak current was 10 mA with 10% duty factor. The RFQ is four vane structure resonated at 200 MHz. It has total 40 sets of frequency tuners. There are no dipole rods and resonant coupling plate because the mode separation was large enough and the length of the RFQ was only two times of the wavelength. In this paper, the development status and field tuning results of the 1 MeV/n RFQ are presented.

INTRODUCTION

A Radio-frequency Quadrupole (RFQ) has been developed for several application fields at KOMAC. It was designed to accelerate various kinds of beams to 1 MeV/n with maximum charge to mass ratio (A/q) 2.5. The considered application fields are as follows. The first is to accelerate helium beam in order to irradiate the power semiconductor devices with the purpose of improving switching performance. The second is to accelerate the heavy ion beam in order to create micro-pore of the sample of which purpose is to produce filter system with nanoscale pore. The third is to accelerate deuteron beam to produce the neutrons with beryllium target [1, 2].

The system layout is shown in Fig. 1. There are two ion sources. One is the microwave ion source which will be used for the proton, deuteron, and helium ions. The other is an Electron Beam Ion Source (EBIS) for highly ionized heavy ions such as argon. There are also two beam lines in the system. One is an irradiation beam line which covers semiconductor irradiation and micro-pore production which has 30 degree bending angle with respect to RFQ. The other is a neutron production beam line. An ion beam injector based on microwave ion source, RF system and beam lines have been prepared. The field tuning of the RFQ is underway [2].

SYSTEM STATUS

Ion Source

Two kinds of ion source were considered. One is a microwave ion source for proton, deuteron and helium beam, the other is an electron beam ion source (EBIS) for highly charged heavy ion beam as shown in Fig. 1. A microwave ion source was installed to commission the system at first stage. It is the same type ion source with the one used for the KOMAC 100 MeV proton linac. It uses a 2.45 GHz magnetron as a microwave source. The magnetron is insulated from the high voltage section through the isolation waveguide. And the solenoid magnet is also insulated by the insulator. Therefore, there are no power supplies operated at high voltage potential, which greatly reduces the mal-function of the system caused by the high voltage arc [3].

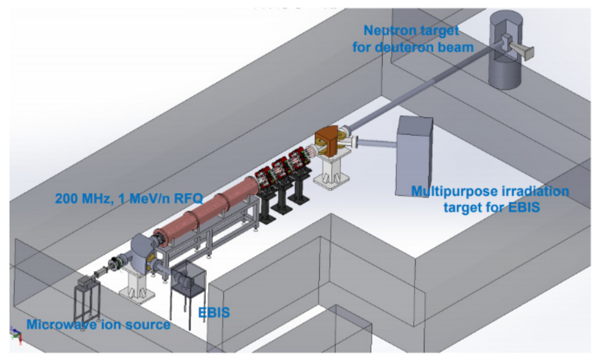

Figure 1: Layout of the 1 MeV/n RFQ system.

The plasma properties such as a plasma density depending on the microwave power and solenoid current were measured to investigate the ion source characteristics. In addition, the beam properties were measured such as the beam profile and emittance. The beam profile was measured by fluorescent plate and the beam emittance was measured by solenoid scan. The measured normalized rms emittance was 0.26 π mm mrad for 50 keV proton beam. The measurement result of the solenoid scan is shown in Fig. 2 [4].

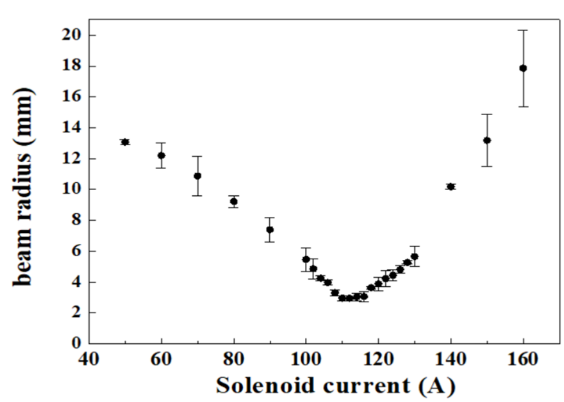

Figure 2: Solenoid scan results.

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RF System

The high power RF system is based on the solid state amplifier. The saturation power is 240 kW with 10% duty factor and consists of 16 sets of 15 kW RF power module. The system was prepared and the high power test up to maximum power was done with all high power transmission components such as a circulator, full power dummy load and directional couplers. The low level RF system was also developed. It used non-IQ sampling and iterative learning algorithm. The system was tested at the test bench and showed rms stability in amplitude was less than 0.02% as shown in Fig. 3 [5].

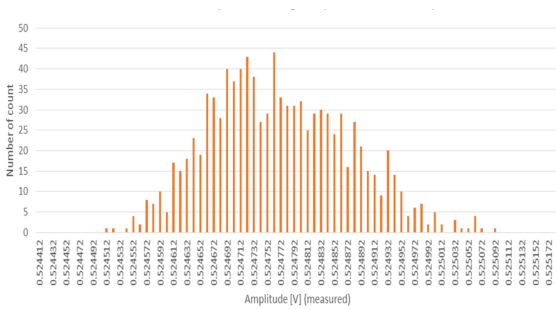

Figure 3: RF test of amplitude control.

RFQ FIELD TUNING

The design parameters of the RFQ is summarized in Table 1. The total length is 3.2 m long and it consists of 3 sections. It was machined and brazed successfully. The installed RFQ is shown in Fig. 4.

Table 1: RFQ Design Parameters

Particle	$^4He^{2+}$
Input beam energy	100 keV
Output beam current	4 MeV
Peak beam current	10 mA
Emittance (nor. rms)	0.2 π mm mrad
Type	Four vane
RF frequency	200 MHz
RF power	130 kW
Maximum electric field	1.63 Kilpatrick
ρ/r_0	0.87
Length	320 cm
Transmission	96.4%

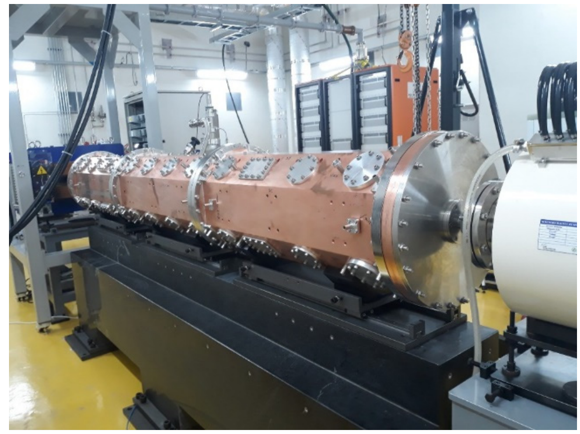

Figure 4: Installed RFQ.

The frequency spectrum was measured and the result is summarized in Table 2. As shown in the Table 2, the mode separation between quadrupole and nearest dipole mode is more than 4 MHz, which is good agreement with the simulation results.

Table 2: Measured Spectrum

D010	195.439 MHz
	195.506 MHz
Q011	199.996 MHz
D011	204.040 MHz
	204.100 MHz

For field measurement, an aluminium hollow ball was used. The diameter of the ball was 12.7 mm. The measurement position was 30 mm away from the center of the RFQ. The measured quadrupole profile is shown in Fig. 5. The field uniformity was less than 3% without any tuner adjustment. The measured dipole profile is shown in Fig. 6. The field uniformity of D13 was higher than 10%. Therefore, it was decided to focus on the adjustment of dipole field during tuning process.

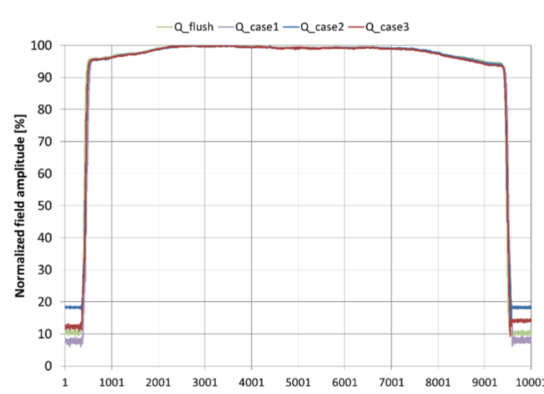

Figure 5: Quadrupole field profile (flush: all tuners are design position, case1: first iteration, case2: second iteration, case3: third iteration).

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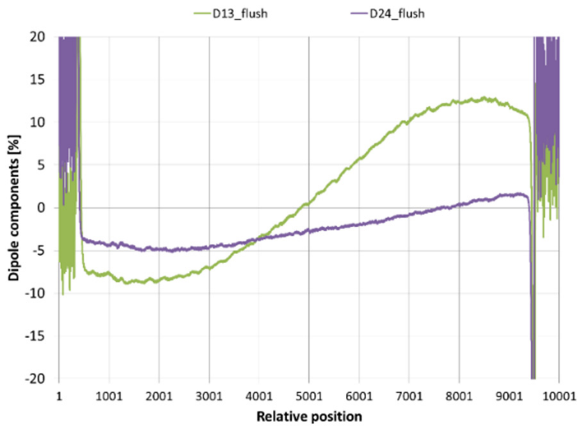

Figure 6: Dipole field profile (flush: all tuners are design position).

The tuner position during tuning was summarized in Table 3. The dipole field was less than 5% with 3 iterations. The final field uniformity of the quadrupole was 2.7% and dipole fields were 3.2% and 3.0% respectively as shown in Fig. 7 [6].

Table 3: Tuner Position (tuner designation: S1-9 means 1 is quadrant number, 9 is the longitudinal position number).

Designation	Tuner position
Flush	28.3 mm (All tuners)
Case1	23.3 mm (S1-9)
	33.3 mm (S3-9)
Case2	33.3 mm (S1-2)
	23.3 mm (S3-2)
	23.3 mm (S1-9)
	33.3 mm (S3-9)
Case3	38.3 mm (S1-2)
	18.3 mm (S3-2)
	18.3 mm (S1-9)
	38.3 mm (S3-9)

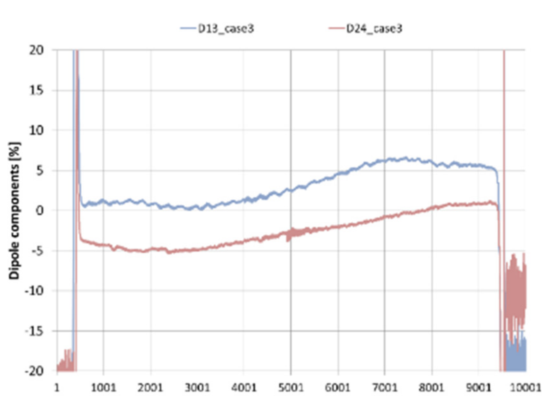

Figure 7: Dipole field profile after 3rd iteration.

CONCLUSION

A 1 MeV/n RFQ has been developed at KOMAC. The microwave ion source and RF system have been installed and under test. The RFQ was also installed and under field tuning. The spectrum measurement showed enough mode separation more than 4 MHz. The field uniformity of the quadrupole mode was less than 3% when all the tuners were the same position, but the dipole field uniformity was higher than 10%. After 3rd iteration, the uniformity of the dipole mode could be reduced to 3% keeping the uniformity of the quadrupole mode unchanged.

The high power test of the RFQ is planned in July and the beam commissioning is planned in September in 2021.

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