Model Test of a Resonator for Flat-Top Acceleration System in the RIKEN AVF Cyclotron

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Abstract

A full-scale model of the flat-top resonator in the RIKEN AVF Cyclotron was fabricated and was coupled to the existing main resonator in order to generate the flat-top accelerating voltage on the dee. The flat-top accelerating voltage is generated by a superimposition of the fundamental-frequency and 5th-harmonic-frequency voltages. The fundamental-frequency range is from 12 to 23 MHz. Because the 5th-harmonic-frequency is used, the frequency range is required to be from 60 to 115 MHz. In the cold model test, the flat-top accelerating voltage was generated in the whole frequency range. Result of the cold model test performed with the flat-top acceleration system is described in this report.

1 Introduction

The RIKEN Ring Cyclotron (RRC) can accelerate various kinds of ions ranging from proton to uranium in a wide energy region [1]. One of the two injectors of the RRC is the AVF Cyclotron, which is used for ions mainly from proton to light heavy ions like Argon [2]. The rf system of the AVF Cyclotron has been working well after its completion in March 1989 [3]. The flat-top acceleration system in the AVF Cyclotron has been planed to obtain better quality beam.

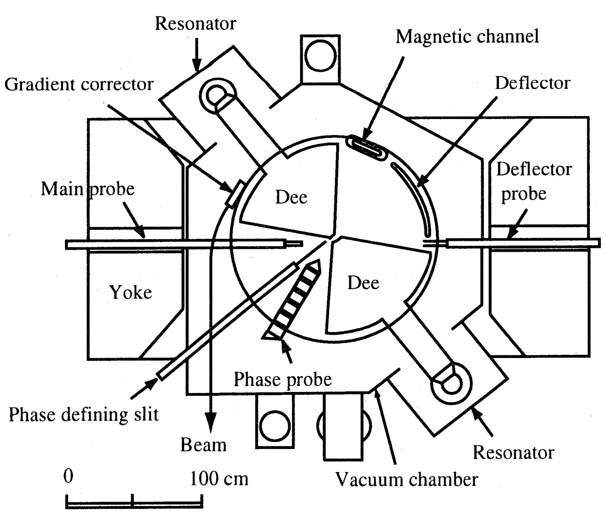

Fig. 1 Layout of the AVF Cyclotron.

A layout of the AVF Cyclotron is shown in Fig. 1. The injection and the extraction radii are 1.64 cm and 71.4 cm, respectively. The initial phase of the beam is made less than $\pm 10^\circ$ with a phase defining slit. The AVF Cyclotron has two resonators, each of which is the coaxial quarter-wave-length type with a dee angle of 83°. The frequency range is from 12 to 23 MHz. The required maximum accelerating voltage of each resonator is 50 kV. A grounded-cathode tetrode amplifier is capacitively coupled to each resonator with a fixed vacuum coupling capacitor. Its maximum output power is 20 kW.

2 Structure of the resonator

The cross-sectional views of the main resonator and flat-top resonator are shown in Fig. 2 [4]. The flat-top resonator shown inside the square of dashed line is designed to be a coaxial resonator with a movable shorting plate, and is coupled with the main resonator shown in the left hand

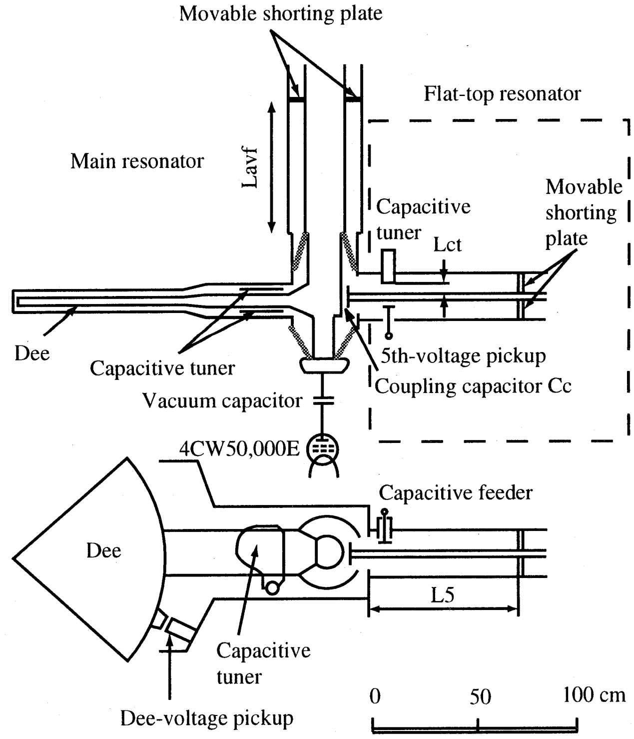

Fig. 2 Cross-sectional view of the resonator of flat-top acceleration system for the RIKEN AVF Cyclotron.

side of Fig. 2 via the coupling capacitor (Cc). The flat-top resonator is used to generate the 5th-harmonic-frequency voltage. The fundamental-frequency voltage is generated by the main resonator. A photograph of the flat-top resonator prototype installed on the existing main resonator is shown in Fig. 3.

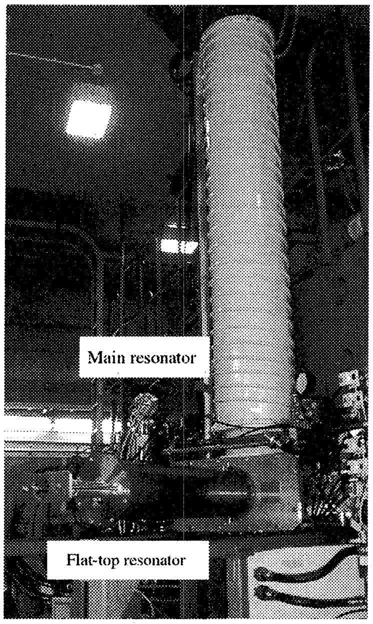

Fig. 3 Photograph of the model flat-top resonator installed on the existing main resonator.

3 Cold model test

In the cold model test, the resonance of 5th-harmonic voltage was measured to see if the required frequency range can be achieved. In the measurement, both the coupling capacitor (Cc) and the movable shorting plate of flat-top resonator (L5) were adjusted after the movable shorting plate of main resonator (Lavf) was set for the fundamental frequency. In this case, the 5th-harmonic-frequency signal was fed into the flat-top resonator through the voltage pick-up of 5th-harmonic frequency and was monitored by the dee-voltage pickup. It was found that the 5th-harmonic-resonant frequency was successfully generated on the dee in the whole required frequency-range along with the fundamental-resonant frequency. The measured positions of the movable shorting plates of the flat-top and main resonators are shown in Fig. 4 as a function of the 5th-harmonic-resonant frequency. This result gives the specifications of flat-top resonator, which proves achievement of the required frequency range. The moving distance of shorting plate and the length of resonator should be at least 57 cm and 66 cm, respectively, when the coupling capacitance (Cc) is set to be 16 pF. The measured resonance was found to be very close to the frequency 5 times as large as the fundamental frequency.

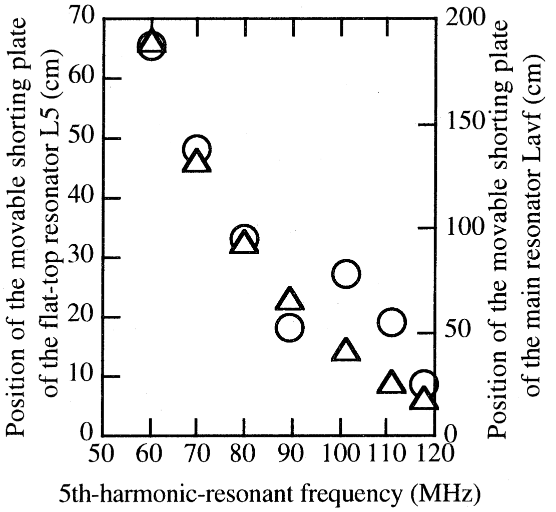

Fig. 4 Position of the movable shorting plates of the flat-top and main resonators as a function of the 5th-harmonic resonant frequency. The capacitance of the coupling capacitor (Cc) was 16 pF. Circles represent the position of the shorting plate of the flat-top resonator. Triangles represent the position of the shorting plate of the main resonator.

The measured Q-values of the fundamental and 5th-harmonic modes as a function of the resonant frequency are shown in Fig. 5 (a) and (b), respectively. The measured Q-value (Q1) of the fundamental mode was found to vary from 1500 to 2400, while the measured Q-value (Q5) of the 5th-harmonic mode was from 300 to 740. Frequency shift measured as a function of position of the capacitive tuner of flat-top resonator is shown in Fig. 6. The shape of the capacitive tuner is like a cylinder and its size is 60 mm in diameter. Frequency coverage of the capacitive tuner is wide enough to compensate a frequency shift due to heat in normal operation.

In the cold model test, the flat-top accelerating voltage was generated by feeding low-level signals of the fundamental and 5th-harmonic frequencies at the same time. In this case, the fundamental-frequency signal was fed into the resonator through the vacuum capacitor, while the 5th-harmonic-frequency signal was fed into the resonator through the capacitive feeder of flat-top resonator. The flat-top accelerating voltage generated on the dee was measured by the dee-voltage pickup. The amplitude and phase of the 5th-harmonic-frequency signal were adjusted to obtain the flat-top voltage on the dee after those of the fundamental-frequency signal were fixed. It was found that the flat-top voltage can be generated in the whole frequency range. The typical wave form of the flat-top voltage is shown in Fig. 7.

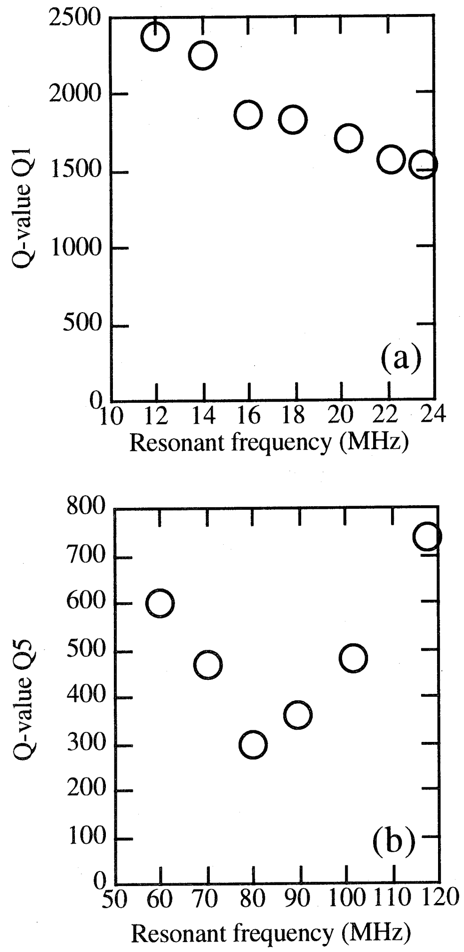

Fig. 5 (a) Q-value of the fundamental mode as a function of the resonant frequency. (b) Q-value of the 5th-harmonic mode as a function of the resonant frequency.

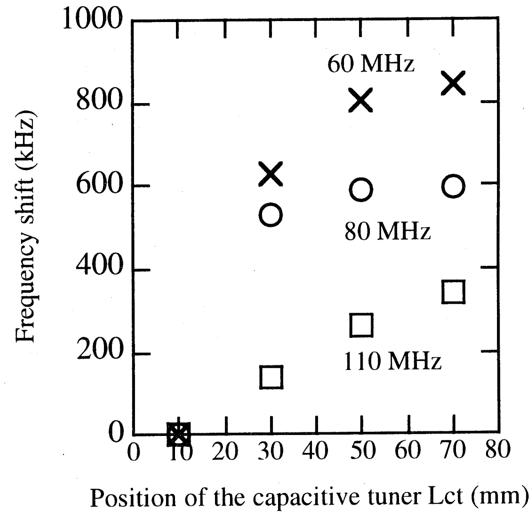

Fig. 6 Frequency shift of the capacitive tuner of flat-top resonator.

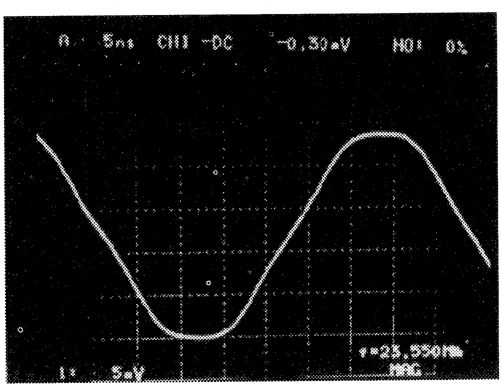

Fig. 7 Typical wave form of the flat-top voltage measured by the dee-voltage pickup. The fundamental frequency was 23.55 MHz and the 5th-harmonic frequency was 117.75 MHz. Horizontal time scale:5ns/div., Vertical voltage scale:5mV/div.

4 Conclusion

We performed the cold model test of the flat-top acceleration system of the AVF Cyclotron. As the result, it was found that the flat-top voltage can be generated on the dee in the whole frequency range. The moving distance of shorting plate and the length of resonator should be at least 57 cm and 66 cm, respectively, when the coupling capacitance (Cc) is set to be 16 pF. The measured resonance was found to be very close to the frequency 5 times as large as the fundamental frequency. Design of the real resonator is under progress.

References

[1] Y. Yano, "Status report on RIKEN Ring Cyclotron", Proc. 12th Int. Conf. on Cyclotrons and their Applications, Berlin, Germany (1989) 13

[2] A. Goto et al., "Injector AVF cyclotron at RIKEN", Proc. 12th Int. Conf. on Cyclotrons and their Applications, Berlin, Germany (1989) 51

[3] S. Kohara et al., RIKEN Accel. Prog. Rep., 23, (1989) 110

[4] S. Kohara et al., RIKEN Accel. Prog. Rep. 32 (1999) 186