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

Shigeo KOHARA, Yoshitoshi MIYAZAWA, Osamu KAMIGAITO, and Akira GOTO

The Institute of Physical and Chemical Research (RIKEN)

Wako-shi, Saitama 351-01, Japan

Abstract

A resonator for a flat-top acceleration system in the RIKEN AVF cyclotron is designed to improve the extraction efficiency and the energy spread of a beam. In order to generate the flat-top accelerating voltage on the dee, an additional resonator or a transmission line is capacitively coupled to the AVF resonator with a coupling capacitor. The flat-top accelerating voltage is obtained by the superimposition of the fundamental frequency and the fifth-harmonic-frequency voltages. Length of the additional resonator is 90 cm and capacitance of the coupling capacitor 30 pF. The frequency range of the AVF resonator is from 12 to 23 MHz. Structure and rf characteristics of the resonator designed for the flat-top acceleration system is described.

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 Ar[2]. The rf system of the AVF cyclotron has been working well after its completion in March 1989[3].

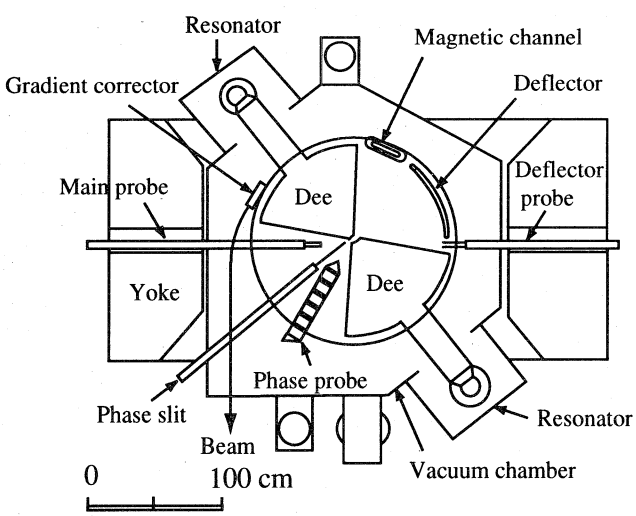

Fig. 1. Layout of the AVF cyclotron.

A layout of the AVF cyclotron is shown in Fig. 1. The AVF cyclotron has two resonators, each being of 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 is 50 kV. In general, the amplitude of the fifth-harmonic-frequency voltage required is about 1/25 of the fundamental-frequency voltage. Therefore, the frequency range and maximum voltage of the fifth-harmonic-frequency system are estimated to be from 60 to 115 MHz and 2 kV, respectively, when the voltage distribution is flat. A movable shorting plate has been used for the coarse tuning and a capacitive tuner for automatic fine tuning in the AVF resonator. The stroke of the movable shorting plate is 2 m. The frequency-shift range of the capacitive tuner is about 500 kHz. A grounded-cathode tetrode (4CW50,000E) amplifier is capacitively coupled to the AVF resonator with a fixed vacuum coupling capacitor (16 pF). Its maximum output power is 20 kW.

2 Structure and rf characteristics

A cross-sectional view of the resonator designed for the flat-top acceleration system is shown in Fig. 2. It consists of AVF and additional resonators to generate the flat-top accelerating voltage on the dee[4]. The additional resonator is employed to excite a higher harmonic resonance in the AVF resonator with the frequency five times of the fundamental frequency without shift of the fundamental frequency. The additional resonator consists of a transmission line and a coupling capacitor (Cc). The fifth-harmonic resonant frequency is determined by adjusting both the position of the movable shorting plate (L5) and the coupling capacitance of the additional resonator after the fundamental frequency of the AVF resonator is set by the movable shorting plate (Lavf).

The rf characteristics of the resonator was calculated with the transmission-line approximation. Figure 3 shows the positions of the movable shorting plates of the additional and AVF resonators to obtain the fifth-harmonic resonant frequencies. The most upper position of the movable shorting plate of the additional resonator is 50 cm when the coupling capacitance is 30 pF. Shunt impedances calculated as a function of the fifth-harmonic resonant frequency are shown in Fig. 4. The ratio of the voltage at the

extraction position to that of the injection position of the AVF cyclotron is from 0.85 at 60 MHz to 0.49 at 115 MHz.

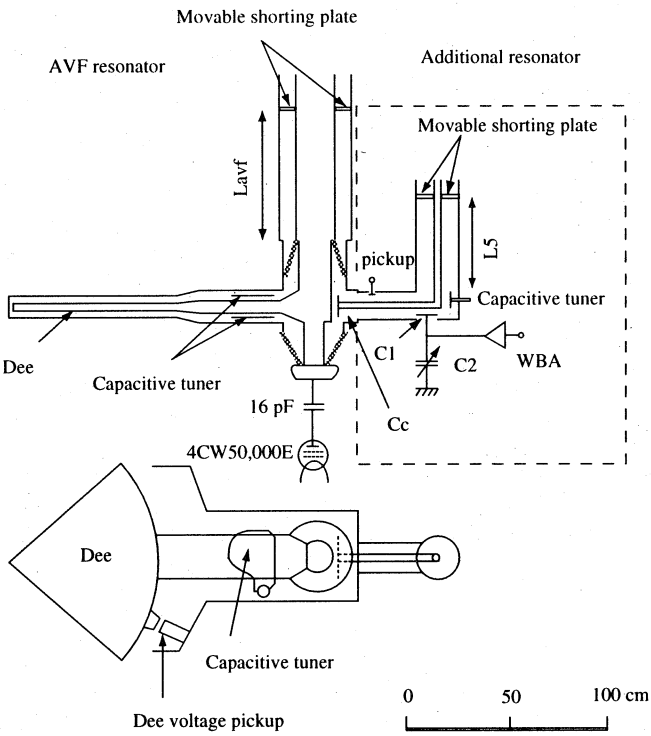

Fig. 2. Cross-sectional view of the resonator for the flat-top acceleration system.

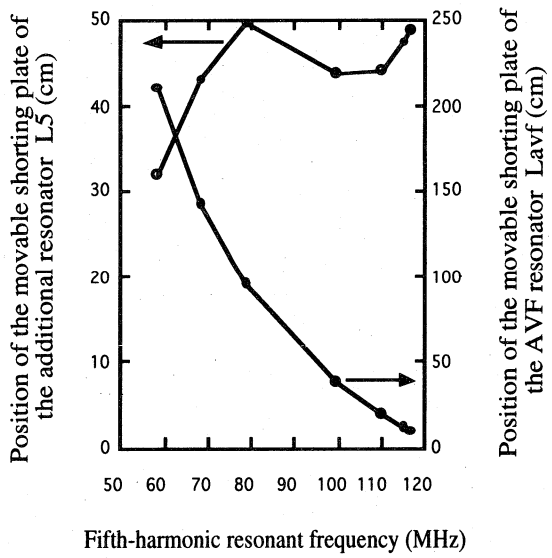

Fig. 3. Position of the movable shorting plates of the additional and AVF resonators calculated as a function of the fifth-harmonic resonant frequency. The coupling capacitance (Cc) is 30 pF.

Therefore, the required fifth-harmonic-frequency voltage at 115 MHz is estimated to be 1/17 of the fundamental-frequency voltage; its maximum voltage is to be 3 kV. Power losses are estimated to be 2,900 W at 58.5 MHz, 560 W at 80 MHz, and 690 W at 115 MHz when the voltage is 3 kV.

Each movable shorting plate is used for coarse tuning and each capacitive tuner for fine tuning. Frequency shift calculated as a function of capacitance of the capacitive tuner of the additional resonator is shown in Fig. 5.

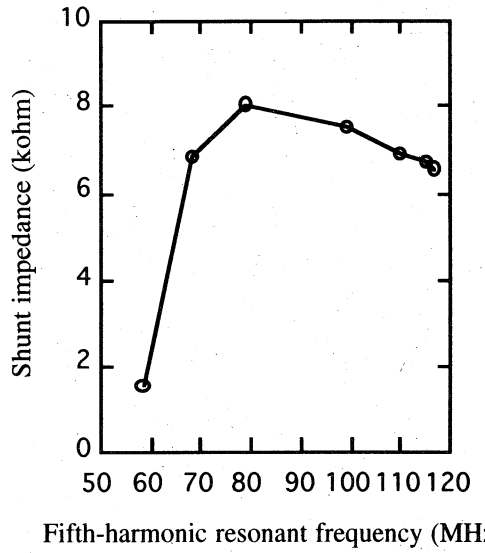

Fig. 4. Shunt impedance calculated as a function of the fifth-harmonic resonant frequency. The coupling capacitance (Cc) is 30 pF.

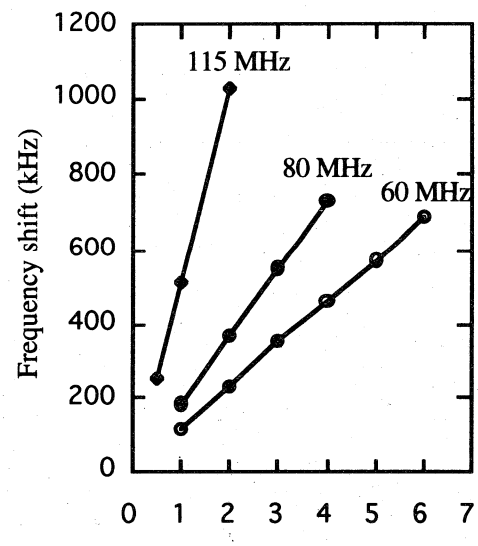

Fig. 5. Frequency shift calculated as a function of the capacitance of the capacitive tuner of the additional resonator.

3 Power feeding

A power amplifier for the fifth-harmonic frequency will be a solid-state wide-band amplifier (WBA), whose output impedance is 50 Ω. A capacitive divider is used to match the input impedance of the additional resonator to the output impedance of the wide-band amplifier. The capacitive divider consists of a coupling capacitor (C1) and a variable capacitor (C2). To get a good impedance matching, the capacitance of the variable capacitor is estimated to be from 90 to 120 pF when the coupling capacitance is 3 pF.

4 Conclusion

Voltage of the fifth-harmonic frequency was obtained on the dee without shift of the fundamental frequency, when capacitively coupling an additional resonator to the AVF resonator with a coupling capacitor. Therefore, a flat-top accelerating voltage can be generated on the dee by feeding rf powers synchronously to the respective resonators with fundamental-frequency and fifth-harmonic-frequency amplifiers. The required frequency range was found to be covered with a fixed coupling capacitor of 30 pF.

References

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