

Design of the RIKEN-SRC RF System

Naruhiko SAKAMOTO, Osamu KAMIGAITO, Akira GOTO, Yoshitoshi MIYAZAWA, Toshiya Chiba, Hiroki Okuno, Toshinori Mitsumoto, Yasushige YANO

RIKEN, 2-1, Hirosawa, Wako-shi, Saitama 351-01, Japan

Abstract

The acceleration and flat-top resonators for the RIKEN Superconducting Ring Cyclotron (SRC)[1] are required to work in a wide frequency range with a high acceleration voltage. To satisfy the requirement, a design study has been made by using a three dimensional rf calculation code MAFIA[2] as reported in ref [3]. Recently, since a rearrangement of the injection and extraction devices was made[4], the configurations of the resonators has been reconsidered.

1 Introduction

For the RIKEN RI-Beam factory (RIBF) [5] the new booster ring cyclotrons, intermediate-stage ring cyclotron (IRC) and superconducting ring cyclotron, are planned to be constructed to boost the energy of heavy ion beams from the RIKEN ring cyclotron (RRC) to the intermediate energy region of 60~400 MeV/u with a beam intensity of $1 \text{ p}\mu\text{A}^1$.

The SRC requires acceleration resonators having a wide frequency range from 18 to 38.2 MHz to suit the condition of the RRC operation.

The maximum magnetic field of the SRC sector magnet is as large as 4.2 T. Due to the strong magnetic field a high acceleration voltage is also required to obtain a large turn separation. A large turn separation around the extraction is crucial to reduce the beam losses at the extraction devices. For example, in the case of the $^{16}\text{O}^{7+}$ ion acceleration up to the maximum energy of 400 MeV/u at the rf frequency of 38.2 MHz with a harmonic number $h=6$, an acceleration voltage of 2.4 MV/turn is needed to obtain a turn separation larger than 4 mm at the extraction orbit.

A flat-top system is also helpful to reduce the beam losses at the extraction because the energy spread of the accelerated beam can be reduced by a flat-top acceleration. The phase acceptance $\Delta\phi$, which is defined by $|V(\Delta\phi)|/V(\phi=0) \leq 10^{-4}$, for the nonflat-top acceleration and flat-top acceleration are $\pm 0.81^\circ$ and $\pm 7.3^\circ$, respectively.

In order to realize a large turn separation,

- Four acceleration resonators which are single-gap type are employed.
- The peak voltage of the resonators is set to be 600 kVp/gap.
- A flat-top system is employed.

The key parameters of the present design of the resonators are listed in Table 1. Since the location of the

Table 1
Key parameters of the acceleration and the flat-top resonator for the SRC

resonators	accel.	flat-top
No. of units	4	1
Frequency [MHz]	18 ~ 38.2	85.97 ~ 114.6
Acc. gap [mm]	single gap	
Aperture [mm×mm]	250	120
Coarse tuner	60 ^H	60 ^H
Tuner stroke	$\times 2240^W$	$\times 1975^W$
Trimmer	flapping panel	shorting plate
Feeder	0° ~ 90°	500~1100 mm
Max. V _p [MV/gap]	block tuner	-
Voltage stability	inductive loop	
Phase stability	0.6	0.36
Max. Power [kw]	10^{-4}	10^{-3}
Q-values	$\pm 0.1^\circ$	$\pm 0.3^\circ$
	81	43
	37000	25000

flat-top resonator has been moved from the center region of the valley chamber to the next to the acceleration resonator (see Fig. 1), a new design of the flat-top resonator has been introduced. The dimension of the accelerator resonator also has been rearranged.

For the flat-top system the third, fourth, and fifth harmonics are used. It is helpful for the mechanical design of the flat-top resonator because the frequency range becomes narrower. The frequency range of the new flat-top resonator is 85.97~114.6 MHz instead of 54.0~114.6 which is for the third harmonic system. The phase acceptances of the fourth and the fifth harmonic fat-top system are large enough (Fig. 4) to accept the beam from the RRC.

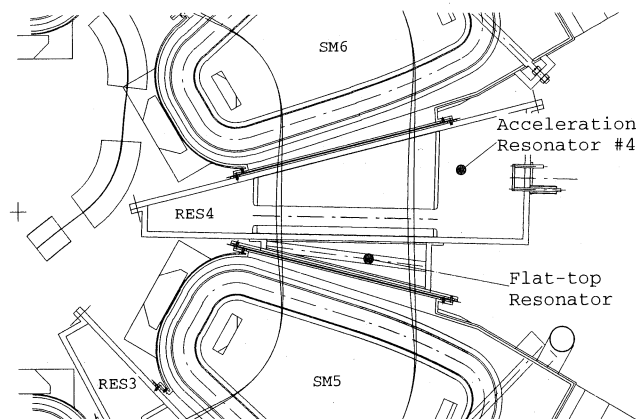


Fig. 1 Top view of the acceleration resonator No.4 and the flat-top resonator.

¹particle micro ampere

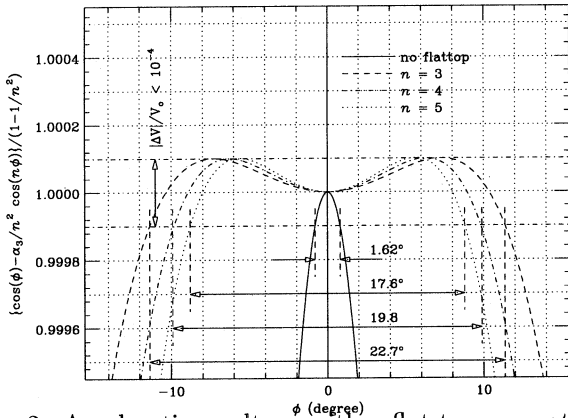


Fig. 2 Acceleration voltage with a flat-top resonator. $\Delta\phi \equiv |V(\Delta\phi)|/V(\phi = 0) \leq 10^{-4}$

2 Acceleration resonator

The acceleration resonator is a single-gap type whose structure is basically same as that of the RCNP Ring Cyclotron(RCNP-RC)[6]. The single-gap type resonator is suitable for the narrow valley section of the 6-sector ring cyclotron because its size is compact compared with the double-gap type resonator.

The rf characteristics of the acceleration resonator are obtained at the flapping panel positions of 0° and 90° by using MAFIA as shown in Table 2. Since the Q-value and the shunt-impedance of the real resonator is expected to be 60~70 % [7] of the theoretical values, the maximum wall loss of the real resonator is estimated to be 115~135 kW.

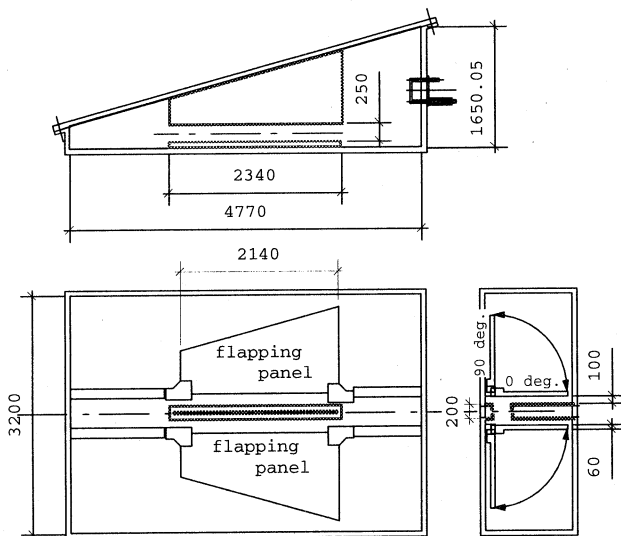


Fig. 3 Schematic drawing of the acceleration resonator. Resonances with the lowest and highest resonant frequencies are obtained when the flapping panel is horizontal(0°) and vertical(90°), respectively.

Table 2

The calculated rf characteristics of the acceleration resonator by using MAFIA.

Flapping Panel	0 deg.	90 deg.
Frequency [MHz]	17.474	38.607
Q-value	28200	36649
Rs [MΩ]	0.63	2.23
Vp [kV]	250	600
P _{w.l.} [kW]	50	81

3 Flat-top resonator

The new design of the flat-top resonator for the SRC is shown in Fig. 4. The resonant frequency tuning is made by moving the shorting plates which are placed symmetrically with the median plane. By utilizing the multi-harmonic numbers of 3, 4, and 5, the required frequency range becomes 85.97~114.6 MHz. As shown in Fig. 5 the frequency range is successfully covered by moving the shorting-plate from 500 to 100 mm with large Q-values. The maximum wall loss is estimated to be 85 kW if the Q-value of the real resonator was 50 % of the theoretical value.

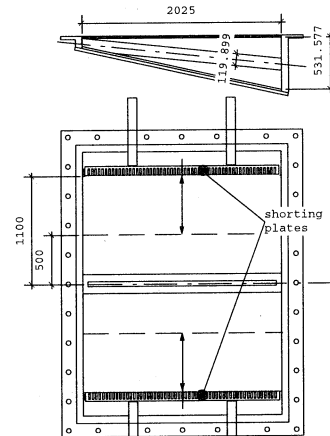


Fig. 4 Schematic drawing of the flat-top resonator.

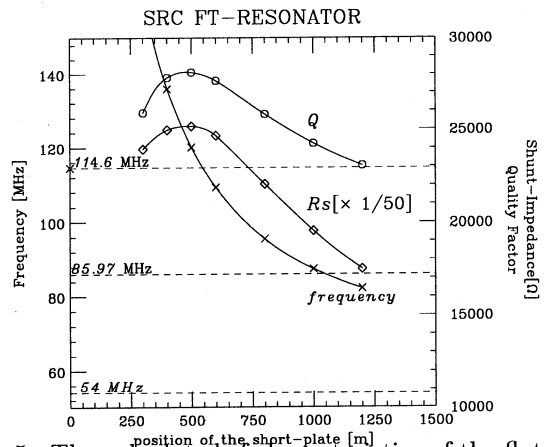


Fig. 5 The calculated rf characteristics of the flat-top resonator by using MAFIA.

4 Amplifiers and Transmission lines

The main parameters of the rf amplifiers are listed in Table 3. The design of the final stage amplifier for the acceleration resonator is the same as that of the RRC. Since the transmitter tubes do not work in the strong magnetic field, the amplifiers are planned to be placed where the leakage field of the SRC sector magnets becomes smaller than 50 Gauss. The length of the power transmission lines is estimated to be 50 m.

Table 3
Characteristics of the RF amplifier

		acceleration	flat-top
Frequency	[MHz]	18.0 ~ 38.2	85.97 ~ 114.6
1st stage	[kW]	1	1
2nd stage		RS2012CJ	-
power	[kW]	15	5
Final stage		RS2042SK	RS2058CJ
power	[kW]	300	100
Trans. line		WX152D/50Ω	

5 Summary

A design study of the SRC rf system has been made. According to the rearrangement of the SRC, new designs of the acceleration and the flat-top resonators are

obtained. Further investigation on the feasibility of the resonator design will be made.

Acknowledgement

The authors are grateful to Mr. Y. Kumata for useful discussion on the design of the resonator and the amplifiers.

References

- [1] A. Goto et al., "Construction of the RIKEN Superconducting Ring Cyclotron", in this paper.
- [2] The MAFIA collaboration, User's Guide MAFIA Version 4.0, CST GmbH, Lauteschägerstraße 38, D-64289, Darmstadt, Germany.
- [3] N. Sakamoto et al., Proc. 15th Int. Conf on Cyclotrons and Their Applications, (Caen 1998), p 223.
- [4] H. Okuno et al., "Design study of the Injection and Extraction Systems of the RIKEN Superconducting Ring Cyclotron", in this paper.
- [5] Y. Yano et al., Proc. of 1997 Partl. Accel. Conf., p.930.
- [6] T. Saito et al., Proc. 12th Int. Conf. on Cyclotrons and Their Applications (Berlin 1989), p. 201.
- [7] N. Sakamoto et al., "Model Test of the RIKEN-IRC Main Resonator", in this paper.