CONSTRUCTION OF THE RF-RESONATORS FOR THE RIKEN SUPERCONDUCTING RING CYCLOTRON

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Abstract

Frequency tunable rf-resonators for the RIKEN superconducting ring cyclotron (SRC) [1] have been constructed and a low power test was made. The resonant frequency range is from 15.2 to 42.7 MHz. The Q-values and the parallel shunt impedances are as large as 70-80% of the values calculated by MAFIA.

INTRODUCTION

At the RIKEN RI-Beam Factory (RIBF), the energy of heavy-ion beams from the existing facility will be boosted up to 400 MeV/u with a beam intensity of 1 particleμA. The new booster ring cyclotron SRC whose K-number is 2600 has a magnetic field as high as 4.2 T by utilizing a superconducting technique. Due to the strong magnetic field, a high acceleration voltage is required in order to obtain a large turn separation of the beam orbits. Large turn-separation is crucial to reduce the beam losses at the extraction devices. For example, in the case of $^{16}O^{7+}$ 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 required to obtain a turn separation of 4mm at the extraction orbit. To make the turn separation as large as possibe, four acceleration resonators(type I and type II) with a voltage gain of 600 kV$_p$/resonator and one flat-top resonator are employed (see Fig. 1). The resonators are single-gap type and the maximum output power of the rf amplifier is 150 kW. The final amplifier is based on a tetrode (SIEMENS RS2042SK) with a grounded-grid circuit. The flat-top resonator is also helpful because the flat-top acceleration reduces radial beam size in principle. Table 1 summarizes the key parameters of the acceleration resonator(type I). Low power test of the acceleration resonator(type I) was made and the results are described in this report.

Table 1: Key parameters of the rf-resonator(type I).

resonators	Acceleration(type I)
Frequency[MHz]	18∼40.5
Acceleration Gap	single gap (400 mm)
Maximum Voltage [kV$_p$/gap]	600
Aperture (W×H)	2240 mm × 60 mm
Coarse Tuner	Flapping Panel (pair)
Trimmer	Block Tuner (pair)
Feeder	inductive loop
Voltage Stability	$\|\Delta V/V\| \leq 10^{-4}$
Phase Stability	$\|\Delta\phi/\phi\| \leq 0.1°$
RF Amplifier	150 kW(RS2042SK)

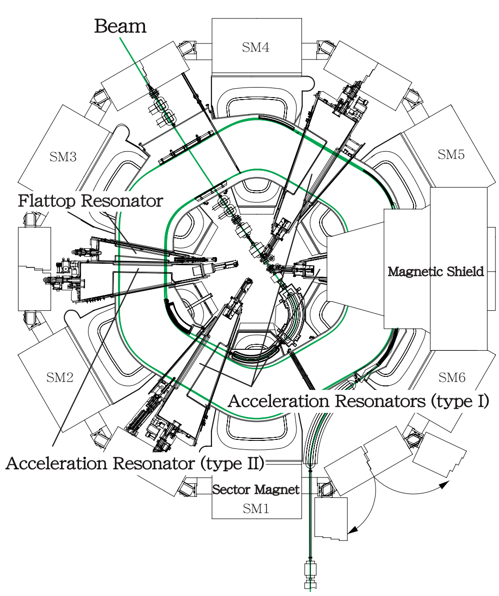

Figure 1: Layout of the RIKEN superconducting ring cyclotron(K2600).

ACCELERATION RESONATOR

The schematic of the acceleration resonator(type I) is shown in Fig. 2. The acceleration resonator is a single-gap type which is the modified version of the IRC resonator[2].

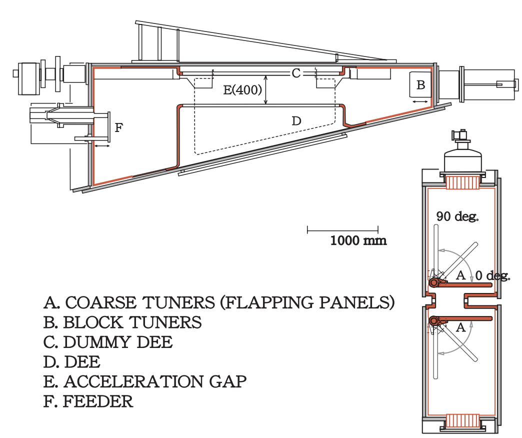

Figure 2: Schematic of the acceleration resonator(type I).

The dimensions of the resonator are optimized by using the computer code MAFIA to suit to the SRC. The resonant frequency is coarsely tuned by adjusting two flapping panels(A) which are placed symmetrically to the median plane. The resonant frequency is finely tuned by inserting the block tuners(B). Rf power is fed by an inductive loop feeder(F) whose coupling is variable by sliding its position so as to match the input impedance.

LOW POWER TEST

frequency and Q

The resonant frequencies and loaded Q-values are measured and plotted in Fig. 3. The frequency varies from 15.2 MHz to 42.7 MHz by flapping the tuning panels from -3° to 91°. The tuning range with the block tuners is about 0.7% for whole frequency range. The higher modes appear at frequencies higher than 70 MHz. The first harmonic mode of 70 MHz is fairly constant against the coarse tuner position.

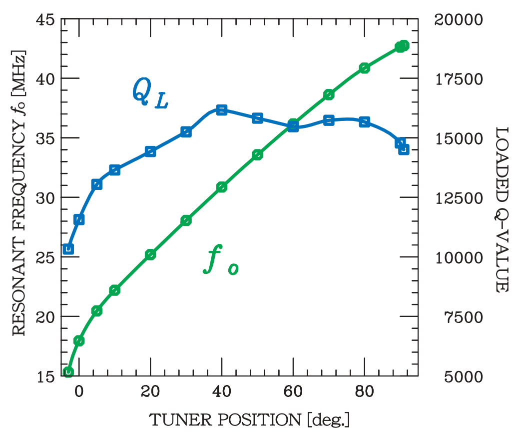

Figure 3: Measured resonant frequencies and loaded Q-values.

Electric Field Measurement

Electric field strength were measured by means of a perturbation method. From the measurement the parallel shunt impedance Rs is obtained (Fig. 4). In Table 2 Rs and Q-values with the tuning panel angle of 0° and 90° are compared with those obtained from MAFIA calculation. The frequencies are in good agreement with calculation. Measured Rs and Q are as large as about 70 % and 80 % of calculated ones The radial distribution of the gap voltage was measured and were also well reproduced by calculation.

CONCLUSIONS

The construction of the rf-resonators for the SRC has been finished and low power tests were made at Niihama works, Sumitomo Heavy Industry(SHI). The measured frequencies are in good agreement with the calculated ones

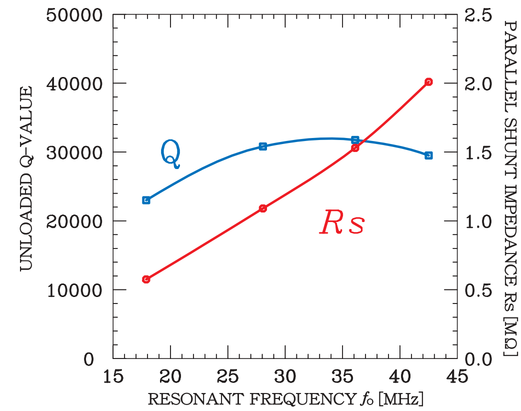

Figure 4: Measured unloaded Q-values and parallel shunt impedances at the frequencies of 17.9 MHz, 28.1 MHz, 36.1 MHz, and 42.5 MHz.

Table 2: Measured resonant frequency, Q and Rs are compared with those obtained from MAFIA calculation.

Tuner	f_o[MHz]	$Q_{\text{unloaded}}[\times 10^4]$	Rs[MΩ]
0°	17.7/17.9	3.22/2.30(71%)	0.79/0.58(72%)
90°	42.3/42.5	3.65/2.95(81%)	2.56/2.01(79%)

MAFIA/Measurement(ratio)

and the ratios of the measured one to calculated one of Q-values and parallel shunt impedance are 70 % $\sim$ 80 %. The power dissipation is estimated to be 120 kW at 38.2 MHz with a gap voltage of 600 kV$_p$. The installation of the resonators are scheduled for completion by the summer of 2006.

Figure 5: The rf-resonators(acceleration type I,II, and flat-top) during fabrication at Niihama works, SHI.

REFERENCES

[1] H. Okuno et.al., “Magnets for the RIKEN Superconducting Ring Cyclotron”, this conference.

[2] N. Sakamoto et.al., Proc. 16th Int. Conf. on Cyclotrons and Their Applications(Michigan 2001), p. 306.