

RF-SYSTEM FOR THE RIBF SUPERCONDUCTING RING CYCLOTRON

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Abstract

The main components of the rf-system for the superconducting ring cyclotron (SRC) at RIBF, RIKEN are described and the commissioning in switching on the resonators is briefly reported. After the installation of the rf-system, a high-power test was performed at a frequency of 36.5 MHz to achieve our first goal of Uranium acceleration with an energy of 345 MeV/u. As soon as the rf-system became ready in December, 2006, the beam commissioning of the SRC started. Finally, an acceleration voltage of 2 MV/turn has been achieved and we succeeded the uranium beam acceleration with a energy of 345 MeV/u.

INTRODUCTION

In RIKEN RIB-factory an accelerator complex which consists of IRC and SRC have been designed and built to accelerate ion beams up to 400 MeV/u. The rf-system has a wide frequency range of 18 ~ 42 MHz required for the acceleration of both light and heavy ions. One of the main

Table 1: Parameter specification of the rf-system

cavity	main	ft
No. of resonators	4	1
Acceleration gap	single-gap	
Frequency [MHz]	18~42	72~126
Harmonic number	6	18 (24)
Amplifier output	150 kW	60 kW
Power tube	RS2042SK /RS2012CJ	RS2058CJ
Driver	Solid state	
	1 kW	3 kW
Stability	$ \Delta V/V \leq 10^{-4}$ $ \Delta \phi < 0.1^\circ$	$ \Delta V/V \leq 10^{-3}$ $ \Delta \phi < 0.3^\circ$

issues of the RIKEN RIB-factory is a radio-isotope production by a fission fragment method utilizing Uranium beams. The SRC accelerates $^{238}\text{U}^{86+}$ up to 345 MeV/u with a rf frequency of 36.5 MHz.

The SRC consists of six superconducting sector magnets, four acceleration resonators and one flattop resonator. The schematic is shown in Fig. 1. The 6 pairs of superconducting main coils generate a magnetic field with a strength of 3.8 T and a K-value of 2600 MeV has been realized. Due to the strong magnetic field an acceleration voltage is required to be as high as possible to obtain a turn separation between beam orbits. Four single-gap resonators (RES1~4) were installed and their maximum voltage is set to be 600 kV/gap at the high end of the frequency range. A third/fourth-harmonic resonator (FT) enables a flat-top acceleration. A flat-top acceleration is helpful to reduce the energy spread, i.e. beam size in radial direction. Each resonators are equipped with rf power amplifiers which are located at the outside of the magnetic shield. The voltage and phase are accurately controlled by low level circuits to be $\Delta V/V \leq \pm 10^{-4}$ and $\Delta \phi \leq \pm 0.1^\circ$.

COMPONENTS OF THE RF SYSTEM

Resonators

The main resonators[1] for acceleration are single-gap type and work with a sextuple frequency of the beam revolution frequency ($H=6$). The resonant frequency of the resonator varies from 18~42 MHz by symmetrical adjustment of two large capacitor-panels. The Q-value and parallel shunt impedance measured by a low power test are

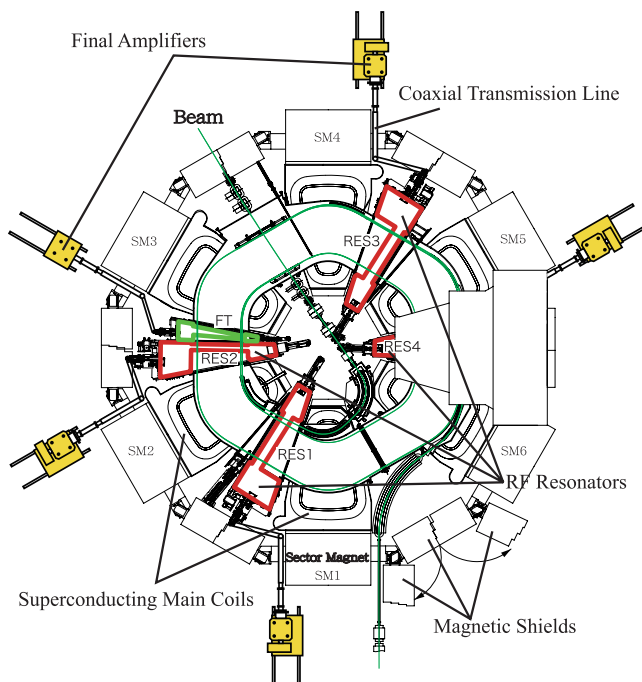


Figure 1: Schematic of SRC showing the arrangement of superconducting magnets, rf resonators (RES1~4, FT) and power amplifiers.

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Table 2: Parameter specification of the resonators at the frequency of 36.5/109.5 MHz

cavity	main	ft
Q_{unloaded}	28000	28000
R_s [$M\Omega$]	1.5	1.6
Max. gap voltage	500 kV	350 kV
Wall loss	80 kW	40 kW
Max. current density	80 A/cm	40 A/cm

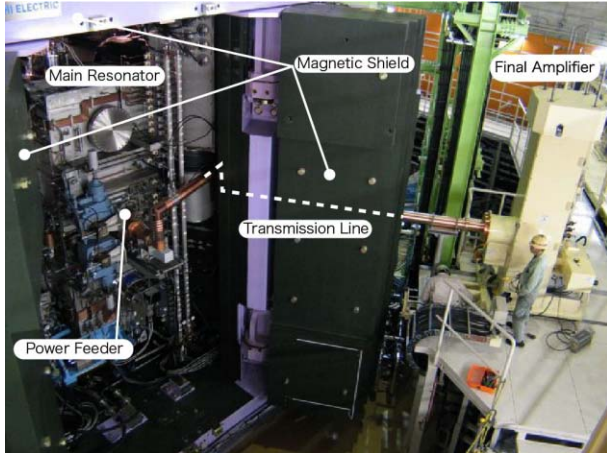


Figure 2: Photograph of the SRC rf-system.

70~80 % of the ideal values estimated by the computer code MAFIA[2] for the whole frequency range. The rf characteristics at 36.5/109.5 MHz of the resonators are summarized in Table 2.

The third and fourth harmonic of the acceleration frequency is employed for flat-top acceleration for the acceleration frequency of 24~42 MHz and 18~24 MHz, respectively. The flat-top resonator, which is also single-gap type, has a pair of sliding short plate for a frequency tuning.

A servo control to tune the resonant frequency is made by moving a pair of block tuners. Rf power is fed by an inductive loop coupler whose coupling is variable by sliding its position.

Cooling of the resonator surface is designed so that maximum temperature is about 80 °C.

Amplifiers

The four main power amplifiers are based on a tetrode SIEMENS RS2042SK coupled with a tetrode RS2012CJ with a grounded-grid circuit. The amplifiers are basically same as those for RIKEN Ring Cyclotron (RRC)[3]. The main amplifier provides a rf power of 150 kW to the acceleration resonator. A 60 kW power amplifier utilizing a power tube RS2058CJ for a flat-top resonator.

The amplifiers are situated just outside the magnetic shield of SRC, where the stray magnetic field of the superconducting sector magnets is about 100 Gauss in vertical direction. Before connecting to the resonators, a high

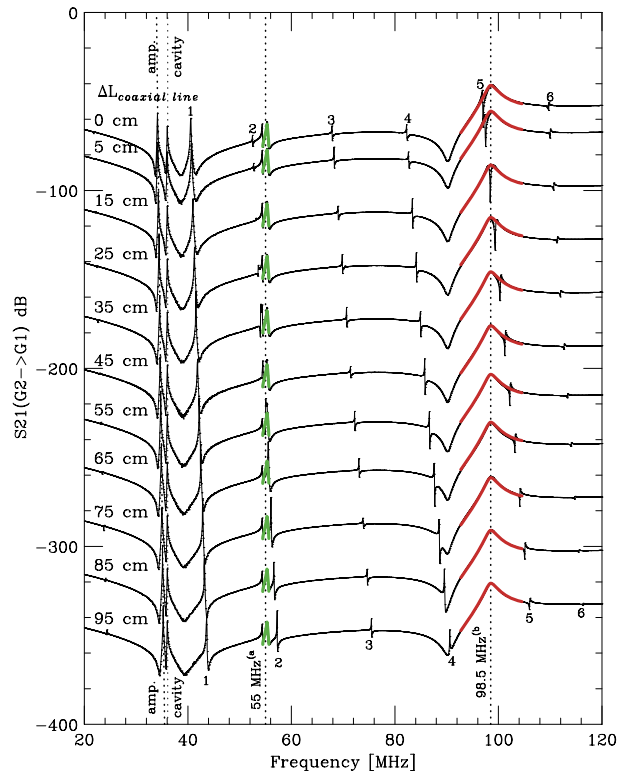


Figure 3: Resonance modes of the rf-system. The resonator and amplifier are tuned to the frequency of 36.5 MHz. The resonances labeled with numbers are HOMs of the transmission line. a) The green peak is a HOM of input circuit. b) The red peak is a resonance between G1- and G2-electrodes.

power test in a stray field was made with a maximum power output. The power was generated quite stably and no change of plate loss was observed.

Transmission lines

Output port of the amplifiers are connected to the resonators with a 50 Ω coaxial line of WX152D for main resonators and WX120D for a flat-top resonator and the resonators are coupled with the coaxial line by inductive couplers. The couplers are tunable to match the impedance of resonator to 50 Ω .

The coaxial-transmission line is equipped with a sliding-system (variable length) and the amplifier is placed on a movable platform so that the length of the transmission-line varies from 7 to 8 m. This is crucial to avoid the HOMs of the transmission line couple with HOMs of the amplifier and the resonator at the whole range of operational frequency. Fig. 3 shows the HOMs of the main rf-system. The resonator and the amplifier were tuned for 36.5 MHz. S-parameter (S_{21}) between ports for power supply of control(G1) and screen(G2) was measured by a network analyzer(Agilent Technology E5061A). From our experiences with the amplifiers for RRC, it is known there are two critical modes. One is the resonance of the input stubs at

