FP49

Proceedings of the 3rd Annual Meeting of Particle Accelerator Society of Japan
And the 31th Linear Accelerator Meeting in Japan (August 2-4, 2006, Sendai Japan)

Construction of the RF system for FRC in RI-Beam Factory

N. Sakamoto[*], O. Kamigaito, S. Kohara, N. Inabe, M. Kase, A. Goto, and Y. Yano
Nishina Center for Accelerator-Based Science, RIKEN, Wako, Saitama, Japan

Abstract

The paper presents the rf system for FRC[1] in RIKEN ri-beam factory(RIBF). Uranium 72+ ions are accelerated by two rf cavities (E- and W-cavity) with a third harmonic flattop cavity. The cavities are single-gap resonators with inductive coupled power feeders. The rf transmitters for acceleration cavity are the same type of those for CSM[2]. For flattop cavity a newly designed amplifier is made. Installation of the rf system has been already finished. Commission of the whole system is underway.

INTRODUCTION

In-flight radioisotope beam production with uranium beams (350 MeV/u) is one of the most important issues of RIBF. FRC, fixed-frequency Ring Cyclotron, is built for uranium acceleration. The velocity gain of FRC is 2. Uranium ions with an injection energy of 10.5 MeV/u is accelerated to 50.7 MeV/u. Large energy gain of 1 MV/turn is required to separate the particle bunches radially, turn by turn and hence to reduce the extraction losses.

The geometry of the cavity is optimized for a maximum shunt impedance with the constraint that the whole structure has to fit into a valley region of the cyclotron. To make its size compact and to get large parallel shunt impedance, single-gap resonator with a frequency of 55 MHz which is the third harmonic of the frequency of an injector RRC cavity. Therefore a flattop cavity which add a third harmonic to make the accelerating voltage broader is needed. The resulting broader acceleration voltage reduces the energy spread of the particle bunches so as to make the phase acceptance about 3 times larger.

Table 1: Key parameters f rf characteristics.

Cavity	Accel.	FT
Frequency [MHz]	55	165
No. of cavities	2	1
No. of gap	1	1
Gap voltage [kVp]	500	180
Tuner	block tuner	block tuner
$\Delta f/f$ [%]	1.5	2.5
Transmitter tube	RS2058CJ	4CW50000E
Amplifier	grounded grid	grounded grid
Power [kW](CW)	100	20

RF TRANSMITTERS

To reduce the cost, existing rf transmitters were planned to utilized for acceleration cavity. The amplifier, which was developed for CSM, is the grounded grid type using a power tube of tetrode RS2058CJ. The maximum output power is 100 kW for the frequency range from 36 to 72 MHz. The rf transmitter for the third harmonic flattop cavity has been newly developed. The grounded grid type based on the 4CW50000E tube is employed.

DESIGN OF RF CAVITIES

The three-dimensional computation code MAFIA is used to predict the resonant frequency, Q-value, parallel shunt impedance, and wall losses. The schematic of the acceleration cavities and flattop cavity are shown in Fig. 1 and Fig. 2, respectively. The tuning system consists of a pair of coarse tuners. Since effect of the deformation to the flattop cavity is large, a trimmer is adopted for a fine tuning to the flattop cavity. The fundamental frequency of the acceleration and flattop tuner is tuned by 1.5% and 2.5 %, respectively. The theoretical rf properties are listed in Table 2. The power dissipations of the acceleration and flattop cavities are estimated 71 kW and 15 kW if the Q-values of the real cavities are 70% of calculation. The rf power from the final amplifier is transmitted with a coaxial line of WX120D and fed into the cavity with a tunable inductive coupler.

LOW-POWER TEST

Before installation of the cavities, low power test was performed at SHI(Sumitomo Heavy Industries) Niihama site. Resonant frequency, Q-value, higher order modes (HOMs) are measured by a network analyzer HP8753E.
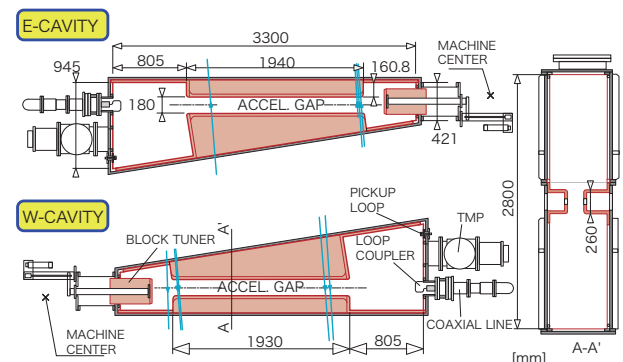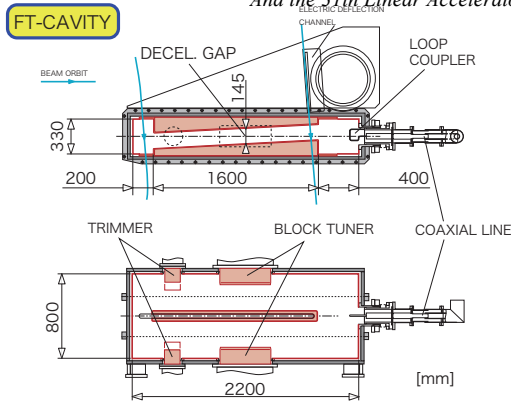

Figure 1: Schematic of the acceleration cavities.

[*] Electric address: nsakamot@rarfaxp.riken.go.jp

Figure 2: Schematic of the flattop cavity.

Table 2: Theoretical frequency, Q-value and Rs.

Cavity	Freq.[MHz]	Q-value	Rs[MΩ]
E	54.0	43400	2.5
S	54.0	43500	2.6
FT	164.6	31000	1.5

The parallel shunt impedance (Rs) was also measured by a perturbation method. The measurement is summarized in Table 2. The ratio of the measured Q-value to that of calculation is 60∼63%. This ratio is rather small in comparison that the IRC cavity has 80 % Q of calculation. In Fig. 3 and Fig. 4, the HOMs and the gap voltage distribution are shown. They are well reproduced by calculation.

Table 3: Measured frequency, Q-value and Rs.

Cavity	Freq.[MHz]	Q-value	Rs[MΩ]
E	54.57	26000	1.46
S	54.52	27000	1.53
FT	166.2	18700	0.91

INSTALLATION AND POWER TEST

The installation of the cavities was finished in March 2006. The rf properties of cavities were measured after installation.

The resonant frequency of the cavity is sensitive to the gap size of the acceleration electrodes. The mechanical structure of the cavity mount is designed to make the deformation due to the pressure of the atmosphere less than 1 mm. The frequency shift of the acceleration resonator from atmosphere to vacuum is +50 kHz which is compensated by shifting block tuner 10 mm into the cavity.

It is turned out that the Q-value of the cavity becomes about 10% larger than that measured before. It might be due to an improvement of electric contact by re-fabrication at construction site.
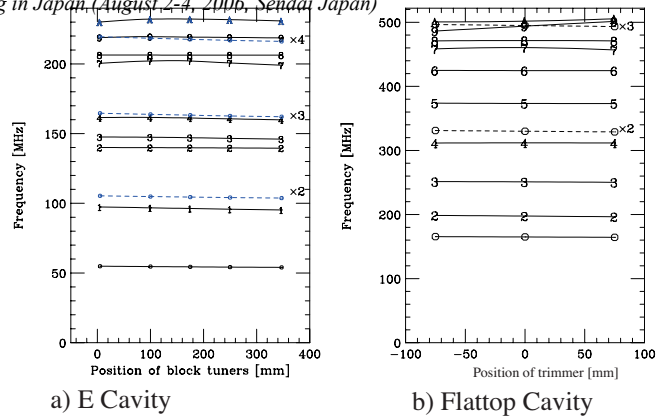

a) E Cavity b) Flattop Cavity

Figure 3: HOMs of the E and flattop cavity.
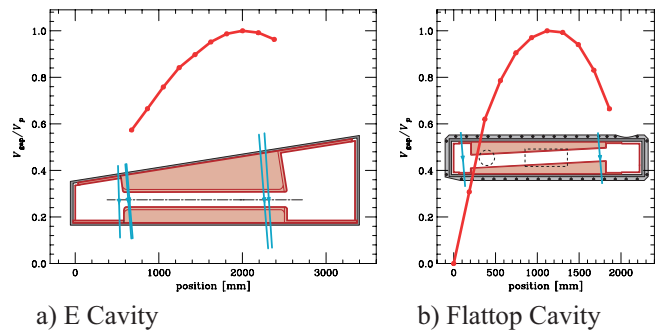

a) E Cavity b) Flattop Cavity

Figure 4: Distribution of the gap voltage.

Conditioning of the cavity started on 5 June with a pulsed rf power. In the beginning, very small pickup signal of the cavity due to the multipacting discharge was observed. Day by day, the pickup signal became larger and larger. Finally, the gap voltage of 300 kV in c.w. mode was obtained on 7 June. After a tuning of low level cir-
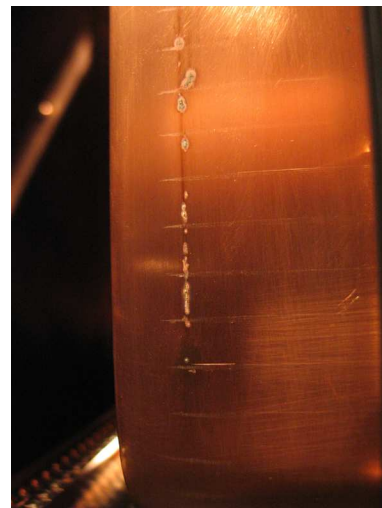

Figure 5: Silver deposits observed on the surface of the block tuners.

cuit, inspection of the cavity was made. Nothing but some harmless spots due to discharge were observed on the surface of block tuner (Fig. 5). Since 26 June, conditioning with a stray field of the sector magnet started. On 7 July, the gap voltage of 440 kV was achieved(Fig. 6).
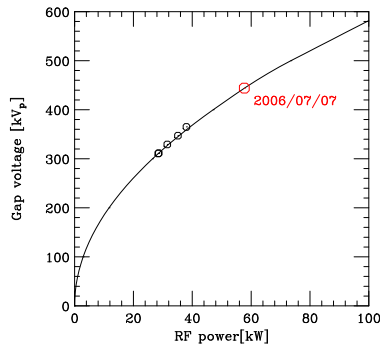

Figure 6: Gap voltage vs rf power input.

OUTLOOK

- Further study and operational experience is needed for a operation with a maximum rf power of 100 kW.

- Commission of flattop system is still underway. Some modification of amplifier is planned.

ACKNOWLEDGEMENT

REFERENCES

[1] N. Inabe et al. Proc. 17th Int. Conf. on Cyclotrons and Thier Applications, Tokyo, 2004-10(Particle Accelerator Society of Japan, 2005), p. 200.

[2] Y. Murakami et al. Proc. 13th symp. on Accelerator Science and Technology, Wako, 1999-10(1999), p. 239.