Remodeling of acceleration cavity resonators for RIKEN Ring Cyclotron

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The RIKEN Ring Cyclotron (RRC)[1] has two acceleration cavities that consist of variable-frequency half-wavelength resonators constructed over 30 years ago. The design range of resonant frequency is between 20 and 45 MHz. Additionally, the resonant frequency can be varied by moving two movable boxes,[2] as shown in Fig. 1. During the acceleration of ^{238}U, which is one of the most important beams in the operation of RIBF, the maximum beam current in the RRC was limited by large beam losses in the electrostatic deflection channel (EDC) that were caused by small turn separations and a space-charge effect owing to the insufficient acceleration voltage of the cavity resonators. The ^{238}U beam was accelerated in a fixed-frequency mode using RILAC2[3,4] as an injector. Consequently, the RRC resonators have to be operated at a low frequency of 18.25 MHz, which is less than the designed lower limit. To resonate at this low frequency, the capacitance was increased by bringing the movable box close to the location of 20 mm from the dee electrode, which caused the extremely low shunt-impedance and frequent discharge. Moreover, the acceleration voltage could not be raised above 80 kV/gap. Therefore, we decided to increase the acceleration voltage at 18.25 MHz operation by remodeling the inner component of the stems and dee electrode, excluding the outer box of the resonator and the movable boxes, respectively.

The frequency range of the RRC resonator was shifted to the lower side by inserting notches in the stem that was originally straight. Because the RRC resonator had not operate at a frequency higher than 39 MHz in recent years, the frequency range after remodeling was set to be 16–38 MHz. Although this slant type stem is similar to the early design[5] of the RRC resonator, the shunt-impedance, voltage distribution, and frequency range were optimized by changing the notch sizes based on 3D electromagnetic calculation using Microwave Studio (MWS).[6] Figure 1 shows a calculation model of MWS for the original resonator and the modified resonator. It was expected that the shunt-impedance could be doubled at 18.25 MHz by this remodeling.

The remodeling work on site was carried out from February to March 2018. We performed a low power RF test with a network analyzer in April. According to the test results, it was found that the frequency range and quality factor Q_0 were almost consistent with the expected values for each resonator. Figure 2 shows an image of the inside of the resonator after modification. Simultaneously, the old-degraded power supplies for the grid of tetrodes in RF power amplifiers were updated for stable operation.

The new resonators were used for the machine time from May and showed good performance in the operation from 18.25 MHz to 32.6 MHz. Especially, a stable operation with the voltage of 120 kV/gap was realized for 18.25 MHz owing to the shunt-impedance improvement and discharge decrement. However, owing to the water leakage from the cooling channel in the vacuum due to the production problem, we are currently considering countermeasures.

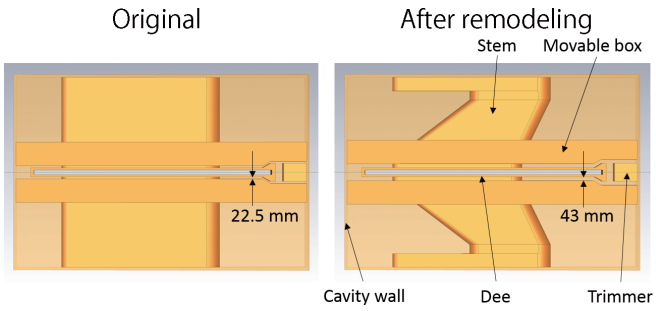

Fig. 1. Calculation models of the original cavity (left panel) and remodeling cavity (right side) used in the MWS.

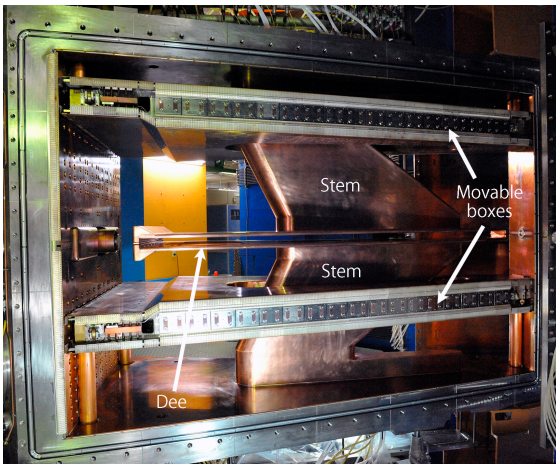

Fig. 2. Inside view of the remodeled RRC cavity.

References
1) Y. Yano, Proc. 13th Int. Cyclo. Conf., 102 (1992).
2) T. Fujisawa *et al.*, Nucl. Instrum. Methods Phys. Res. A **292**, 1 (1990).
3) K. Yamada *et al.*, Proc. of IPAC12, TUOBA02, 1071 (2012).
4) K. Suda *et al.*, Nucl. Instrum. Methods Phys. Res. A **722**, 55 (2013).
5) K. Ogiwara *et al.*, RIKEN Accel. Prog. Rep. **18**, 172 (1984).
6) `https://www.cst.com/products/cstmws` .

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