

CONSTRUCTION STATUS OF THE RIKEN INTERMEDIATE-STAGE RING CYCLOTRON (IRC)

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Abstract

The RIKEN Intermediate-stage Ring Cyclotron (IRC) [1] is a K-980 MeV ring cyclotron with four room-temperature sector magnets. Its construction and magnetic field measurements were completed at a factory of the manufacturer by 2002. The sector magnets with the total weight of 2800 t were installed at the RIKEN site from October 2003 to December 2003. They were aligned with the accuracy of better than 0.3 mm and 0.1 mm in the horizontal and vertical positions, respectively. Three RF resonators were installed and connected with the vacuum chambers in the sector magnets from June to August 2004. The vacuum pumping system, which consists of 18 pumping lines and 13 cryopumps, was assembled and pumping out of the beam chamber started from October 2004. The wiring of power cables for the magnet system were also completed and the excitation tests will be carried out in November 2004.

INTRODUCTION

The IRC is a room-temperature ring cyclotron with K-980 MeV and the fourth accelerator of an accelerator cascade for the RIKEN RI beam factory [2], which consists of one linear accelerator and four ring cyclotrons. Main parameters of the IRC are listed in Table 1. The maximum energy is 127 MeV/nucleon. The average radii for the injection and extraction are 2.77 m and 4.15 m, respectively. The RF frequency is variable from 18.0 MHz to 38.2 MHz. A plan view of the IRC is shown in Fig. 1. The IRC consists of four sector magnets, beam injection and extraction elements, two acceleration and one flattop RF resonators, and beam diagnostic instruments.

The mechanical design and fabrication of the IRC started in 1998 and completed in March 2001. The sector magnets were assembled at a factory and the excitation tests and the magnetic field measurements [3] were performed. After completion of the building, the installation of the IRC at the RIKEN site started from October 2003.

INSTALLATION OF THE SECTOR MAGNETS AND ALIGNMENT

The pole gap, the maximum magnetic field and the weight of the sector magnets are 80 mm, 1.9 T and 750 t per each, respectively. They were installed to the RIKEN site from October to December in 2003. The alignment of the sector magnets was done as follows. First, only the lower-half yokes and both the upper and lower poles with

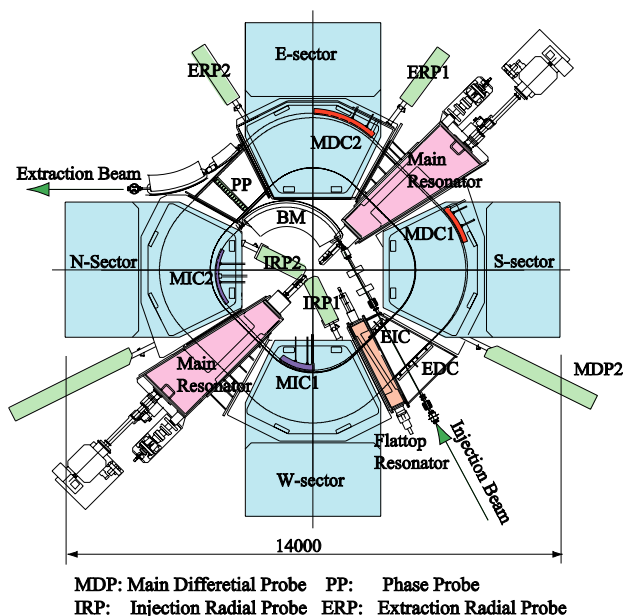


Figure 1: Plan view of the IRC.

Table 1: Parameters of the IRC

K-value	980 MeV/A
Number of sector magnets	4
Harmonics	7
Injection radius	2.77 m
Extraction radius	4.15 m
Maximum energy	127 MeV/nucleon
Maximum magnetic rigidity	4.57 Tm
Number and frequency of RF resonators	
Main	2 (18.0-38.2 MHz)
Flattop	1 (72.0-114.6 MHz)

beam chambers for the four sectors were placed in rough positions. Each weight is about 400 t. Second, the distances between the fiducial points machined on the surface of each upper pole were measured with a micro meter. Third, each position was adjusted by using two 400-ton and one 300-ton jacks so that these distances agreed with the design values within 0.5 mm. Fig. 2 shows horizontal deviations after the alignment. The heights of the median planes of four sectors were also adjusted within 0.1 mm. Finally, the upper-half yokes were installed. Although the vertical levels of the four sectors were low by about 0.5 mm, re-alignment was not done because there was no difference in the levels among the four sectors.

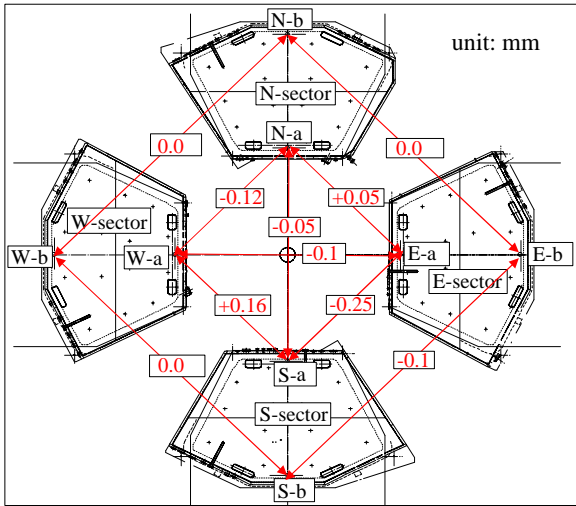


Figure 2: Deviations from the design values of the distances between the fiducial points after alignment.

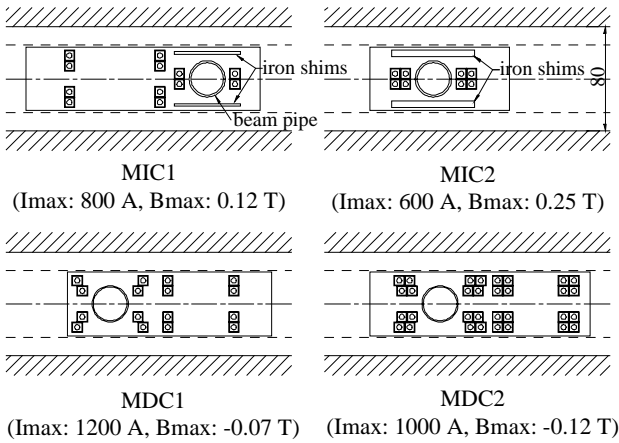


Figure 3: Cross sections of the magnetic channels. The maximum current and magnetic field are also shown.

BEAM CHANNELS FOR THE INJECTION AND EXTRACTION

The injection and extraction system of the IRC consists of two electrostatic deflection channels (EIC, EDC) and four magnetic channels (MIC1, MIC2, MDC1, MDC2) as shown in Fig. 1. Their parameters are given in Ref. 1.

Fig. 3 shows cross sections of the magnetic channels. The magnetic channels are placed inside the beam chambers of the sector magnets with a gap height of 52 mm. Their coils are made of 7 mm x 7 mm hollow conductors with a hole of 4 mm in diameter for cooling water and epoxy-molded in vacuum-tight stainless cases. Iron shims are used for the MIC1 and MIC2 to increase the magnetic field strength. Their thicknesses are 2.2 mm and 5 mm, respectively. The magnetic channels except for the MIC2 have compensation coils for reducing the leakage magnetic fields on the circulation orbits of the beam.

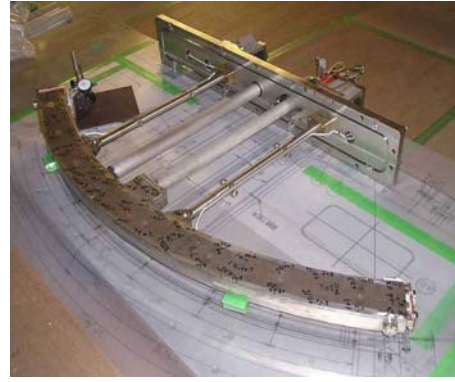


Figure 4: MIC2 under positioning.

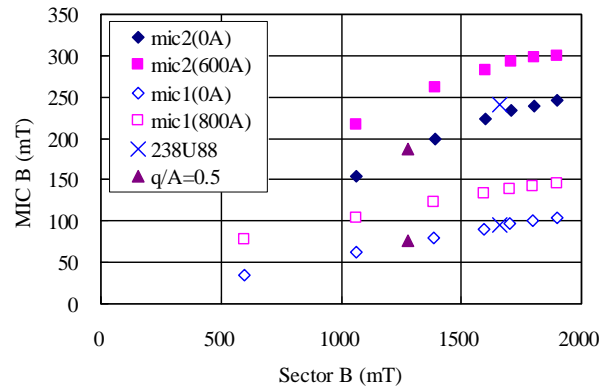


Figure 5: Magnetic fields produced by MIC.

Fig. 4 shows a photograph of the MIC2 under positioning on a full-scale drawing. All the channels were positioned in the accuracy of within 1 mm. The positions of the EIC and the EDC can be remotely adjusted by ± 15 mm with motors. The magnetic channels can also be moved manually by ± 10 mm. Fig. 5 shows the magnetic field strength generated by the MIC1 and the MIC2. The magnetic field when the current is 0A corresponds to those produced by the iron shims and it increases with the magnetic field of the sector magnets. The maximum field strengths are 100 mT and 250 mT for the MIC1 and the MIC2, respectively. The magnetic fields required for the beams of $^{238}\text{U}^{88+}$ and ions with $q/A = 0.5$ are plotted in the figure.

THE RF RESONATORS AND THEIR INSTALLATION

The RF system consists of two main resonators and one flattop resonator. The main resonators are of a single-gap type and the frequency can be varied from 18 MHz to 40.5 MHz with flapping panels. The maximum acceleration voltage is 600 kV. The flattop resonator is operated in the third harmonic frequency. The details of the RF system is given in Ref [4]. These resonators were completed in 2001

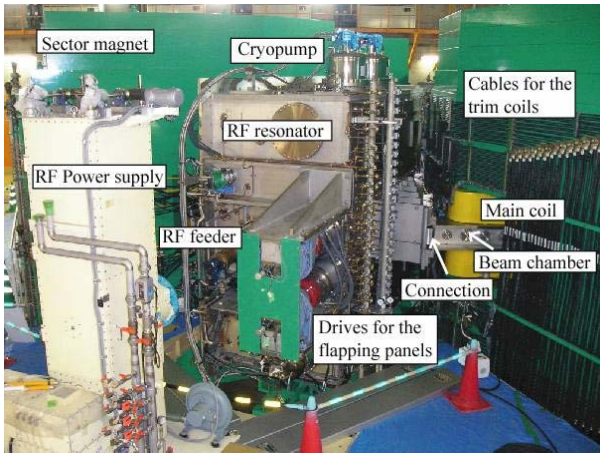


Figure 6: Installed main RF resonator.

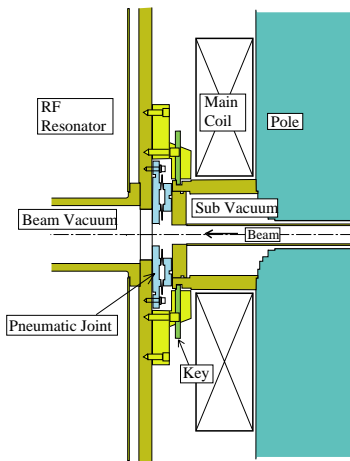


Figure 7: Cross section of a connection part of the main RF resonator with the beam chambers in the sector magnet.

The vacuum is sealed with a rubber O-ring pressed by pneumatic expansion of bellows. The resonators are fixed to the sector magnets through the beam chambers by keys to prevent the deformation due to the atmosphere pressure. The keys were adjusted to meet the design requirement of the clearance of smaller than 0.2 mm. The resonators can be moved backward 2.3 m on tracks for their maintenance with the position reproducibility of smaller than 0.2 mm.

THE VACUUM SYSTEM

A layout of the vacuum pumping system of the IRC is shown in Fig. 8. A roughing pumping system consists of two sets of one rotary pump with a pumping speed of 300 m³/h and one mechanical booster pump of 2,600 m³/h. A main pumping system composed of four turbo molecular pumps of 3,200 L/s, 12 cryopumps of 10,000 L/s and two cryopumps of 4,000 L/s. Furthermore, we have differential pumping systems for the RF resonators and the auxiliary systems pumping the sub-vacuum area of the

and tested in low power. The installation to the RIKEN site was carried out in June, 2004. They were aligned with the position accuracy of below 0.5 mm in the horizontal and vertical directions. A photograph of the installed main resonator is shown in Fig. 6. The resonators are connect-ed to the beam chambers in the sector magnets using pneu-matic seal joints. A cross-sectional view of the connection parts is

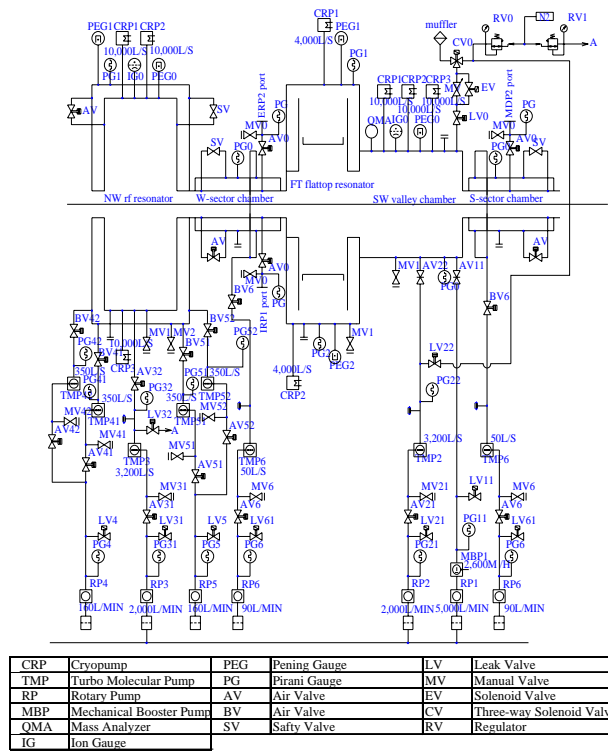


Figure 8: Layout of the vacuum pumping system. Only half of the IRC is shown in this figure.

sector magnets. The required pressure for the beam vacuum is below 1×10^{-5} Pa. The installation of the apparatus for the vacuum system started in June, 2004. The whole system including control and electricity has been completed and pumping out of the beam vacuum started from October, 2004.

CONCLUSION

After the sector magnets were installed onto the RIKEN site in 2003, installation of the RF resonators, assembling of the vacuum system and cabling for the magnets were carried out in 2004. The magnet system and the vacuum system were completed by October 2004. The excitation test of the magnets will be carried out in November 2004. Cabling for the electricity of the RF system and the high power test will be carried out in 2005. Beam commissioning of the IRC is scheduled to start in the autumn of 2006.

REFERENCES

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