CONSTRUCTION OF THE FRC SECTOR MAGNET FOR RIKEN RI BEAM FACTORY

T. Mitsumoto, Sumitomo Heavy Industries, Ltd. Niihama, Ehime, 792-8588, Japan
N. Fukunishi, A. Goto, N. Inabe, O. Kamigaito, H. Ryuto, N. Sakamoto, Y. Yano,
RIKEN, Wako-shi, Saitama, 351-0198 Japan

Abstract

Construction of the fixed-frequency ring cyclotron (fRC) for the RIKEN RI-Beam factory was started. The sector magnets of the fRC were designed to minimize the current of the trim coils. Two sector magnets among four are completed.

INTRODUCTION

The fixed-frequency ring cyclotron (fRC) is a room temperature ring cyclotron with four sectors that is utilised for RIKEN RI-Beam Factory[1]. It will be installed between the RIKEN Ring Cyclotron (RRC) and the Intermediate-stage Ring Cyclotron (IRC). The fRC will enable us to obtain a 350 MeV/nucleon very heavy ions such as Uranium or Xenon at the exit of the Super-conducting Ring Cyclotron (SRC)[2].

GENERAL SPECIFICATIONS

Figure 1 shows a plan view of the fRC. Main parameters of the fRC are listed in Table 1. The injection and extraction radius are defined taking into account of the energy losses through two charge strippers placed upstream and down stream of the fRC[3]. In the case of uranium ions, energy losses by the upstream and downstream strippers of the fRC are considered to be 0.4 and 4.5 MeV/nucleon, respectively. The major ions to be accelerated by the fRC are considered to be $^{238}U^{71+}$ and $^{136}Xe^{45+}$.

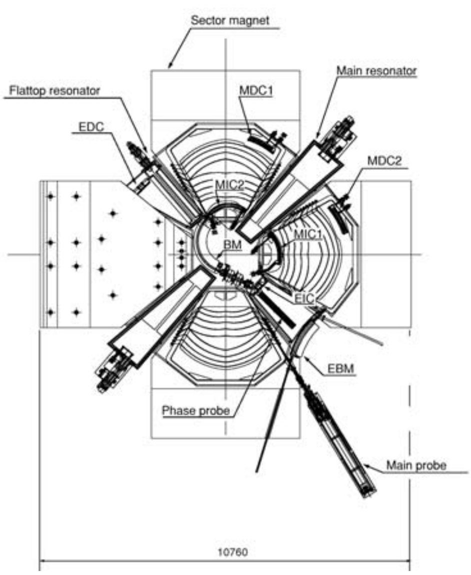

Figure 1: Plan view of the fRC

The RF frequency is three times the frequency of the injector linacs. A new rebuncher to be installed between the RRC and the fRC will compensate the reduction of phase acceptance.

Table 1: Main parameters of the fRC

Kb-value	570 MeV
Number of sectors	4
Injection radius	1.55 m
Extraction radius	3.30
Harmonics	12
Max. energy of ions	50.7 MeV/nucleon
Frequency	54.99 MHz

SECTOR MAGNETS

The fRC will be installed in the E4 experimental room of RIKEN Accelerator Research Facility (RARF) [4]. The height of beam lines is at 1.7 m from floor level. This condition restricts the height of the sector magnets.

The main parameters of the sector magnets are listed in Table 2.

Table 2: Main parameters of the sector magnets.

Pole gap	50mm
Sector angle	58.4 degree
Height	3.34 m
Weight	330 ton/sector
Maximum magnetic field	1.68 T
Main coil	
Max. current	650 A
Max. excitation current	91 kA/sector
Power consumption	60 kW/sector
Trim coils	
Number of trim coil	10 pair/sector
Current	100A, 200A

Pole and Yoke

The sector magnets of the fRC were designed based on the design of the sector magnets of the RRC and the IRC. Structure of the yokes is a stack of slabs low carbon steel with the thickness of 290mm at the maximum.

The fRC will be operated at fixed frequency i.e. a fixed energy cyclotron. Charge to mass ratio, however, has range from 45/136 for Xenon to 71/238 for Uranium. Magnetic field distribution is not the same between two cases because of the difference of the excitation currents. The profile of the pole edge is designed to minimise the errors to isochronous fields for both cases. Figure 2 shows the pole surface and the vacuum chamber. The pole edge profile is slightly curved in order to compromise two conditions. This profile is defined in consideration with the isochronous fields, deformation by magnetic forces, magnetic field distortion by the iron in the injection magnetic channel and mechanical errors. Figure 5 shows the photo of the sector magnet.

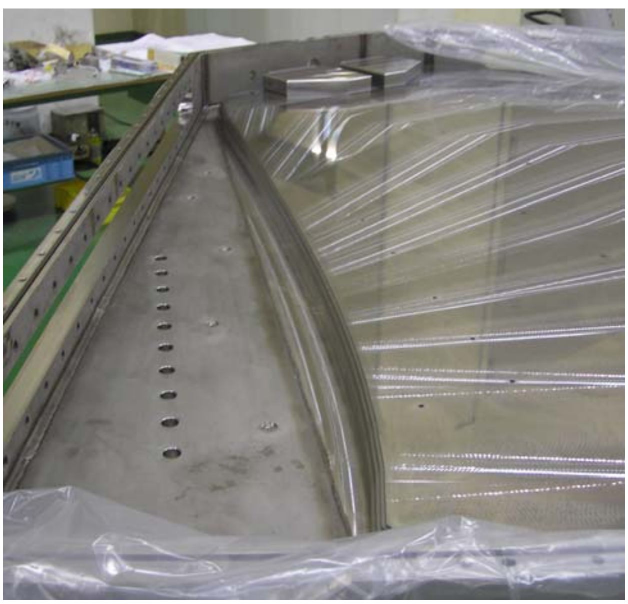

Figure 2: Pole surface of the sector magnet.

Figure 3: Sector magnet of the fRC under construction.

The yoke of the sector magnet is designed to be wide and low because the height of the beam lines from floor is 1.7m. This means that space for the resonators are reduced by the sector magnet. We chose that the RF frequency is three times the frequency of the injector linacs instead of twice in order to have small size of the resonators.

Trim coils

Trim coils for ring cyclotrons excited by several hundreds amperes are designed as insulated plates whose outlines are the same as the beam orbits. They are put in the sub-vacuum chamber separated from the beam vacuum. This design is used in the RRC[5] and the IRC[6]. In the case of the trim coils of the fRC, the excitation current is less than 200 amperes. The trim coils for the fRC are designed as copper pipes placed in the diagonal curve of the virtual plate shape of the trim coils. Magnetic field distribution along the radial direction is stepwise because of the discrete trim coils. The average field, however, has a good accuracy to the isochronous field. Figure 4 shows the layout of the trim coils. The first five trim coils put along the same direction of the diagonal and the last five trim coils are use the other diagonal in order to have the space for magnetic channels for the injection and the extraction. Figure 5 shows the cross-section of the trim coils. A copper pipe insulated by glass tapes is inserted in a stainless pipe. In the insulation layer, epoxy is filled to keep mechanical position constant.

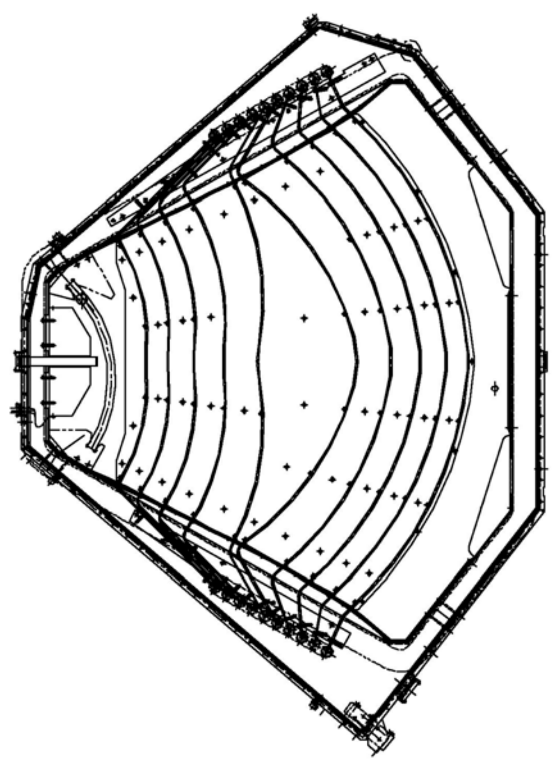

Figure 4: Layout of the trim coils on the sector surface. The first five trim coils and the last five trim coils are put along the different diagonal of virtual plate trim coils.

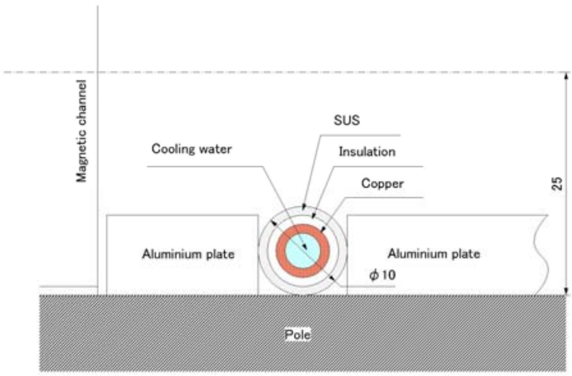

Figure 5: Cross-section of the trim coil.

This structure enable us to install the trim coils in the beam vacuum because of the insulation layer which is harmful for high vacuum is inside the stainless pipe. The sub-vacuum chamber for the trim coils is not required. Aluminium plates are put between trim coils in order to keep the position and the shape of the trim coils. Adopting the structure, The pole gap of the fRC is shortened to 50 mm compared with the gap of 80 mm of the IRC.

SCHEDULE

The construction of the fRC is started in 2002. Two sector magnets are completed at the Niihama works of Sumitomo Heavy Industries, Ltd. in Ehime prefecture. The first excitation test was done for the sector magnet. The rest of the sector magnets are under construction. The construction of the fRC will be finished by March of 2005 including the cavities and vacuum chamber. Installation of the fRC will be started in summer of 2005.

CONCLUSIONS

The construction of the fRC for the RIKEN RI-Beam Factory has started. The pole shape was carefully designed in order to minimise the current of the trim coils. New design of the trim coil are adopted in the sector magnet the fRC. Two sector magnets are completed and tested. Construction will be finished by March 2005.

REFERENCES

[1] N. Inabe, et al., “Fixed-frequency Ring Cyclotron (fRC) in RIBF,” these proceedings.
[2] Y. Yano, et al., “RI Beam Factory Project at RIKEN,” 16th Int. Conf. on Cyclotrons and their applications, East Lansing, Michigan, 2001.
[3] H. Ryuto, et al., “Charge stripping plan of the RIKEN RI-Beam Factory,” these proceedings.
[4] http://www.rarf.reiken.jp/.
[5] H. Kamitsubo, “IPCR SEPARATED SECTOR CYCLOTRON WITH K=540”, 9th Int. Conf. On Cyclotrons and their applications, Caen, 1981
[6] T. Mitsumoto, et al., “Construction of the RIKEN IRC,” 16th Int. Conf. on Cyclotrons and their applications, East Lansing, Michigan, 2001.