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DESIGN OF INTERDIGITAL H-MODE RE-BUNCHER AT KoBRA BEAMLINE

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Abstract

KOrea Broad acceptance Recoil spectrometer and Apparatus (KoBRA) are experimental facility for low energy nuclear physics in the heavy ion accelerator complex RAON. Two re-buncher systems at KoBRA beamline are required to longitudinally focus the $^{40}Ar^{9+}$ with 27 MeV/u. The normal conducting IH resonator with seven-gap as the re-buncher structure was chosen because of the reduction in the risk of particulate contamination and total power consumption. In this paper the detailed design results of the 162.5 MHz IH re-buncher cavity will be presented.

INTRODUCTION

RAON is the heavy ion accelerator complex currently under construction in Republic of Korea, and is an abbreviation for the rare isotope accelerator of newness. Figure 1 shows the schematic layout of the RAON accelerator [1]. The heavy ion beam is extracted from the electron cyclotron resonance (ECR) ion source and isotope separation on-line (ISOL) system. The low energy ion beam accelerated at the superconducting linac 3 (SCL3) is used for low energy nuclear physics at KoBRA experimental facility. Two re-buncher cavity are required for beam longitudinal focusing at transfer beam line between SCL3 and KoBRA.

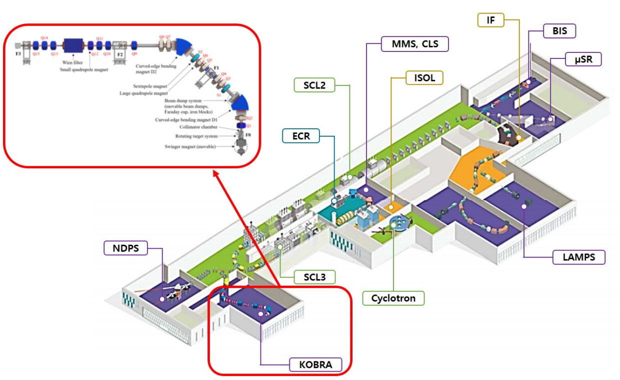

Figure 1: Schematic layout of heavy ion accelerator complex RAON.

Design Goal of Re-buncher Cavity

The main requirements of the re-buncher cavity design are as follows. The re-buncher cavity should have:

- Low total power consumption because the re-buncher will be operated in continuous wave (CW) mode.
- Optimized installation position at KoBRA beam line for efficient beam bunching.

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DESIGN SIMULATION

Table 1: Parameters for Beam Dynamics Design

Specification	Value
Resonant frequency	162.5 MHz
Beam velocity	0.234 4
A/q	4.44
Cell length	216.4 mm
Operating mode	CW

On the KoBRA beam line, various heavy ion beams from proton to uranium beam are transmitted for the research of the low energy nuclear physics. The $^{40}Ar^{9+}$ with 27 MeV/u is reference particle for the re-buncher cavities design and two re-buncher structure are installed in the beam line. The detailed parameters for beam dynamics design is shown in Table 1.

Location of Re-buncher Cavity

Figure 2 shows the six locations within the KoBRA beam line where two cavities can be installed. In order to determine the locations of the re-buncher cavities installed in the KoBRA beam line, the required voltage for the beam bunching is confirmed by using the beam dynamics simulation.

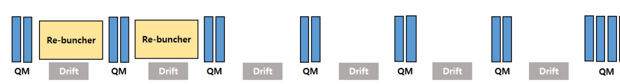

Figure 2: Locations of two re-buncher cavities.

Figure 2 represents the positions of two cavities in KoBRA beam line. The required bunching voltage in the case of Fig. 2 is calculated so that the smallest value is required. Figure 3 shows the longitudinal beam profiles at the end of KoBRA beam line without and with two re-buncher cavities in the KoBRA beam line.

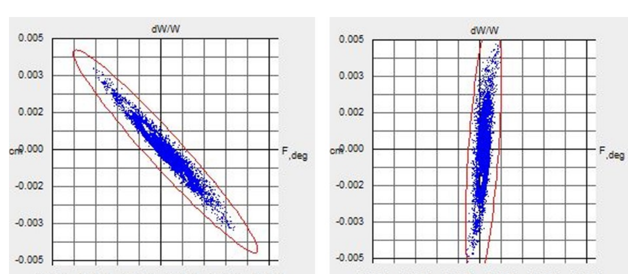

Figure 3: Longitudinal beam profiles at the end of KoBRA beam line without (left) and with (right) the beam bunching.

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Type of Re-buncher Cavity

In the original KoBRA beam line design, the superconducting cavities are considered as the re-buncher cavities. The collimators increase the risk of particulate contamination of the superconducting cavities. Thus, the normal conducting cavities are chosen to prevent some contaminant ion species inside the re-buncher structures [2].

The cooling issue of the re-buncher cavity is also considered. As the number of gaps in the cavity increases, the shunt impedance of the cavity increases [3, 4]. The high shunt impedance value can reduce the heat generated in the cavity because the power loss of the cavity becomes small. They can be calculated by the following expression :

$$R = \frac{{V_0}^2}{P}, \tag{1}$$

where R is the shunt impedance, P is the dissipation power of the cavity, V_0 is the bunching voltage. Thus, the normal conducting cavities of interdigital H-mode (IH) drift tube linac (DTL) type are selected as the re-buncher structures for the beam bunching. Figure 4 shows the 3D modeling of the re-buncher cavity with IH-DTL type.

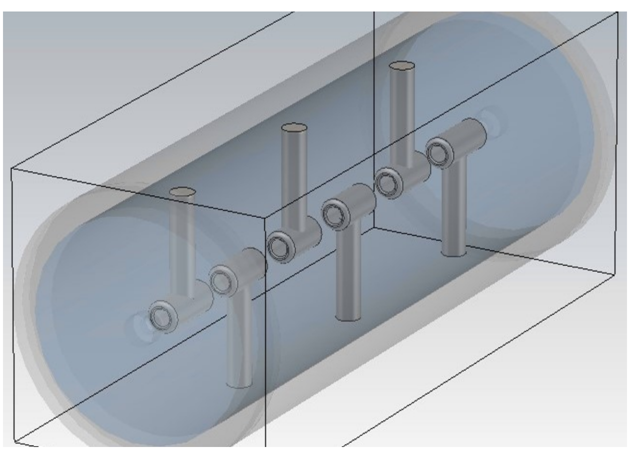

Figure 4: 3D modeling of re-buncher cavity with interdigital H-mode DTL type.

Electromagnetic Design

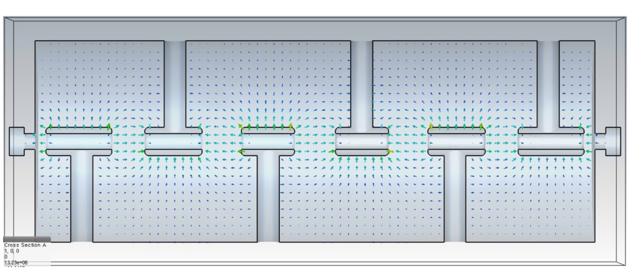

Figure 5: Electric field distributions at the resonant mode of the re-buncher.

Figures 5 and 6 indicate the electric field distributions and profiles of the resonant mode, respectively. The re-buncher cavity has 7 gaps and total length is about 1.3 m. The shunt impedance, Q value and power consumption are 57 MOhm, 15 200 and 7.8 kW, repectively. The main results of electromagnetic simulation are presented in Table 2.

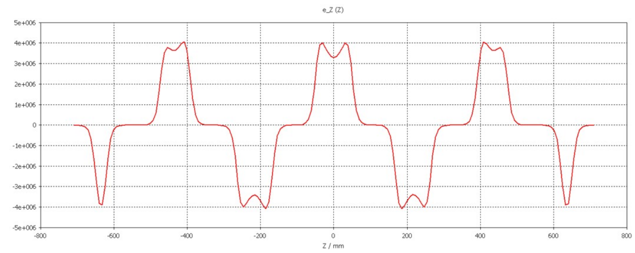

Figure 6: Electric field profiles at the resonant mode of the re-buncher.

Table 2: Simulation Results

Characteristic parameters	**Results**
Resonant frequency	162.3 MHz
Shunt impedance	57 MOhm
Accelerating voltage	670 kV
Q value	15 200
Total power loss	7.8 kW
Cavity diameter	468.4 mm
Cavity length	1.3 m

Thermal Analysis

The heat generation in the cavity causes structural deformation, resulting in a change in frequency.

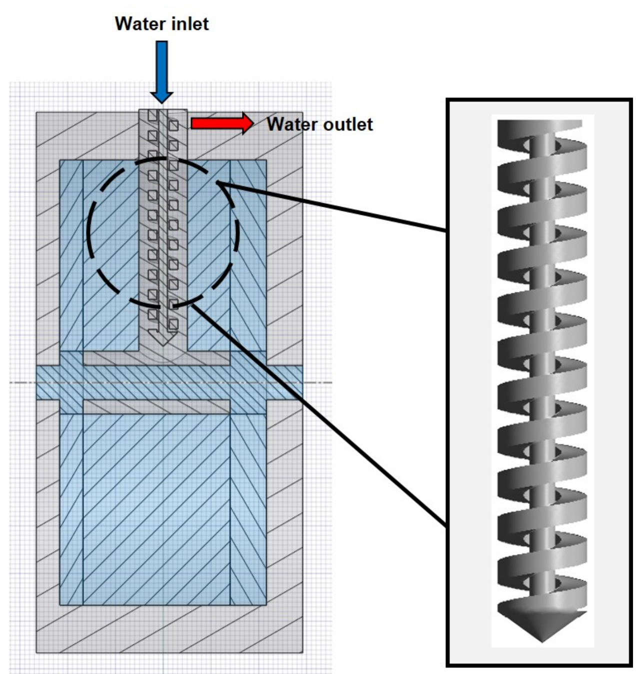

Figure 7: Cooling line of the re-buncher.

Thermal analysis was performed using ANSYS code for efficient cooling of the cavity. Figure 7 shows the cooling

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line inside the drift tube. In order to cool the stem and drift tube, water at 20 °C enters a inlet with straight line, rotates in a screw line, and exits.

Figure 8 presents the thermal analysis results for first drift tube of the re-buncher. The temperature at the end of the drift tube is 56 degrees Celsius. Therefore, the electromagnetic field of the drift tube must be adjusted to a low level by adjusting the length of the first gap.

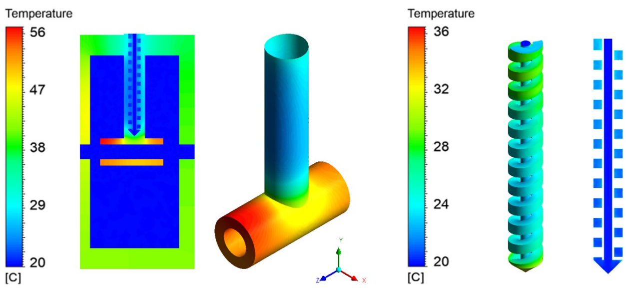

Figure 8: Thermal analysis results for first drift tube.

CONCLUSION

KoBRA is experimental facility for low energy nuclear physics in RAON accelerator complex. Two re-buncher structures are required for the longitudinal focusing at KoBRA beamline. The normal conducting resonator of interdigital H-mode DTL type was chosen as the re-buncher structure. The electromagnetic and thermal analysis of the re-buncher are performed by CST studio and ANSYS code. The adjustment of first gap from the thermal analysis results is required. Thermal analysis for the modified re-buncher is in progress.

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REFERENCES

[1] RISP, http://www.risp.ibs.re.kr

[2] P. N. Ostroumov *et al.*, "Accelerator Physics Advances in FRIB (Facility for Rare Isotope Beams)", in *Proc. 9th Int. Particle Accelerator Conf. (IPAC'18)*, Vancouver, Canada, Apr.-May 2018, pp. 2950–2952. doi:10.18429/JACoW-IPAC2018-THYGBF4

[3] A. Lara, I. Podadera, and F. Toral, "RF Design of the Rebuncher Cavities for the LIPAC Deuteron Accelerator", in *Proc. 2nd Int. Particle Accelerator Conf. (IPAC'11)*, San Sebastian, Spain, Sep. 2011, paper MOPC047, pp. 184–186.

[4] Sun Lie-Peng *et al.*, "Design study of the SSC-LINAC rebuncher", *Chinese Physics C*, vol. 37, p. 027002, 2013. doi:10.1088/1674-1137/37/2/027002