Current injector R & D for RISP SC linac

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1. Introduction

The injector for the main driver linac of the Rare Isotope Science Project (RISP) in Korea has been designed to supply ions ranging from proton to uranium which will be used to meet requirements of the 400 kW inflight fragmentation (IF) system. The core element of the injector a superconducting electron cyclotron resonance (ECR) ion sources and a radio frequency quadrupole (RFQ).

2. ECRIS design

ECR ion sources are based on the 28GHz superconducting ECR ion source at LBL[1,2,3] and RIKEN. The design goal of the ECRIS is to produce various ions with the kinetic energy of 10 keV/u and a normalized rms emittance of less than 0.12 mm-mrad.

Table 1: ECR ion source specification

Frequency (GHz)	28 + (18)
RF Power (kW)	10
Plasma Chamber Diameter (mm)	150
Plasma Chamber Material	Aluminum
Mirror Length (mm)	500
V_{ext} (kV)	30
SC Wire	NbTi
Number of Solenoid Coils	4
Sextupole Winding Type	Saddle
B_{inj} (T)	3.5
B_r (T)	2
B_{ext} (T)	2
B_{min} (T)	0.4 ~ 0.8

The main design parameters of this ion source are summarized in Table 1.

The design of the SC magnets is the most important part of the ECR ion source design. The superconducting magnets will to use 4 solenoids and 6 sextupoles to adjust the ECR zone. The coils for the sextupoles will use the saddle winding technique. The nominal axial fields of the magnets are 3.5 T at the injection side and 2 T at the extraction side, while the minimum axial field is variable between 0.4 T and 0.8 T. The nominal radial field strength is 2 T at the plasma chamber wall with a 150mm inner diameter. Detailed design parameter can be seen in Table 2. A special ferromagnetic shimming technique is applied to the sextupole magnets. Figure 1 shows the SC magnet design.

Table 2: Magnet specification

	solenoid 1	solenoid 2	solenoid 3	solenoid 4	hexapole
Axial position of center (mm)	-250	-76	65	250	
Inner radius (mm)	188	188	188	188	108
Depth (mm)	67	45	58	67	50
Width (mm)	230	55	65	145	
Conductor size (mm)	1.6*0.91	1.6*0.91	1.6*0.91	1.6*0.91	1.43*0.98
Cu/NbTi ratio	3.65	3.65	3.65	3.65	3
Turns/coil	8945	1436	2188	5639	1367
Design Current (A)	-165	125	140	-144	254
Wire length (km)	12.46	1.9	2.98	7.85	2.56 km /1 unit

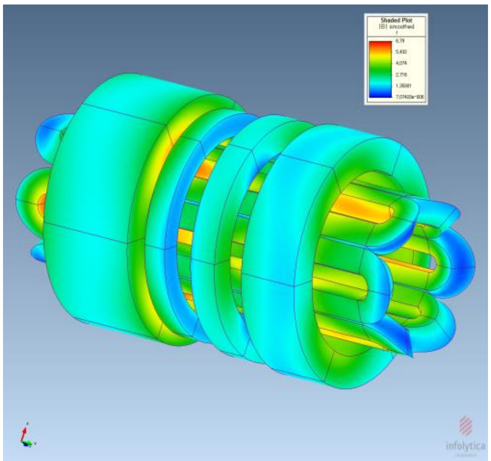

Fig. 1. Magnetic field calculation

As shown in figure 2, cryostat for the magnet will be constructed. 6 2 step 4 K cryocoolers and a single step cryocooler will be assembled to meet cooling capacity of 9 W.

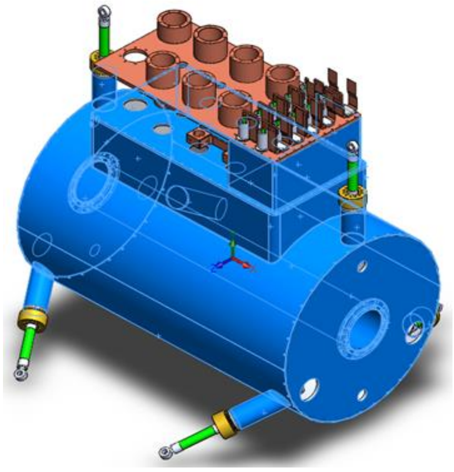

Fig. 2. 3 dimensional drawing for cryostat.

2. RFQ

An RFQ was designed to bunch and accelerate beams transported from the LEBT with the energy of 10keV/u. The RFQ can accelerate two-charge state (238U33+ and 238U34+ of 12 pμA) beams from 10 keV/u to 500 keV/u. PARMTEQ was used to obtain the RFQ design parameters. RF frequency is 81.25 MHz. Table 3 shows the detailed parameters of the RFQ.

Table 3: RFQ ion source specification

Reference Particles	$^{238}U^{33+}$ and $^{238}U^{34+}$
RF Frequency	81.25 MHz
Input charge state	33.5
Input Energy	10 keV/u
Output Energy	500 keV/u
Beam Current	12 pμA
Input Transverse Emittance	0.1 mm-mrad (normalized rms)
Vane Voltage	70 kV

The total length of the RFQ is approximately 5 m. The length of the 500 keV/u RFQ is longer than the 300 keV/u RFQ in previous designs. So, the vane voltage, focusing strength(B) and modulation(m) factor in the PARMTEQ input file(RFQ.IN4) have been adjusted to optimize the 500 keV/u RFQ.

Smulation results of Parmeteqm using input type 6 generated by Parmeteqm with rms normalized emittance of 0.12 mm-mrad. The Scheff line in Parmeteqm uses particle current so the Scheff line uses. 012 mA if the particle mass is defined for 238 amu for 0.4 mA electrical current. To simplify the changes to run different mass particles and charge states, we defined the ions to be mass 1 amu and used charge state of 0.14 to represent U23833-34 charge states. U23833 has a charge to mass ratio of 0.1387 and U23834 has a charge state of 0.1429. The fringe field region is adjusted to have the beam exit the RFQ with α near zero in both x and y planes.

Keeping the ratio of these focusing strengths constant improves the longitudinal emittance. Once the ~ 20% of the beam outside the core of the bunched beam is lost, the emittance is constant in all 3 directions. The Transverse emittance is ~ unchanged from the input emittance. By cell 63 the beam outside the longitudinal fish has been excluded from the emittance calculation.

3. Conclusions

Major elements were optimized and selected by calculating uranium beam optics which will then be delivered to the low energy superconducting linac.

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