STUDY OF EXTRACTION AND TRANSPORT OF INTENSE HIGHLY CHARGED IONS FOR 18GHZ SC-ECRIS AT RCNP*

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Abstract

An 18 GHz superconducting ECRIS is installed to increase beam currents and to extend the variety of ions, especially for highly charged heavy ions which can be accelerated by RCNP cyclotrons. The production development of several ions like B, O, N, Ne, Ar, Ni, Kr and Xe has been already done and the further studies for those beam extraction and transport have been done in order to increase the beam current more injected to cyclotron. The extraction electrode and einzel lens are modified to be applied minus voltage for the beam extraction and the extracted beam is increasing as the electrode voltage rising. Additional steering magnets have been installed to reject the effect of magnetic field leakage from AVF Cyclotron and the transmission of transport line has been improved with these steering magnets successfully.

INSTRUDUCTION

These are four ion sources at RCNP cyclotron facility as shown in Figure 1, and 18-GHz SC-ECRIS is the one of those and installed in order to increase beam currents and to extend the variety of ions, especially for highly charged heavy ions which can be accelerated by RCNP cyclotrons. The mirror magnetic field is produced with four liquid-helium-free superconducting coils and the permanent magnet hexapole is of Halbach type with 24 pieces of NEOMAX-44H material. The production development of several ion like B, O, N, Ne, Ar, Ni, Kr and Xe has been performed and these beams are already provided to experimental users [1, 2] and more beam currents are requested for such experiments. For further improvement of beam quality and intensity, it is needed more improvement not only for the SC-ECR itself but also for the beam transmission on beam transport line and for the injection efficiency to AVF cyclotron. For that purpose, the extraction electrode has been modified to increase extracted beam from plasma chamber of SC-ECRIS. The detail studies for transmission also have been done and additional steering magnet has been installed.

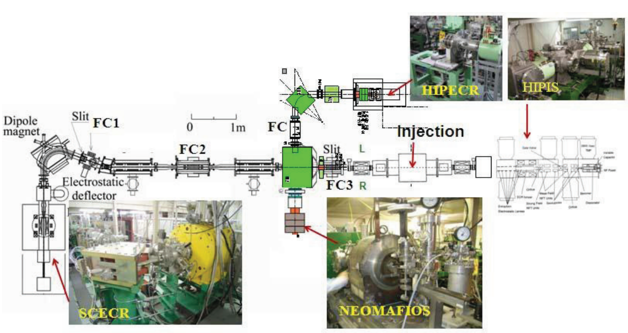

Figure 1: Ion Source Complex at RCNP: The room for ion sources is upstairs of AVF cyclotron; the transport line is 5980mm behind of median plane of cyclotron. There are 4 ion sources; HIPIS for polarized p, d, 2.45 GHz HIPECR for intense p, 10 GHZ NEOMAFIOS for p~Mg and 18GHz SCECR for highly charged heavy ions.

EXTRACTION ELECTRODE MODIFICATION

To increase the ion beam current and minimize the emittance, extraction electrode and einzel lens are modified. Figure 2 (a) shows the electrodes before modification and (b) shows after. the extraction electrode can be applied to -20 kV against the plasma electrode applied to +15kV. The baffle downstream of einzel lens is ground level. The einzel lens position is movable. The position of both of plasma electrode and extraction electrode can be controlled from outside chamber and those positions are monitored by potentiometer so that both of the RF resonance inside the plasma chamber and extraction condition can be optimized in combination with optimization of mirror fields, bias disk position and so on. Especially eigen mode of RF inside the plasma chamber might take important role [2].

The beam test with new extraction electrode has been carried with applied voltage bellow -6kV for the moment.

Table 1 shows the conditions and results of 20Ne6+ beam test. Acceleration voltage and drain current has been kept to 12 kV and 1.9 mA, respectively. The diameter of both electrode of plasma and extraction is 10 mm and gap between both electrode is 20 mm beam current is

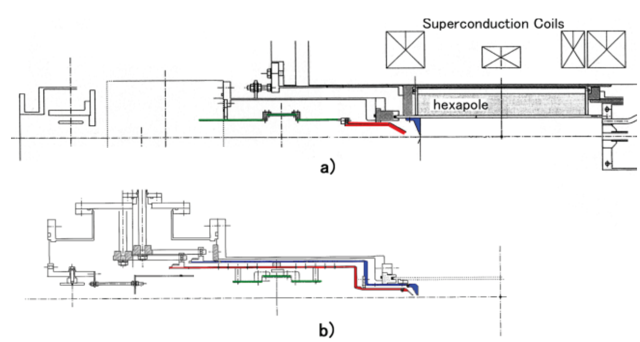

Figure 2: The schematic views of extraction system before modified in a) and after in b).In both figure, structure in blue is plasma electrode, red is extraction electrode and green is einzel lens.

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measured by Faraday cup (FC1) shown in Figure 2. As shown in Table 1, the ion beam increases successfully when the extraction voltage is increasing.

Table 1: Condition and result of 20Ne6+ beam test with modified electrode. The position of FC1 is shown in Figure 1.

Acceleration Voltage [kV]	Drain Current [mA]	Extract Voltage [kV]	Extraction Electrode Current [mA]	FC1 [uA]
12	1.9	0	0.13	50
12	1.9	-2	0.18	82
12	1.9	-4	0.24	100
12	1.9	-6	0.3	130

BEAM TRANSMISSION AND FIELD LEAKAGE OF AVF

It is known through daily beam commissioning that there is the effect of field leakage from AVF cyclotron whose median plane is 5980mm below of SC-ECR beam transport line [3]. The correlation between AVF main coil current and bending of ion beam from SC-ECR is confirmed by measurement of ion beam profile profile monitor BPM82 installed downstream of FC3 shown in Figure 1. This BPM82 has rotating molybdenite wire driven by 18cps and measures secondary emitted electrons from the wire by surrounded collector. The BPM can measure x and y profile at once with 18cps. Figure 4 shows the typical BMP82 profile. Horizontal axis is time axis which is corresponding to rotating angle of wire and this angle is corresponding to x or y position. The time width of 1347Ch shown in this figure is correlated with 118mm space width.

Figure 5 shows the result of this correlation measurement. Measured beam is Ar11+ produced by SC-ECR and each parameter for like Triplet Q's is optimized

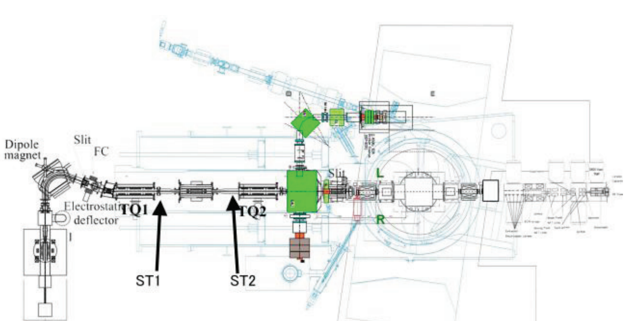

Figure 3: The schematic top views of ion beam transport line and AVF cyclotron. The difference between the levels of transport line and median plane of cyclotron is 5980 mm. TQ1,2 shows the triplet Q lens. ST1,2 shows the additional steering magnets

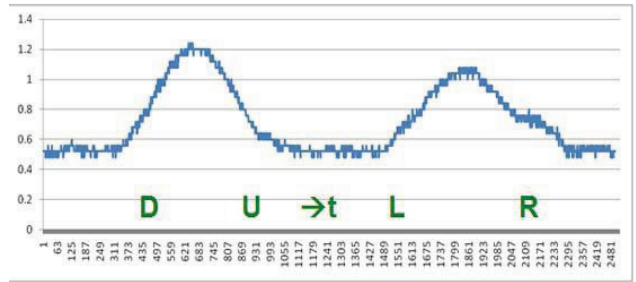

Figure 4: The typical graph of beam profile measured by BPM82. The x axis is corresponding to time that related to the X and Y position of the beam. In this figure, left bump shows the Y profile and right is for X.

under condition of 0A of AVF main coil current. According to the result, the beam is bended to R direction which shown in Figure 1 horizontally and shortly with coil current below 600A and is bended to opposite L direction largely over 600A. This is that fringing field take main role especially at the region of upper triplet Q far from center of AVF below 600A of main coil but leakage field in opposite direction due to saturation of yoke gets domain over 600A. The field leakage effect is not seen in vertical direction. The usual operational value of the AVF main coil current for the heavy ions acceleration with the combination of SC-ECR is over 600A.

To improve the beam transmission, the material of the supporting stands of Triplet Q's has been changed from iron to stainless steel to aim to avoid concentration of leaked field. But the beam transmission is not improved

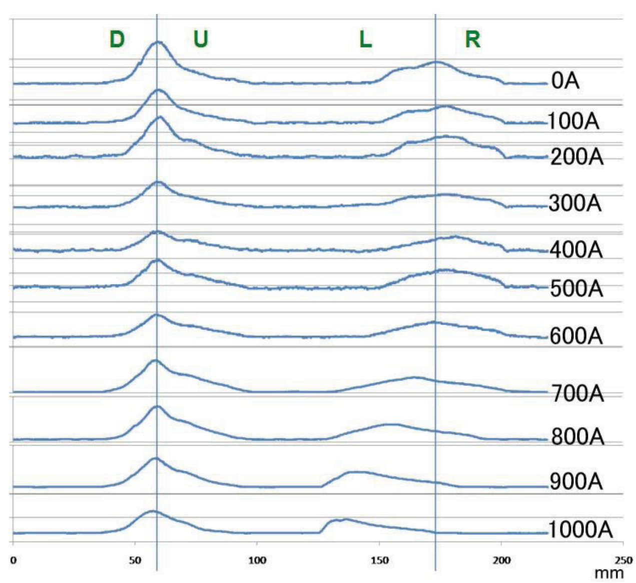

Figure 5: The beam profiles which are corresponding to each current of the main coil of AVF cyclotron. In this figure, D and U mean down and up side on the Y profile and L and R are left and right on X direction also shown in Figure 3.

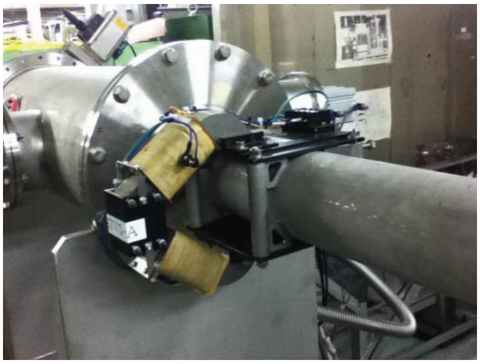

Figure 6: additional steering gmagnet

even though the optimum values of Triplet Q's are changing. Additional steering magnet as shown in Figure 5 also has been installed between two triplet Q's. This steering magnet pole length on beam axis is 180mm.

Beam test of 20Ne6+ for the transmission improvement with these new steering magnets has been carried. The position of steering magnets installation is shown in Figure 3. The conditions and results are shown in Table 2. Currents of steering magnets are optimized for the beam current at FC3 to be maximum and it is shown that the steering magnets are effective for improvement of transmission of ion beam transport line.

Table 2: Conditions and results of 20Ne6+ beam test for transmission improvement with additional steering magnets ST1 and ST2. The positions of FC1~3 are shown in Figure 1.

Main Coil [A]	Extract Voltage [V]	ST1 [A]	ST2 [A]	FC1 [uA]	FC2 [%]	FC3 [%]
1200	-6	0.2	0.55	130	69	54
1200	0	0.3	0.41	50	70	54
1200	0	0	0	65	46	32
600	-4	0.17	0.45	77	58	55

SUMMARY

The modifications of extraction electrode system have been done for increasing beam current from the SC-ECR ion source. Installation has been done and preliminary beam test has been carried with -6 kV extraction voltage against the 12 kV plasma voltage and ion beam of 20NE6+ is increasing as the extraction voltage rising. The beam test with full voltage of -20 kV would be done after solving the discharging problem.

The installation of additional steering magnet on the transport line has also been done for improving beam transmission from SC-ECR to AVF cyclotron injection. The transmission might get worth due to the field leakage from main coil of AVF cyclotron. Beam test for the improving transmission also has been done and it is confirmed that the steering magnets work well but not enough. Detail studies for the improvement with whole transport system would be continued.

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