DEVELOPMENT IN HEAVY ION ACCELERATION AT RCNP

T. Itahashi, T. Saito, H. Ogata, N. Matsuoka, K. Hosono, M. Inoue, A. Shimizu, I. Miura, T. Yamazaki and M. Kondo

Research Center for Nuclear Physics, Osaka University

Abstract

Several highly stripped ions could be accelerated and extracted using a newly constructed pulsed arc power supply. Optimum parameters for accelerator and ion source were obtained to extract $^{7}Li^{3+}$, $^{12}C^{5+}$, $^{13}C^{5+}$ and $^{20}Ne^{7+}$ ions respectively.

1. High Power Pulsed Arc Supply

The arc power supply for the cold-cathode PIG source has been constructed. It consists of a series tetrode tube (4CW50000E) for the regulation of output current, its driver circuits, feedback circuits for the constant current, a pulse generator, high voltage power supplies for the anode, control and screan grid and monitor and interlock circuits. The supply can deliver up to 10A of DC current at 6.0 KV. It can also operate in pulse mode without switching dc to pulse, making it possible to superpose these voltages and currents. The maximum output current of pulse mode is limited to 30 A under 30% duty factor. The supply can be isolated up to 15 KV for the PIG source to use at high voltage. Electrical specifications are shown in Table 1

2. Heavy Ion Acceleration

The work for heavy ion acceleration using the high power pulsed arc supply has been focussed to generate $^{12}C^{5+}$ and $^{20}Ne^{7+}$ ions. In the case of $^{20}Ne^{7+}$ ions, its resonance could not be found easily due to very small yield of the ions. For overcoming these difficulties, it is useful to start with an easier one, that is, $^{20}Ne^{6+}$ ions. However, it was frequently happened to misunderstand $^{20}Ne^{2+}$ and $^{20}Ne^{6+}$ at the tuning of the main magnetic field. Generally, it happens occasionally to accelerate ions that have the same product of change to mass ratio and rf harmonic number, that is, $h_1q_1/m_1 = h_2q_2/m_2$, where h_1 or $h_2 = 1,3,5, \cdots$. $^{20}Ne^{2+}$ on the 3rd harmonics is in close resonance with $^{20}Ne^{6+}$ on the fundamental mode. These mixed ions beams at different harmonics are separated by the electrostatic deflector. So, even if the tuning is set to $^{20}Ne^{2+}$ on the 3rd harmonics, these beams cannot be extracted by the proper deflector voltage for $^{20}Ne^{6+}$ beams. Although these circumstances do not make excuses to mistake $^{20}Ne^{6+}$ and $^{20}Ne^{2+}$, it is not so simple to fix the several parameters for $^{20}Ne^{6+}$ acceleration and to get optimum condition for the PIG ion source. In order to reduce the yield $^{20}Ne^{2+}$ beam on the 3rd harmonic mode, the pullers having the shape of a cannal was tried to block out ions of the low charge state at the initial region of acceleration. The graphite pullers with a dimension of 5 mm (width) × 10 mm (height) at inlet and 7 mm × 13 mm or 3 mm × 8 mm at outlet affected hardly the reduction of $^{20}Ne^{2+}$ ions beam. The effective way to distinguish $^{20}Ne^{6+}$ beam from $^{20}Ne^{2+}$ beam, was the detection of neutron generated from the beam probe. Most optimum condition of the pulsed arc power supply for the PIG ion source was usually obtained after 3~4 hours after its ignition. The extracted beam current was 350 nA at Ne gas flow rate of 1.2 ~1.5 cc/min. At the time which $^{20}Ne^{6+}$ ions beam increased to the nearly maximum, the cyclotron parameter was set to the condition for the $^{20}Ne^{7+}$ acceleration. By this procedure, 5 ~ 7 nA (electrical ampere) of $^{20}Ne^{7+}$ ions beam was obtained at the extraction.

The same method was applied to get $^{12}C^{5+}$ beams from intense beams of $^{12}C^{1+}$ on the 5th harmonics. In this trial methane gas was turned out not to fit to the higher ionization potential than C^{4+} ions although for C^{4+}

ions, usage of methane gas can maintain the lifetime of the PIG source for more than 20 hours. Due to this fact, CO_2 gas mixed with N_2 was used to get $^{12}C^{5+}$ ions beam. The optimum arc condition is 17 A at 500 V with 30% duty factor. Gas flow rate of N_2 and CO_2 is 1.00 cc/min and CO_2is1.6 cc/min respectively. The extracted beam current was 48 nA.

Another success was an acceleration of the element of solid material which was made using a method developed at ORIC. INS also used the same method and applied to the single orystal of LiF to accelerate $^6Li^{3+}$, $^7Li^{3+}$ ions. Our method was the same procedure as those at the former laboratories. A single crystal of LiF (5 mm 5 mm 20 mm) was buried into the back side of the anode. The single crystal was sputtered by Xe^{1+} ions returned from its 1st turn. At the start of the arc, Xe gas mixed with N_2 gas was used to stabilize the arc and then pure Xe gas at the flow rate about 0.08 cc/min was used. Extracted beam current reached to 300 nA which was closely correlated to the angle of the ion source rotation and the dee voltage.

The work now in progress is to get more intense $^{20}Ne^{7+}$ ions beams and $^{12}C^{5+}$ ions beams. The lower and upper cathode will be fixed into cathode holder inorder to cool down more effectively. The another work is to make the gas feed system for corrosive or poisonous gases. The first try is scheduled to accelerate B^{4+} or F^{5+}, F^{6+} using BF_3 gas. Heavy ions which are presently accelerated by the RCNP cyclotron are shown in Table 2.

Table 1

Ignition voltage	6.0 kV
Output current	DC 0 ∿ 10 A pulse 0 ∿ 30 A DC + pulse 0 ∿ 10 A
Repetition rate	300 Hz ∿ 10 kHz
Duty cycle	0.1, 0.15, 0.2, 0.25, 0.3
Pulse rise and fall time	10 μS
Output current stability	less than 1%
Insulation voltage at output	15 kV DC

Table 2

RCNP CYCLOTRON HEAVY ION BEAM. (Sep. 1982)

	MeV	$120q^2/A$	I_{ext} (μA)	
$^7Li^{3+}$	115-148	154	0.5	single crystal LiF
$^{11}B^{3+}$	95	98	1	$BF_3 + N_2$
$^{12}C^{2+}$	36-39	40	$\gtrsim$3	
$^{12}C^{3+}$	80	90	$\gtrsim$3	
$^{12}C^{4+}$	80-160	160	1∿3	CO, CO_2, CO_2+N_2
$^{12}C^{5+}$	146-215	250	0.05	CO_2+N_2
$^{13}C^{2+}$	36	40	>5	
$^{13}C^{3+}$	56-88	90	>5	*
$^{13}C^{4+}$	146	147	0.5	*
$^{13}C^{5+}$	172	230	0.01	*
$^{14}N^{4+}$	115-135	137	>5	
$^{14}N^{5+}$	160-210	214	5	
$^{14}N^{6+}$	297	309	<1 nA	
$^{15}N^{4+}$	96	128	2	*
$^{16}O^{4+}$	80	120		
$^{16}O^{5+}$	180	188	1	
$^{16}O^{6+}$	260	270	0.15	
$^{18}O^{5+}$	160	167	1	*
$^{20}Ne^{4+}$	90-95	96	>1.0	
$^{20}Ne^{5+}$	150	150	1.0	
$^{20}Ne^{6+}$	200-216	216	0.5	
$^{20}Ne^{7+}$	254	294	0.005-0.01	
$^{22}Ne^{3+}$	42	49	0.4	5th. *
$^{22}Ne^{4+}$	76	97		*

* Isotopically enriched source feed