IMPLEMENTATION AND PRELIMINARY TEST OF ELECTRON BEAM ION SOURCES AT KOMAC*

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Abstract

Electron beam ion source (EBIS) has been one of widely used table-top devices for the production of highly charged ions by electron impact ionization. An EBIS employs a magnetically compressed, high energy and density electron beam to sequentially ionize atoms or ions in a low charge state. At Korea Multi-purpose Accelerator Complex (KOMAC), we have a compact room-temperature operated EBIS. It is additionally constructed with a dipole magnet and a Faraday Cup to measure charge spectra of various elements. Using this measurement setup, preliminary tests are performed to characterize suitable operational conditions in the EBIS for a stable production of highly charge ions. First few data is presented as a start of our EBIS setup. Our future plans will be discussed briefly.

INTRODUCTION

Combination of an EBIS and an RFQ is a suitable means of heavy ion beam production at low energies. With EBIS, beams of any element can be prepared including uranium and spin-polarized ^{3}He. It has demonstrated its reliability and flexibility as a pre-injector used at several accelerators and collider facilities such as Brookhaven National Laboratory, Relative Heavy Ion Collider, NASA Space Radiation Laboratory, Argonne National Laboratory and Large Hadron Collider [1, 2, 3].

At KOMAC, we are currently developing an RFQ based ion beam accelerator in which an EBIS is employed as an ion source. It can be applied to experiments related to semiconductor material, nuclear fusion, neutron imaging etc. At present, a simple experimental setup is constructed to characterize our EBIS system with a dipole magnet as a magnetic analyser and a Faraday cup as a detector. Helium (He) and Argon (Ar) gases are tested to produce charge spectra. Here, we present our status of art and first sets of charge spectrum measurements of He and Ar.

In near future, we aim to build an EBIS based pre-injector with a radio frequency quadrupole (RFQ). It has advantages of having a simple operation and production of a large number of ion elements. To accomplish this, we intend to improve and modify the current EBIS design to incorporate with setups at KOMAC. And our ultimate goal is to design and develop a superconducting EBIS for an electron beam of high density and energy to achieve the highest ion charge states of our interest such as xenon and uranium.

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EXPERIMENT

Figure 1 shows an experimental setup at KOMAC, consisting of a commercially available EBIS (Dreebit GmbH), a dipole magnet and a Faraday cup. The EBIS operates with an electron gun, a strong permanent magnetic coil and three drift tubes. The electron gun in the EBIS produces a highly emissive electron beam for the ionization. The magnetic coil compresses the electron beam to increase the density of electrons, which improves the efficiency of the ionization. Ions are produced by electron impact ionization. Then, these ions are confined radially by negative space charge of the electron beam and axially by electrostatic potential formed by three drift tubes. The ions of various charge states and masses are produced in the EBIS. To characterize the extracted ion beam from the ion source, we employ the dipole magnet to separate the ions depending on their charge states and masses. It is basically a bending magnet with a focal length of 1.28 m, deflecting only a certain mass-to-charge ratio at 90°. Magnetic field strength, **B** is plotted as a function of a current, **I** of the dipole magnet in Fig. 2. For detection, we place a slit in front of the Faraday cup to filter out and improve an ion signal. Output of the Faraday cup is connected to a current preamplifier to enlarge the ion signal.

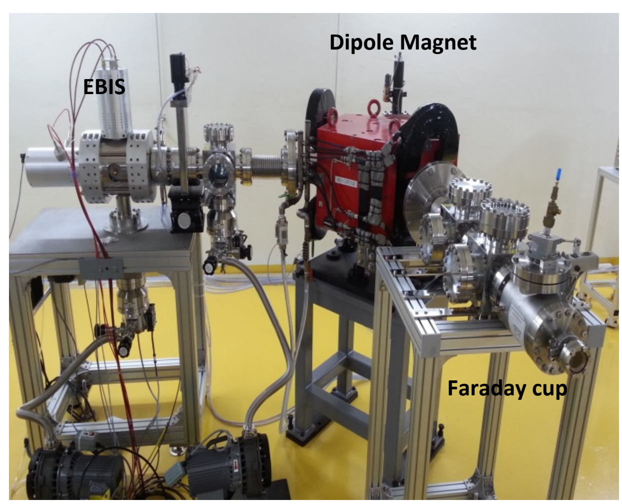

Figure 1: Picture of the experimental setup.

He gas is chosen to study an ion extraction spectrum, due to its simple electronic structure. He is inserted to the EBIS steadily, and ionization time is controlled by switching the exit side of the drift tube. At a certain ionization

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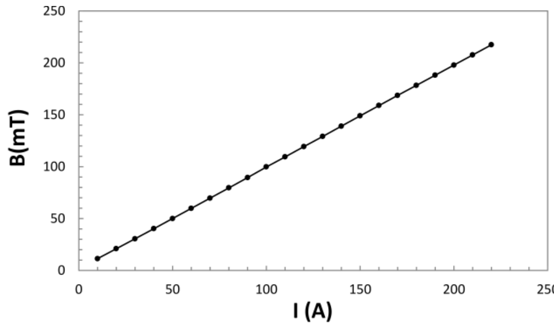

Figure 2: Dipole magnet characterization: magnetic field, **B** as a function of a current in the dipole magnet, **I**.

time, we scan the magnetic field, **B** of the dipole magnet by scanning the magnet current, **I**. A desired mass-to-charge ratio of the ion beam is selected through the slit and detected on the Faraday cup.

Once He is tested for the system, Ar gas is inserted to the EBIS for the production Ar ions of various charged states. Ar has 18 electrons, giving us a much wide scan range of magnetic field in the dipole magnet.

RESULT

Figure 3 shows the measured He charge spectrum. The extracted ion signals from the EBIS via the dipole magnet are plotted as a function of the magnetic field strength. The drift tube base potential is kept at ~9 kV. After 100 ms of ionization time, the exit part of the drift tube switches its potential to push trapped ions out of the EBIS to the dipole magnet, then to the Faraday cup. The data points are obtained from the average of 100 measurements per magnetic field value. The magnetic field is scanned from 30 to 82 mT. In the Fig. 3, H^+, He^+ and He^{2+} are identified with respect to the magnetic field values, corresponding to their mass-to-charge ratios. The peaks

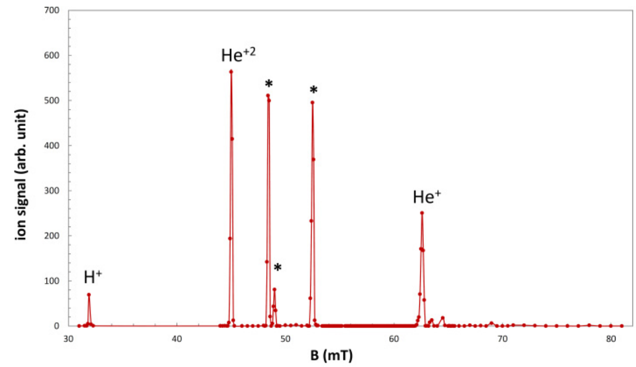

Figure 3: A He ion extraction spectrum measured as a function of magnetic field, **B**.

between the two He peaks are residual gas ions. The EBIS has a background vacuum pressure about ~4 x 10^{-9}. This high background pressure gives rise to additional peaks indicated as * in Fig. 3.

The same procedure is repeated for Ar gas, but with a wider scan range of 60 to 210 mT. Figure 4 shows the Ar charge spectrum from Ar^+, Ar^{2+}… till Ar^{+11} as a function of magnetic field, **B**. They are well separated from the background and very close to our magnetic field calculation of the dipole magnet. But the charge states from +12 onwards upto +18, ion signals are completely indistinguishable from the background residual gases. They are all mixed up with the residual gas ion signals as higher the charge state is smaller the ion signal in general. We are going to further examine the case with an extra care. Nevertheless, Figs. 3 and 4 show our successful working of the EBIS at KOMAC.

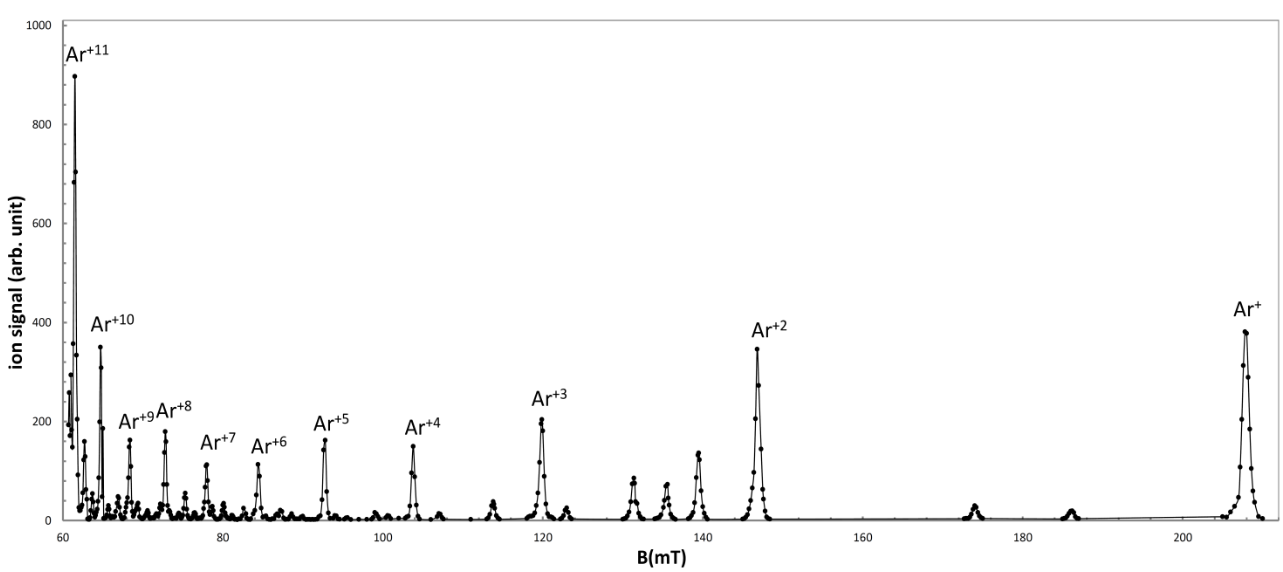

Figure 4: An Ar ion extraction spectrum measured a function of magnetic field, **B**.

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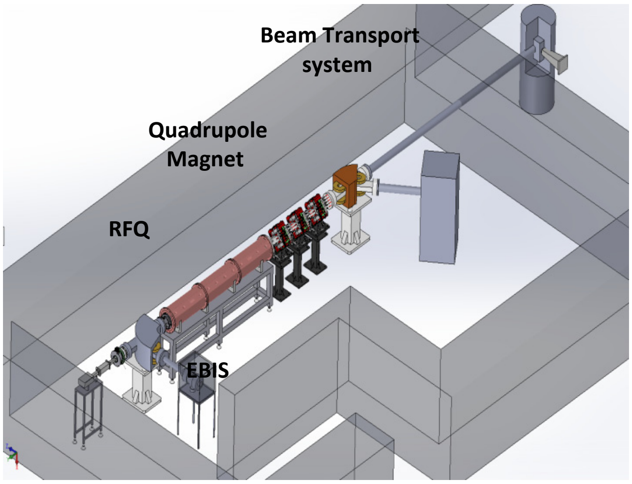

Figure 5: Ion beam accelerator based on RFQ.

CONCLUSION

There has been a considerable progress in our EBIS setup. We have set up the EBIS and measured charge spectra of He and Ar as a preliminary beam test. As it is just a start, there is lots of work to be done in our plan. Figure 5 is a layout of one of the plans at KOMAC. It is an ion beam accelerator based on RFQ for neutron applied experiments. Our next generation EBIS will be a superconducting EBIS for the production of highly charged ions of heavy elements.

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