ISBN: 978-3-95450-184-7 doi:10.18429/JACoW-IPAC2018-TUPML076

INSTALLATION, COMMISSIONING AND CHARACTERIZATION OF EBIS-SC AS A SHORT PULSED PROTON SOURCE AT KOMAC

S. Lee*, H.-J. Kwon, H.-S. Kim, Y.-S. Cho, Korea Multipurpose Accelerator Complex, Korea Atomic Energy Research Institute, 38180 Gyeongju, Korea

Abstract

Neutron sources are applicable to various fields in basic/applied science and industries. There are several neutron sources in the world such LENS, SNS, J-PARC, ISIS and ESS either for short or long pulsed neutron. At Korea Multipurpose Accelerator Complex (KOMAC), to provide wide ranges of research opportunities to beam user, a 100 MeV proton linac based pulsed neutron source is planned for both long and short pulses of neutron source. Currently, the 100 MeV proton linac is operational with a 2 ms long pulsed proton injector, i.e. a microwave ion source. We will upgrade our injector by combining the already existing microwave ion source with an EBIS-SC (Superconducting Electron Beam Ion Source from Dreebit GmbH) for short pulses (< 1 µs) of proton. This planned injector will work one source at the time and provide long/short pulses of accelerated proton hitting a target to emit correspondingly long/short neutron pulses. Main modification on the proton injector is the EBIS-SC, so in this paper we report the installation, and commission of the EBIS-SC test bench at KOMAC. And the characterization of the EBIS-SC is described in detail.

INTRODUCTION

At KOMAC, we have several EBIS projects such as EBIS-A test bench [1], 7 T EBIS and EBIS-SC. To develop a short neutron pulse source, the current proton injector for the 100 MeV accelerator is planned to modified to produce a short pulse below 1 µs. An EBIS-SC from Dreebit GmbH [2, 3] will be installed along with the currently operating 2 ms proton source. Before the installation in the accelerator tunnel, the EBIS-SC is installed and commissioned at KOMAC laboratory. The EBIS-SC is incorperated with a Short Pulse Electronics (SPE) unit also from Dreebit GmbH [4], to switch the high voltage in sub µs during the extraction. The EBIS-SC has been installed together with Dreebit EBIS experts. With the commissioning of the EBIS-SC, it was characterized to test the ion extraction performance. In the paper, we describe the entire installation and commissioning of the EBIS at KOMAC.

EBIS-SC

The EBIS-SC consists of an electron gun of an anode and a cathode of max. 300 mA, a superconducting magnet of 6 T, three drift tubes, an electron collector and an electron repeller. The electron beam from the electron gun is accelerated by the anode and guided to the drift tube region where the electron beam experiences the highest magnetic field and get highly compressed. The highly densed electron beam ionizes neutral gases in the drift tube region. After a certain ionization time, the ions are extracted to the Faraday cup in the beamline to measure the output current via. two Einzel lenses and X-Y deflector. The beamline part is electrically isolated from the EBIS-SC. The base potential of the EBIS-SC can be lifted up to match the required beam energy in the proton injector.

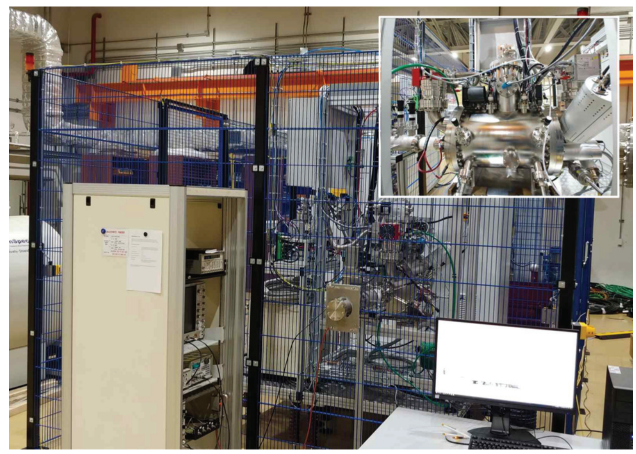

Figure 1: The EBIS-SC test bench at KOMAC. The inset is a zoomed view of the EBIS-SC.

Installation

The EBIS-SC was delivered and assembled at KOMAC. Vacuum pumps were connected to bring the pressure down till 10^{-7} mbar. We baked the entire chamber for about three days at 100°C. The water cooling circuit and the safety interlock were connected. In Fig. 1 shows the EBIS-SC installed at KOMAC. SPE unit is additionally connected with the high voltage supplies to perform the short pulse extraction. The cathode at -1700 V with the cathode heater current at 6 A and the anode at 8000 V emits the electron current about 265 mA. The superconducting magnet at 3.7 K is ramped upto 6 T by supplying the magnet current of 106 A, and operated in the persistent mode.

Commissioning

In the beamline part, an inline diagnostic unit is installed on the ground potential. The ion current is measured by a retractable Faraday cup in the inline diagnostic unit. Ion optics such as Einzel lenses and X-Y deflectors was adjusted to maximize ions detected at the Faraday cup. Output of the Faraday cup is connected to a variable gain low noise current amplifier (DLPCA-200) from Femto.

* shl@kaeri.re.kr

9th International Particle Accelerator Conference IPAC2018, Vancouver, BC, Canada JACoW Publishing
ISBN: 978-3-95450-184-7 doi:10.18429/JACoW-IPAC2018-TUPML076

COMMISSIONING RESULT

Commissioning was performed at the EBIS-SC base potential at ground and at 50 kV as shown in the Fig. 2 a) and Fig. 3 a).

The EBIS-SC on the Ground Potential

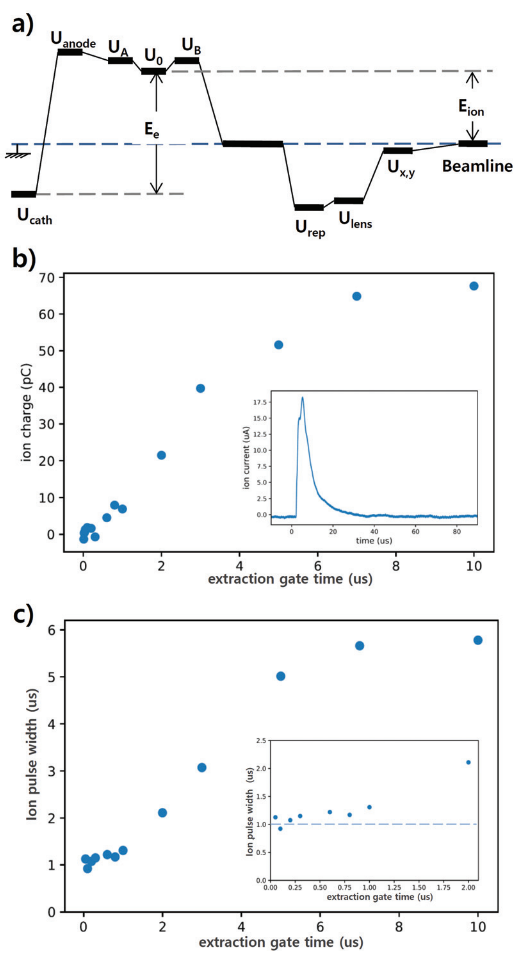

Figure 2: The EBIS-SC at the ground potential. a) Scheme of the potentials in the EBIS-SC, b) a plot of ion charge as a function of the extraction gate time, and c) a plot of ion pulse width (FWHM) as a function of the extraction gate time.

With the repetition rate of 100 ms and the extraction time of 1 ms (normal operation), the maximum beam current was measured to be 18 µA, corresponding to 147 pC shown in Fig. 2 b) inset. When the SPE unit is installed and operated for the short pulse mode at 10 µs, the ion current is decreased almost to the half of that in the normal operation, i.e. about 70 pC due to change in the extraction potential scheme (at U_B). In Fig. 2 b), the ion charge is plotted as a function of the extraction gate time from 10 ns to 10 µs when repetition rate = 100 Hz. The charge is decreased as the extraction gate time gets shorter, and below 30 ns of the extraction gate time, no ion signal was detected. With the same set of data, the ion pulse width (FWHM) is plotted again as a function of the extraction gate time, showin the Fig. 2 c). Below 1 µs extraction gate time, the ion pulse width was all measured about 1 µs.

The EBIS-SC on the 50 kV Potential

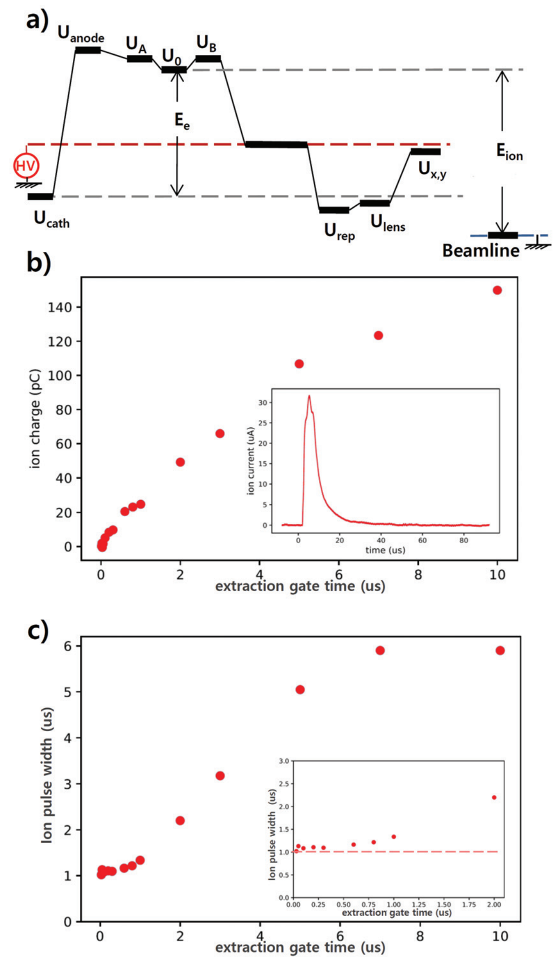

Figure 3: The EBIS-SC at the 50 kV potential. a) Scheme of the potentials in the EBIS-SC, b) a plot of ion charge as a function of the extraction gate time, and c) a plot of ion pulse width (FWHM) as a function of the extraction gate time.

The same measurement procedure was repeated in the normal mode (the repetition rate of 100 ms and the extraction time of 1 ms) and in the short pulse mode. In the normal mode, the maximum ion charge is measured to be 32 µA, corresponding to 249.7 pC. In the short pulse mode, the total charge is also reduced to almost half of that in the normal mode and is measured to be 150 pC. Similar results were obtained from the EBIS-SC on the S50 kV potential as compared with that on ground. The charge is decreased as the extraction gate time gets shorter, and below 30 ns of the extraction gate time, no ion signal was detected. For the pulse width measurement, below 1 µs extraction gate time, the ion pulse width was also measured about 1 µs.

ISBN: 978-3-95450-184-7 doi:10.18429/JACoW-IPAC2018-TUPML076

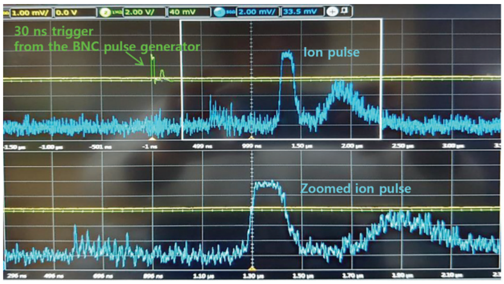

Figure 4: Extracted ion pulse using a fast-filter amplifier (579) from the Ortec.

There are two main reasons why we did not see any short pulses below 1 µs. First is that the inherent capacitance of the trap limits fast-switching of the extraction electrode (U_B). For now, we are working on resolving the first problem. The second reason is the bandwidth limitation of the Femto amplifier for such short pulses. The Femto amplifier has a specification of the rise/fall time as 700 ns for 10^5 gain setting. It would limit our short pulse measurement which showed no ion pulses below 1 µs. We replaced it to another amplifier which is a fast-filter amplifier (579) from the Ortec. It has a specification of the rise time <5 ns. Fig. 4 is a capture of oscilloscope which shows the ion extraction signal (in blue) when 30 ns of the extraction gate trigger (in green). The ion pulse width is measured to be 150 ns for 30 ns extraction gate trigger. Below 28 ns, we did not see any ion beam extracted.

CONCLUSION

We installed and commissioned the EBIS-SC from Dreebit GmbH. To match the energy required for the input of the Radio-Frequency Quadrupole at KOMAC, we lifted up the base potential of the EBIS-SC upto 50 kV. The maximum ion beam pulse we obtained is 249.7 pC when 265 mA of the electron current was applied. In the SPE unit test for the short pulse width measurement, the shortest pulse width was obtained as 150 ns when the extraction trigger was 30 ns. We are currently working on reducing the pulse width further down and optimizing to maximize the ion charge. In very near future, we will install the EBIS-SC in the KOMAC accelerator tunnel and operate it as a short pulse proton injector for the production of short neutron pulses.

ACKNOWLEDGEMENTS

This work has been supported through KOMAC operation fund of KAERI by Ministry of Science and ICT.

REFERENCES

[1] S. Lee, H.-S. Kim, H.-J. Kwon, and Y.-S. Cho, "Implementation and preliminary test of electron beam ion sources at KOMAC", *in Proc. 7th Int. Particle Accelerator Conf. (IPAC'16)*, Busan, Korea, May 2016, pp.1311-1313, doi:10.18429/JACoW-IPAC2016-TUPMR031

[2] G. Zschornack, M. Schmidt, and A. Thorn, "Electron Beam Ion Sources", arXiv:1410.8014v1, Oct. 2014, doi:10.5170/CERN-2013-007.165

[3] G. Zschornack, and M. Kreller, "Compact electron beam ion sources/traps: Review and prospects (invited)", *Rev. Sci. Instrum.*, vol. 79, p. 02A703, Feb. 2008, doi.org/10.1063/1.2804901

[4] U. Kentsch, G. Zschornack, A. Schwan, and F. Ullmann, "Short time ion pulse extraction from the Dresden electron beam ion trap", *Rev. Sci. Instrum.*, vol. 81, p. 02A507, Feb. 2010, doi.org/10.1063/1.3271255