Current Status and Future Plans of the Korea Atomic Energy Research Institute Heavy Ion Irradiation Facility

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1. Introduction

Based on linear accelerators (linacs) of the Tokai Radioactive Ion Accelerator Complex (TRIAC) given from the high energy accelerator research organization (KEK), Japan [1–4], a heavy ion beam irradiation facility named Korea Atomic Energy Research Institute Heavy Ion Irradiation Facility (KAHIF) has been successfully built at Korea Atomic Energy Research Institute (KAERI), Daejeon, Korea. The KAHIF produces heavy ion beams with energies up to about 1 MeV/nucleon for nuclear/fusion materials research and development. In this article, current status and future plans of the KAHIF are presented and discussed.

2. Description of the KAHIF

An ion beamline of the KAHIF comprises an electron cyclotron resonance (ECR) ion source, a low energy beam transport (LEBT), a split-coaxial radio-frequency quadrupole (SCRFQ) linac, a rebuncher (RB), four interdigital H-type (IH) linacs, a high energy beam transport (HEBT), and a target chamber as shown in Fig. 1 (a) and (b).

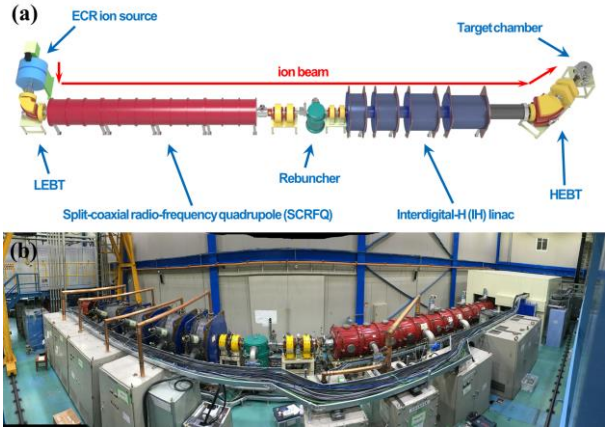

Fig. 1. (a) Schematic layout of the KAHIF, (b) picture of the beamline.

The KAHIF is designed to provide stable non-radioactive beams. The 18 GHz ECR ion source together with the LEBT can supply linacs with ions heavier than protons. The 25.96 MHz SCRFQ linac accelerates the heavy ions up to 178 keV/ nucleon. Then, the accelerated ions reach to the 51.92 MHz IH linacs via a transport system composed of an RB and two sets of quadrupole doublet. Finally, the IH linacs can reaccelerate the ions up with energies up to 1.09 MeV/nucleon. The ions are delivered to the target chamber through the HEBT. The detailed specifications of the KAHIF linacs and available beam energies can be found in Table I [1] and II, respectively.

Table I: Specifications of the KAHIF linacs

	SCRFQ	*IH*
Frequency	25.96 MHz	51.92 MHz
Charge-to-mass ratio	≥ 1/28	≥ 1/9
Input energy	2.07 keV/nucleon	178 keV/nucleon
Output energy	178 keV/nucleon	178–1090 keV/nucleon
Normalized emittance	0.6πmm·mrad	
Energy spread	1.03%	≤ 2.8%
Repetition rate	20–1000 Hz	
Total length	8.6 m	5.6 m

Table II: Available beam energies of the KAHIF

Mode	*RFQ power*	*IH1 power*	*IH2 power*	*IH3 power*	*IH4 power*	*Beam energy (keV/nucleon)*
SCRFQ mode	on	off	off	off	off	172
IH1 mode	on	on	off	off	off	293
IH2 mode	on	on	on	off	off	476
IH3 mode	on	on	on	on	off	726
IH4 mode	on	on	on	on	on	1090

3. Current Status of the KAHIF

To date, acquisition of the radiation safety license, performance testing of the beamline components, and first ion beam acceleration tests have been successfully completed.

The ion beam acceleration tests have been carried out for the purpose of checking the accelerator performance. For the tests, He^{+} and Ar^{10+} ions were selected by adjusting magnetic field intensity of the LEBT bending electromagnets and accelerated in the IH4 mode. Results of the first ion beam acceleration tests are summarized in Table III.

Table III: Results of the first ion beam acceleration tests

	He^{+}	Ar^{10+}
Beam energy	4.2 MeV	42.3 MeV
Peak beam current	7.8 eμA (@ 4.2 MeV)	0.8 eμA (@ 42.3 MeV)
Duty cycle	28.8%	
Repetition frequency	120 Hz	
Pulse width	2.4 ms	
Beam flux	4.9×10^{17} #/m^2·s	5.1×10^{15} #/m^2·s
Beam irradiation condition	Horizontal / Vacuum	
Beam spot size	10×10 mm^2	

The beam currents were measured with a Faraday cup in the target chamber, and the measured values of He^{+} and Ar^{10+} beam currents were 7.8 and 0.8 eμA, respectively.

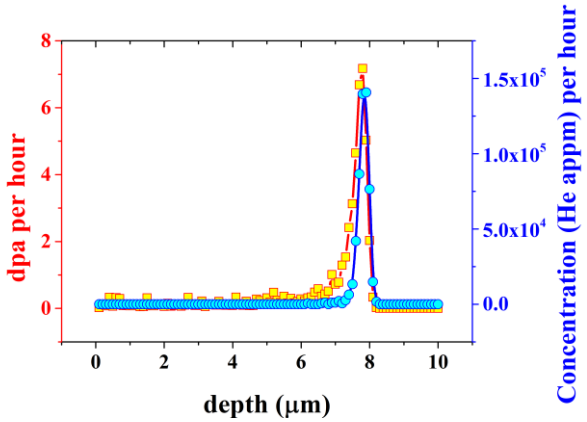

Fig. 2. SRIM/TRIM-predicted depth profiles of displacement per atom (dpa) per hour and induced He ion concentration in Fe per hour for the He^{+} beam acceleration test.

From the beam current information, a damage analysis can be performed using SRIM/TRIM package (Stopping Range of Ions in Matter) [5] as shown in Fig. 2. More details of the damage analysis will be reported in the presentation.

Since the facility is still in need of optimization of beam dynamics, it is expected that the beam currents can be increased by the upcoming delicate beam tuning. Presently, commissioning of the KAHIF accelerators for preparation of user service are in progress.

4. Future Plans

Heavy ion beams in the KAHIF now serve a vast range of scientific users in the fields of nuclear/fusion engineering. The facility can be used for simulating nuclear/fusion reactor environments. In the near future, a project to achieve higher utilization will be launched. The beam tuning for improving the beam quality, development of a new metal ion source for supplying metal ion beams to the users, and applying artificial intelligence to accelerator control system for beam fine tuning may be primary goals of the project.

REFERENCES

[1] TRIAC collaboration (edited by S.-C. Jeong), "TRIAC Progress Report", KEK Progress Report 2011-1, 2011.
[2] Y.X. Watanabe, S. Arai, Y. Arakaki, Y. Fuchi, Y. Hirayama, N. Imai, H. Ishiyama, S.C. Jeong, H. Kawakami, H. Miyatake, K. Niki, T. Nomura, M. Okada, M. Oyaizu, M.H. Tanaka, M. Tomizawa, N. Yoshikawa, S. Abe, S. Hanashima, T. Hashimoto, S. Ichikawa, H. Ikezoe, T. Ishii, N. Ishizaki, H. Kabumoto, I. Katayama, M. Koizumi, M. Matsuda, S. Mitsuoka, T. Nakanoya, K. Nishio, I. Ohuchi, A. Osa, T.K. Sato, S. Takeuchi, H. Tayama, and Y. Tsukihashi, Eur. Phys. J. Special Topics Vol.150, p.259, 2007.
[3] A. Osa and the TRIAC collaboration, Nuclear Instruments and Methods in Physics Research B, Vol.261, p.1048, 2007.
[4] H. Sakurai, Nuclear Instruments and Methods in Physics Research B, Vol.266, p.4080, 2008.
[5] J. F. Ziegler, SRIM-2013 software package, available online at http://www.srim.org.