The Control System 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 [5]. In 2022, a portion of KAHIF has been utilized to provide services to irradiates two types of ion beams, He^{+} and Ar^{10+}. This presentation is about the beam irradiation service performed and the control system used for it.

2. Introduction of facility and services performed

This section introduces the facility and details the services and control systems associated with it.

2.1 KAHIF Description

An ion beamline of the KAHIF consists of 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).

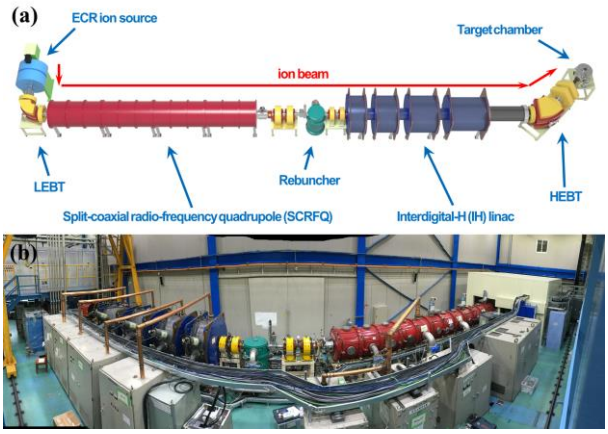

Fig. 1. (a) Schematic layout of the KAHIF, (b) picture of the beamline.

The KAHIF can only provide stable non-radioactive beams. The 18 GHz ECR ion source supplies linacs with ions heavier than protons through the LEBT. 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 major specifications of the SCRFQ and IH linacs can be found in Table I [1].

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	0.6π mm·mrad	
Energy spread	1.03%	≤ 2.8%
Repetition rate	20–1000 Hz	
Total length	8.6 m	5.6 m

2.2 Control System Description

The control system of it has been implemented as a distributed control system using the EPICS framework. Detailed information on the network-based distributed control system is given in Fig 2.

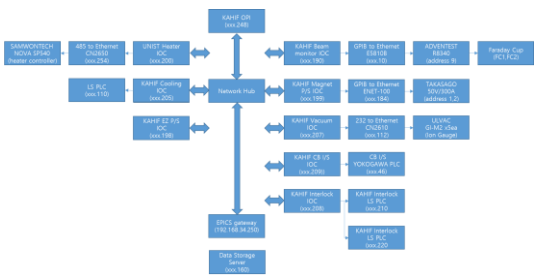

Fig. 2. KAHIF control system network diagram.

There have been added remote-controllable controls for the heater and specimen manipulation. The Table II shows the interface hardware for control of it.

Table II: Interface hardwares of the KAHIF

function	*Interface hardware*
Beam monitor	NI PXI based
Einzel lens control	NI PXI based
Interlock	LS PLC based
cooling control	LS PLC based
Magnet control	GPIB / NI ENET-100
Ion Source control	Yokogawa PLC based
Vacuum monitor	Serial / Moxa server
SCRFQ RF control	RFQ remote control panel & Signal generator
Low-Level RF control	PCI based PC (not used in this services)

2.3 Service Description

Only the SCRFQ linac has been utilized to irradiate specimens with He^{+} and Ar^{10+} ions. The Table III shows the characteristics of the irradiated ion beam and Fig 3 and 4 show the screenshot during the irradiation.

Table III: Properties of the ion beam irradiation services

	He^{+}	*Ar^{10+}*
Beam energy	0.69 MeV	6.9 MeV
Peak beam current	22 eμA (@ 0.69 MeV)	11.7 eμA (@ 6.9 MeV)
Duty cycle	28.8%	
Repetition frequency	120 Hz	
Pulse width	2.4 ms	
Beam flux	13.8×10^{17} #/m^2·s	7.3×10^{16} #/m^2·s
Beam irradiation condition	Horizontal / Vacuum	
Beam spot size	10×10 mm^2	

The beam currents were measured in the Faraday Cup in from of the specimen holder, and the measured values of He^{+} and Ar^{10+} beam currents were 22 and 11.7 eμA, respectively.

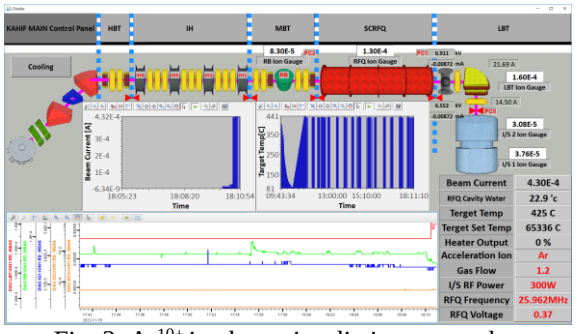

Fig. 3. Ar^{10+} ion beam irradiation screenshot.

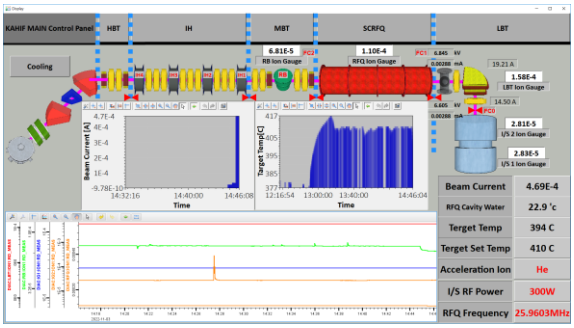

Fig. 4. He^{+} ion beam irradiation screenshot.

3. Conclusions

Due to various circumstances, a modification in the utilization of KAHIF has taken place, and preparations are underway to supply Fe^{+} ion beams to users from next year. The low-level RF control system still uses the method used by TRIAC, and in the conducted test, it was free from various problems that occur in the existing RF control system by using only SCRFQ in the cavity of KAHIF.

The presentation will describe the control systems associated with two types of ion bean irradiation services previously performed.

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