Transaction of the Korean Nuclear Society Spring Meeting
May 12th–14th, 2021

Korea Atomic Energy Research Institute Heavy Ion Irradiation Facility: Status and Improvement Plans

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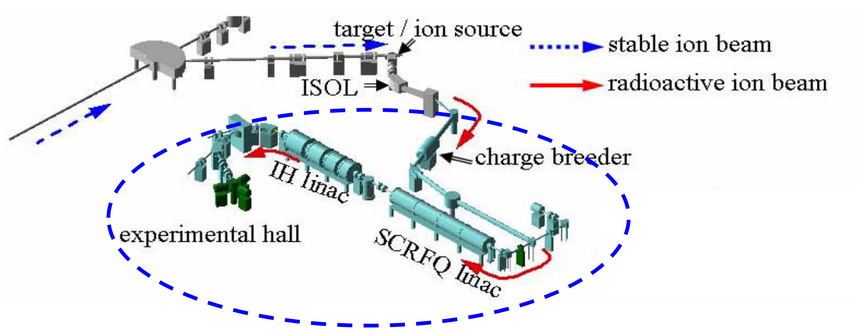
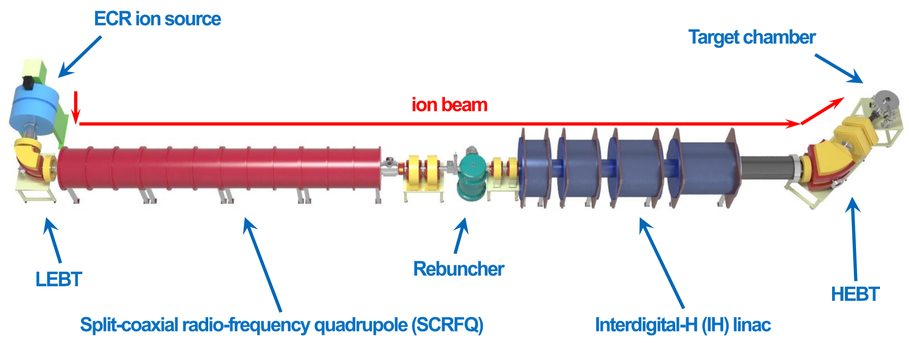
ABSTRACT: For the purpose of supporting nuclear/fusion material research and development, a heavy ion beam irradiation facility named Korea Atomic Energy Research Institute Heavy Ion Irradiation Facility (KAHIF) has been constructed at Korea Atomic Energy Research Institute (KAERI), Daejeon, Korea. This facility is based on linear accelerators (linacs) of the Tokai Radioactive Ion Accelerator Complex (TRIAC) given from the high energy accelerator research organization (KEK), Japan. The KAHIF produces heavy ion beams with energies up to about 1 MeV/nucleon for. In this article, present status and improvement plans of the KAHIF are presented and discussed.

Introduction

TRIAC (Tokai Radioactive Ion Accelerator Complex)



Korea Atomic Energy Research Institute Heavy Ion Irradiation Facility (KAHIF)



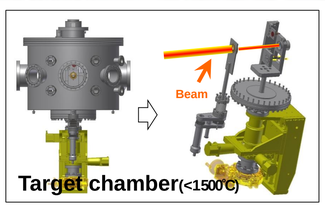
Specifications of the KAHIF linacs

	RFQ	IH
Frequency	25.96 MHz	51.92 MHz
Synchronous phase	- 30 deg.	- 25 deg.
Charge-to-mass ratio	≥1/28	≥1/9
Input energy	2.07 keV/u	178.4 keV/u
Output energy	178.4 keV/u	178.4 – 1090 keV/u
Normalized emittance	0.6π mm·mrad	0.6π mm·mrad
Energy spread	1.03%	≤2.8%
Duty factor	30 – 100%	100%
Repetition rate	20 – 1000 Hz	20 – 1000 Hz
Total length	8.6 m	5.6 m

- 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**.
- 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.

Current Status of the KAHIF and Operator Interface of the Control System

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.
- **Beam acceleration modes** (Available beam energies of the KAHIF)

Beam acceleration	SCRFQ power	IH1 power	IH2 power	IH3 power	IH4 power	Final beam energy
SCRFQ mode	○	X	X	X	X	172 keV/nucleon
IH1 mode	○	○	X	X	X	293 keV/nucleon
IH2 mode	○	○	○	X	X	476 keV/nucleon
IH3 mode	○	○	○	○	X	726 keV/nucleon
IH4 mode	○	○	○	○	○	1.09 MeV/nucleon

Summery of KAHIF control system

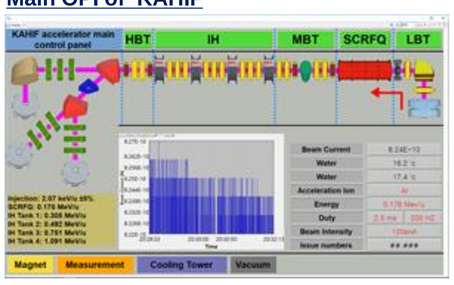
- Some of the previous TRIAC's control interface hardware consisted of a variety of platforms, including Omron PLC (Programmable Logic Controller) using Combo-bus and remote I/Os and FPs (Field Point). Most of them are not produced, so they have been replaced with LS PLCs for ease of maintenance.
- The operator programs of TRIAC were using LabView which was installed in the Window-98 based PC.
- For efficiency reasons, everything except RF and I/S operation was made to operate using EPICS, but the operation date of I/S can be saved and viewed using EPICS.

Interface Hardware of KAHIF

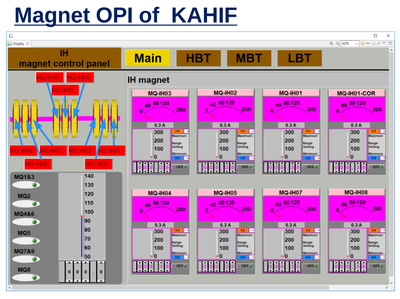
Function	Interface Hardware
Beam Monitor	NI PXI based (Linux)
Einzel Control & Monitor	NI PXI based (Linux)
Interlock	LS PLC based (Linux)
Cooling Control & Monitor	LS PLC based (Linux)
Magnet Control	GPIB/NI ENET-100 (Linux)
Vacuum Monitor	Serial/Moxa (Linux)
Ion Source Control & Monitor	Yokogawa PLC based (Window)
RF Feedback Control	NI PCI based (Window)
LLRF	Traditional Analog circuit

Operator Interface for KAHIF Control

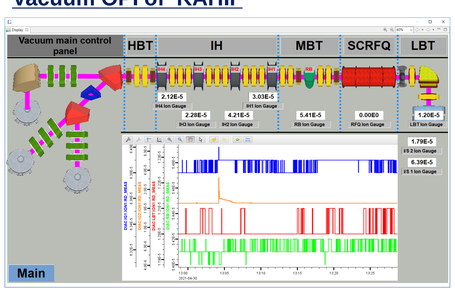
Main OPI of KAHIF



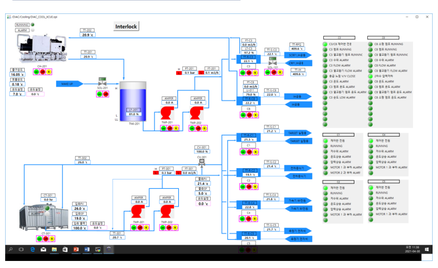
Magnet OPI of KAHIF



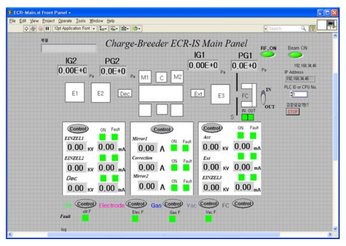
Vacuum OPI of KAHIF



Coolant OPI of KAHIF



LabView VI of Ion Source



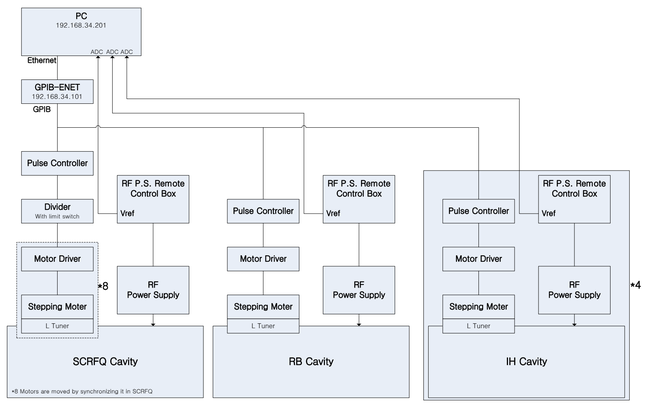
Ion Source OPI

Current RF control of KAHIF and Future Plans

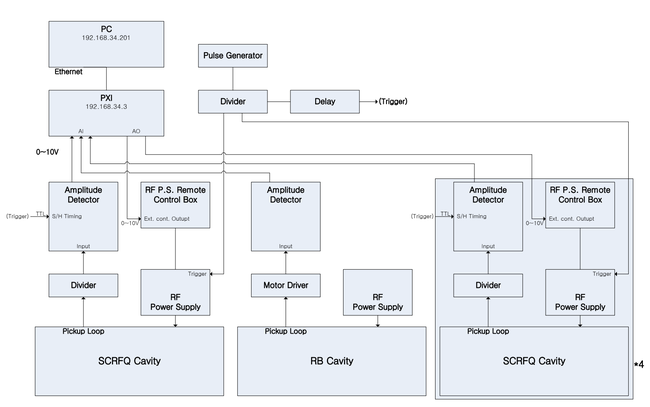
Feedback Control method of KAHIF

- The low level RF (LLRF) control system for KAHIF performs RF field regulation using traditional amplitude and phase loops.
- The tuner is controlled so that V_{ref}, the reflected RF power measured in the cavity, approaches zero.
- The external applied voltage of the RF P/S is adjusted through an amplitude detector that can be monitored with 0.01V resolution.
- The phase shifter is adjusted while maintaining the phase delay between each cavity.

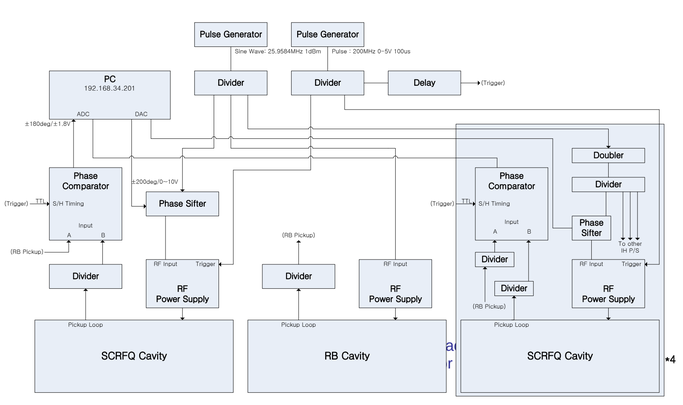
resonace frequency control



RF voltage control



Phase lag control



- Converting amplitude and phase information to IQ (In-phase, Quadrate) is advantageous due to the symmetry of the I/Q signal path, the less complex nature of the electronics, and a wider phase control range. Therefore, it is necessary to adopt and apply the IQ demodulation technique.
- The advantage of using digital LLRF is that is can achieve amplitude and phase stability better than 0.1% and 0.1˚, and provide more flexibility because most of the building blocks are program routines executed by DSP or FPAG.

Summary: The KAHIF has been constructed at KAERI, Daejeon, Korea, for nuclear and fusion materials research and development. This facility is designed to provide stable non-radioactive heavy ion beams with energies up to about 1.09 MeV/nucleon. During the commissioning, the He^{+} and Ar^{10+} ion beam acceleration tests have been successfully accomplished. Therefore, heavy ion beams in the KAHIF are now ready to serve a vast range of scientific users in the fields of nuclear/fusion engineering. The FPGA-based digital LLRF technology to be applied to improve the beam quality, the development of a new metal ion source to supply metal ion beams to the users, and the application of artificial intelligence to accelerator control system for beam fine tuning will be done in the near future.

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