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PRESENT STATUS OF THE DAEJEON ION ACCELERATOR COMPLEX AT KAERI*

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Abstract

The Daejeon ion accelerator complex (DIAC) is being built at the Korea atomic energy research institute (KAERI) for various applications. Based on linear accelerators (linacs) of the Tokai Radioactive Ion Accelerator Complex (TRIAC) given from the high energy accelerator research organization (KEK) [1–4], Japan, the dedicated accelerators in the DIAC are designed to produce stable heavy ion beams. In this article, status, plans, and some test results for the DIAC construction are presented and discussed.

INTRODUCTION

The DIAC is being constructed at KAERI in order to fulfil an increasing demand for heavy ion beam facilities for structural material study, biological research and nanomaterial treatment. The dedicated accelerators in the DIAC are designed to produce stable heavy ion beams with energies up to 1 MeV/u and beam currents up to 300 μA [5, 6]. The construction has now reached the stage where the DIAC system is ready for beam tuning.

OVERVIEW OF DIAC CONSTRUCTION

The heavy ion beam line of the DIAC consists roughly of an electron cyclotron resonance (ECR) ion source, a radio-frequency quadrupole (RFQ) linac, a rebuncher (RB), and an interdigital H-type (IH) linac as shown in Figure 1.

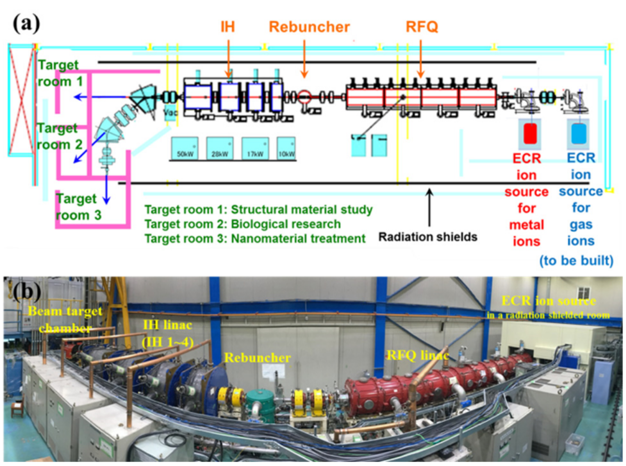

Figure 1: (a) Schematic layout of the DIAC, (b) Panoramic view of the DIAC beam line.

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The DIAC facilities are designed to handle stable non-radioactive beams. According to user demand, the separated two ECR sources (i.e., an 18 GHz KEK – the high energy accelerator research organization ECR ion source with a metal oven and a 14.5 GHz KAERI ECR ion source) together with low energy beam transport line (LEBT) can supply linacs with both metal and non-metal ions. The 25.96 MHz RFQ linac accelerates ions up to 178 keV/u. Then, the ions accelerated by the RFQ reach to the 51.92 MHz IH linac via a transport system composed of a RB and two sets of quadrupole doublet. Finally, the IH linac can re-accelerate the ions up to 1 MeV/u. The detailed specifications of the DIAC linacs can be found in Table 1 [1–4].

Table 1: Specifications of the DIAC 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 keV/u	178–1090 keV/u
Normalized emittance	0.6πmm·mrad	
Energy spread	1.03%	≤2.8%
Duty factor	30–100%	100%
Repetition rate	20–1000 Hz	
Total length	8.6 m	5.6 m

To date, (1) assembly of the ECR ion source and linacs delivered in pieces from the KEK, (2) installation of the power supply, coolant circulation system, and vacuum pump system, (3) acquisition of the radiation safety license, (4) operation test of the ECR ion source, (5) full-power tests of IH and RFQ power amplifiers, (6) construction of radiation shielded walls for the DIAC, (7) tests on the RFQ, RB, and IH RF tuners, (8) reorganization of the integrated control system, and (9) development of a beam target chamber have been completed. Presently, beam tuning of the DIAC accelerators is in progress. The following section gives results on the full-power test of the RFQ/IH linacs, the reorganization of the DIAC integrated control system, and development of the beam target chamber.

FULL-POWER TEST OF THE LINACS

To check performance capacity of the reinstalled IH, RB, RFQ and their power amplifiers, measurement of Q factors of the cavities, stored electromagnetic energy of the IH cavities as a function of peak RF power, and full-power test of the RFQ linac were carried out.

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Q factors of IH, RFQ linacs and RB cavities have been measured using a network analyzer, and the measured values of Q factors were compared with those before the accelerator transfer, as seen in Table. 2 [1–4]. The measured values of Q factors are in good agreement (within about 10%) with those at KEK.

Table 2: The Measured Q Factors of Cavities Before-and-After the Accelerator Transfer

System	Unloaded Q factor (DIAC)	Unloaded Q factor (KEK)
IH1	11802	12510
IH2	14740	14646
IH3	17902	17304
IH4	16750	18558
RB	6400	6000
RFQ	6556	5800

This indicates that the cavities maintain good integrity and there is no degradation in the performance capacity during the transfer and assembly.

The values of squares of RF pickup loop voltages in the IH tanks as a function of peak RF power up to full powers (i.e., IH1: 12 kW, IH2: 22 kW, IH3: 30 kW, and IH4: 50 kW) were measured. Because the square of RF pickup loop voltage is proportional to electromagnetic energy in the cavity, the result represents the relationship between the output power of RF amplifier and the electromagnetic energy.

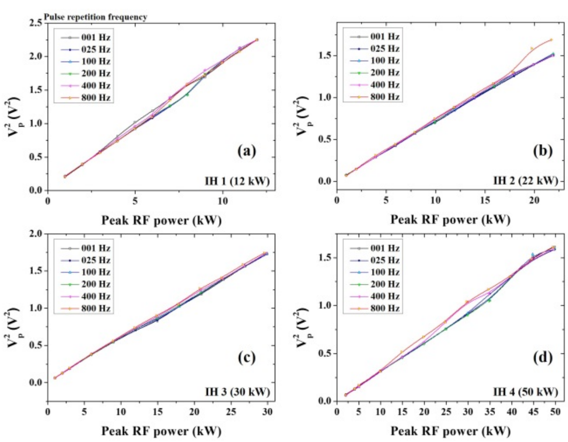

Figure 2: The values of squares of RF pickup loop voltages in the (a) IH1, (b) IH2, (c) IH3, and (d) IH4 tanks as a function of peak RF power.

As shown in Figure 2, the values of squares of RF pickup loop voltages are nearly linear to the applied RF powers, indicating that the IH linacs can accelerate ions without a serious loss of the electromagnetic energy in the cavities.

Figure 3 shows the full-power (350 kW) test result on the RFQ RF amplifier using a dummy load. The output power of RF amplifier increases with power level of the low level RF system and then saturates to the maximum power value with few reflected power. This means that the full-power of the power amplifier can be applied to the load.

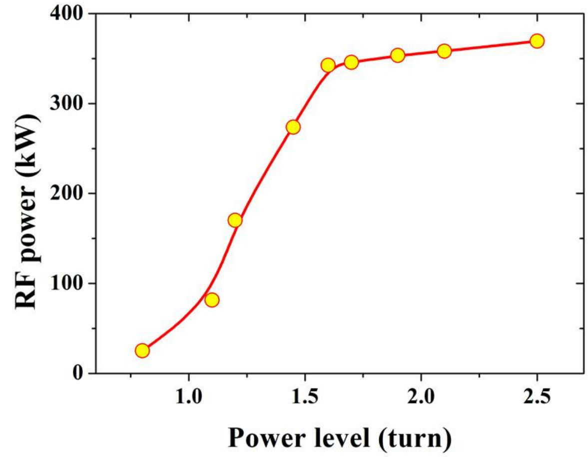

Figure 3: The applied RF power as a function of power level in the RFQ RF amplifier.

INTEGRATED CONTROL SYSTEM

Based on system of the Tokai radioactive ion accelerator complex (TRIAC) [7, 8], we reorganized the integrated control system. Figure 4 illustrates the DIAC integrated control system.

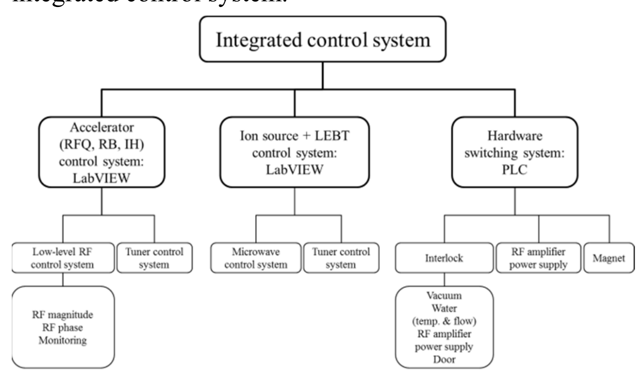

Figure 4: Schematic diagram of DIAC integrated control system.

The integrated control system consists of two control systems for accelerator and ion source/LEBT, respectively, including feedback control system and a hardware switching system. The switching system controls RF amplifiers (power on/off), electromagnets (see Figure 5), and interlocks (see Figure 6).

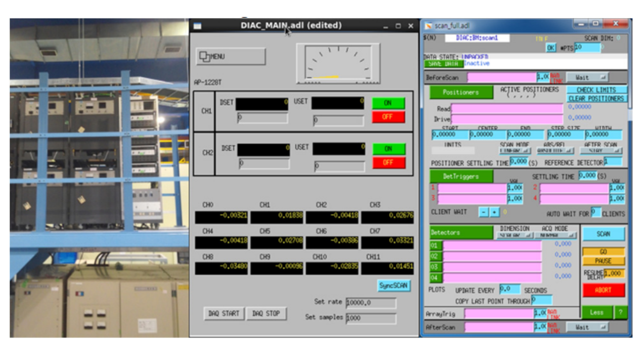

Figure 5: Power supplies and EPICS based control system for electromagnets.

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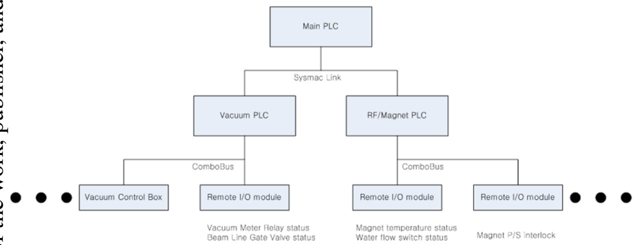

Figure 6: Schematic diagram of the DIAC interlock system.

A LabVIEW program and a PLC program, developed by KEK, handle the control system and switching system, respectively. We have modified the programs and converted old LabVIEW codes to formats that are supported by the latest version of LabVIEW and also EPICS for the DIAC system. Wiring between the integrated control system and individual devices has also been accomplished.

BEAM TARGET CHAMBER

A beam target chamber has been designed and developed for beams of energy up to 1 MeV/u and beam power of 1 kW. It contains cooling system and various diagnostic systems, e.g., a Faraday cup, a thermocouple, an infrared (IR) thermal camera, and a residual gas analyser for users, as shown in Figures 7 and 8.

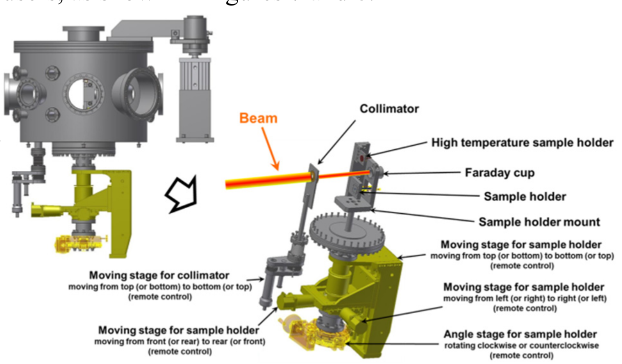

Figure 7: A 3D sketch of the beam target chamber and various diagnostic systems.

The chamber also offers convenience for users by providing two movable sample holders together with heaters. Particularly, the high temperature holder can be heated up to 1900°C while measuring the sample temperature using an IR thermal camera or a thermocouple during the beam irradiation.

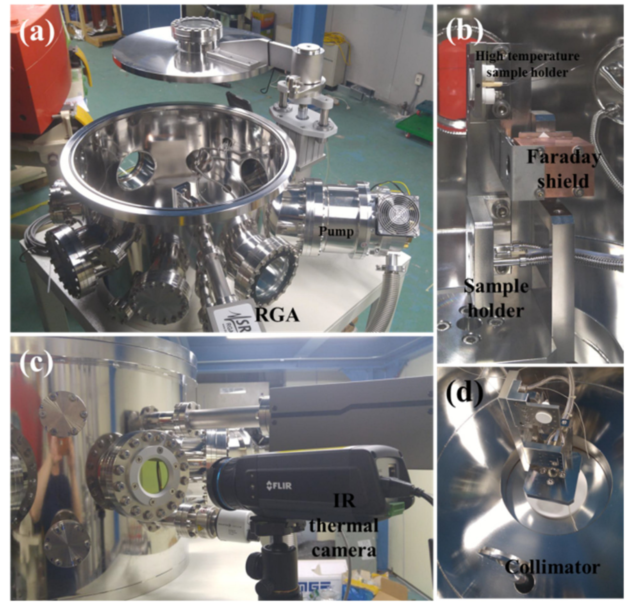

Figure 8: Pictures of (a) the beam target chamber, (b) the sample holders, (c) the IR thermal camera, and (d) the collimator.

FUTURE WORK

From the successful full-power test results, we confirmed that the IH and RFQ linacs work properly and then they are prepared for acceleration of heavy ions up to 1.09 MeV/nucleon. Since the reorganization of the integrated control system, the development of a beam target chamber as well as the tests were successful, it is supposed that the DIAC is ready for beam tuning. Presently, beam tuning test is now in progress. It is expected that the beam tuning and commissioning will be done by the first half of 2018.

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