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New Beam Line Design of TRIAC as a Stable Heavy-Ion Accelerator at KAERI

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1. Introduction

KEK (High Energy Accelerator Research Organization) TRIAC (Tokai Radioactive Ion Accelerator Complex) was a radioactive isotope accelerator which can provide beams of uranium fission fragments with the maximum energy of 1.1 MeV/nucleon produced by protons of 30 MeV and 1 μA (30 W in beam power, actually deposited in the production target) from the JAEA Tandem Accelerator. Because of the critical limitations in the reaccelerated energy and intensity of available RIBs (Radioactive ion beams), TRIAC considered an upgrade program seriously, but it was canceled. Finally the complex had been closed at the end of 2010, and it was transferred to KAERI (Korea Atomic Energy Research Institute) after being disassembled to promote a new availability in Korea.

KAERI team has a plan to reassemble this device as a stable ion beam accelerator with a minimized change for the low energy beam line including the ion source and the target system. The new stable ion accelerator will be used not only for the basic research but also for the application of heavy ion beams. Before the re-assembling of TRIAC at KAERI, new layout of the beam line should be designed, and checked by beam optics simulation. The operation conditions and beam optics characteristics of the new beam line components can be understood with this simulation. The works that should be done before reassembling as a new machine have been done in this study. The beam optics calculations were preferentially carried out with arbitrary order beam physics code COSY INFINITY (COSY) or beam envelope code TRANSPORT.

2. Tokai Radioactive Ion Accelerator Complex

Figure 1 shows a schematic drawing of the TRIAC facility. The TRIAC is based on an isotope separator on-line (ISOL) and the radioactive nuclei are produced via proton-induced fission of ^{238}U or heavy-ion reactions with the primary beams provided by a tandem accelerator [1]. The produced radioactive nuclei are singly charged and mass-separated by the ISOL. They are fed to the 18 GHz electron cyclotron resonance ion-source for charge-breeding, where the singly charged ions are converted to multi-charged ions. The charge-bred radioactive ions, usually with a mass to charge-state ratio of around 7, are extracted again and fed to the post accelerator for re-acceleration. The post accelerator consisting of two linear accelerators, a split-coaxial radio-frequency quadrupole (SCRFQ) linac and an interdigital-H (IH) linac, can accelerate the radioactive ion beam to the energy up to 1.1 MeV/A at the maximum [2].

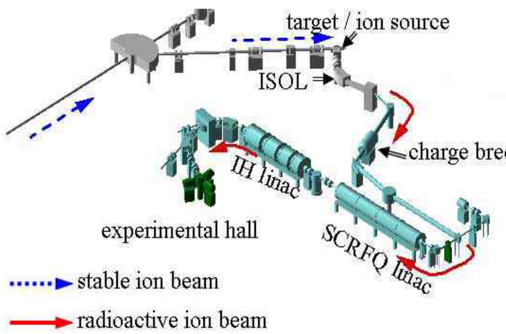

Fig. 1. Layout of the TRIAC

3. New beam line design

3.1 Calculation Method for Beam Optical Design

The beam optics of the accelerator components was calculated by simulation codes such as COSY and TRANSPORT. The COSY is based on differential algebra and adapted for the study and design of beam physics systems including accelerators, spectrometers and beam lines. It offers the option to simultaneously simulate particles with different masses or charges states, the latter being of especial interest for the problem at hand. The results of the beam optical calculations by the COSY could be confirmed by the TRANSPORT. The TRANSPORT is a first and second order matrix multiplication computer program intended for the design of static-magnetic beam transport systems. The calculation of the program is based on the transfer matrix method of the accelerators components. The solution for the complete optics of the components is then just the product of the individual matrices, i.e. the complete transfer matrix of the components is the matrix product $M_{tot} = M_n \cdot M_{n-1} \cdot \cdots \cdot M_1$.

Many parameters of the particle and the beam for the beam optical calculations are required. The parameters can be taken from table 1. The emittance is a property of a charged particle beam in an accelerator.

Table 1. Input parameters for the beam optical calculations

Particle	Mass number : A
	Charge : Q
	Kinetic energy : E_{kin}
	Electric rigidity : E_ρ
	Magnetic rigidity : B_ρ
Beam	Emittance : ε

3.2 Layout of the new beam line

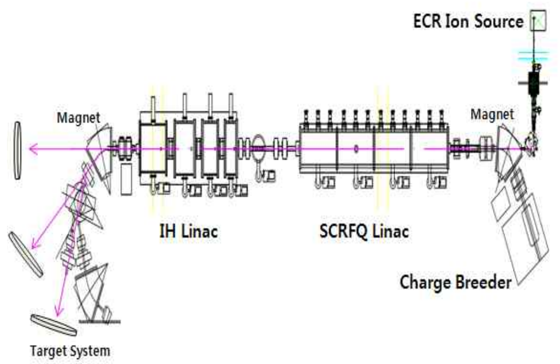

Fig. 2. Schematic of the Stable heavy-ion accelerator applied to ECR ion source and multiple purpose target system

Figure 2 shows a schematic of the planned newly reassembled stable low energy heavy-ion accelerator at KAERI. Stable ions for the accelerator will be produced by 14.5 GHz ECR ion source, which was developed at KAERI [4], and 18 GHz charge breeder, which was used at TRIAC ISOL system. The KAERI ECR ion source will be used in producing multi-charge gas ions, and KEK charge breeder will be used in producing multi-charged metal ions. The emittance and charge state of the selected ion beams should be controlled well to match with the first accelerator SCRFQ acceptance. The SCRFQ linac, which has a 25.96 MHz frequency, accelerates the matched beams up to 178.4 keV/u. This beam is transferred to IH linac, which has a 51.92 MHz frequency, and is finally accelerated up to 1.1 MeV/u [1]. Multiple purpose target and detection system will be developed with 3 large analyzing magnets to execute basic physics and beam application studies.

3.3 Beam Optics Calculation

The beam optics of the new layout shown the figure 2 is calculated by using the TRANSPORT code. The beam parameters of the ECR ion source and the charge breeder used at TRIAC are prepared by referring the experimental data. The transfer matrices of the accelerator components such as pre-buncher, SCRFQ linac, re-buncher and IH linac are simplified by using the old TRIAC data because the stable low energy heavy-ion accelerator would be reassembled almost same as before.

4. Summary

New beam line design of a stable low energy heavy-ion accelerator and beam optics calculation of the system have been done for the reassembly of the TRIAC system at KAERI. The TRANSPORT code is used to calculate of the beam optics. Afterward, the reassembly of the TRIAC system at KAERI will be started from August of this year, and it is expected that 3 years will be taken to finish assembling and tuning of the system.

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