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Operation of the 1.7 MV Tandem Accelerator for User Service

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1. Introduction

After the installation in 2015 [1] and the facility inspection in 2016, a 1.7 MV tandem accelerator has been operating for user service at Korea Multi-purpose Accelerator Complex (KOMAC). Recently, 4 beam lines are operating for user service. Those are a proton induced X-ray emission (PIXE) beam line, a Rutherford Backscattering (RBS) beam line, an implantation beam line and a neutron experiment beam line. In addition to the user operation, several parts were upgraded because it was a 30 years old machine, which was formerly used at Korea Institute of Geoscience and Mineral Resources (KIGAM). An operation of the external PIXE beam line, development of an Elastic Recoil Detection (ERD) analysis platform and a beam buncher for the nano-second pulse neutron production are planned in near future. In this paper, status of machine operation is summarized and upgrade plans are discussed.

2. Operation Status

The operation of the tandem accelerator is based on the annual operation plan of KOMAC. The total number of weeks for beam service is 27 weeks, 9 weeks for machine study and the others for maintenance and upgrade in 2019. The installed tandem accelerator is shown in Fig. 1.

Fig. 1. Tandem accelerator viewed from high voltage terminal to the beam line.

2.1 Upgraded Parts

Several parts were upgraded including a RF-charge exchange ion source, fore-line vacuum pump, magnet power supplies and control system.

A RF-charge exchange ion source (so called Alphatross) was newly installed whereas the sputtering ion source (so called SNICS) was stilled used [2]. The purpose of the RF-charge exchange ion source is to produce negative helium ion beams for the RBS analysis. In this ion source, the helium plasma is generated through 100 MHz RF source and rubidium is used as a charge exchanger.

All the fore-line vacuum pumps were replaced with the oil-free vacuum pumps, and all the magnet power supplies were replaced with the switching-mode power supplies because of the efficient operation of the system.

Most of the analog based control systems are still used for control the accelerator. But the control system of the newly installed parts such as the power supplies was developed as an EPICS-based control system, which makes the control of the power supplies easy and compatible with the existing 100 MeV linac control system.

2.2 Accelerator

A SNICS and Alphatross ion sources were operated in weekly based operation plan. The negative hydrogen beam current from the SNICS ion source is about 5uA during beam service and reached 20uA for machine study. The cathode was replaced every 8 times beam service operation. The negative helium beam from the Alphatross ion source was reached 400nA. The operation characteristics of the high voltage terminal were checked during machine study period. The balance between two chain currents was within 5% and the balance between charging and discharging current was also less than 5%, which showed that the high voltage system is well maintained. The terminal voltage was checked and compared from 3 different methods. The differences of the terminal voltage from generating voltmeter (GVM) and column current measurement were -6 % at 0.5 MV and linearly increased up to 4% at 1.6 MV with the same values at 1 MV. The terminal voltage was also measured from the nuclear reaction and the voltage difference was within 0.3% at 1 MV [3]. A beam buncher section was inserted between ion source and high voltage terminal, which is different from the original geometry. To increase the beam transport efficiency, an einzel lens in the buncher section was operated. The total transmission efficiency of the proton beam from the ion source to the neutron beam line for beam service was 80% at 2.4MeV proton energy.

2.3 Beam Line Operation

4 beam lines are operating. For the Ion Beam Analysis (IBA), two beam lines (PIXE and RBS) are assigned and one beam line for ion beam implantation, another for neutron experiment.

A PIXE beam line is installed at -15 degree from the switching magnet and consists of an electrostatic beam steerer and PIXE chamber. Target motion system, two detectors, filter and beam dump constitute the PIXE analysis system. A Silicon Drift Detector (SDD) and Ultra Low Energy Germanium (LEGe) detector are used, GUPIXWIN is used for the PIXE analysis. The proton energies are in the range of 2~3 MeV and the beam current is in the range of 0.1~20nA.

A RBS beam line is installed at +15 degree direction. It consists of an electrostatic beam steerer and RBS chamber. The RBS system is composed of a goniometer for the control of sample location, a sample holder, two collimators for the beam size control and detector. A Silicon Surface Barrier (SSB) detector is located at the angle of 170 degree from the beam incident direction and the sample is tilted 5 degree from the incident helium beam.

An implantation beam line is installed at +30 degree. It consists of a raster scanner, electrostatic beam steerer and beam irradiation chamber. Nowadays, the implantation beam line is the most popular one. It can supply a beam to 6” wafer area with the uniformity of 10%. A raster scanner is used to increase the irradiation area and beam uniformity. The uniformity is checked through radiochromic film and sets of Faraday cups. 5 sets of the Faraday cups are used to measure the real time beam uniformity during irradiation. The dose on the sample is measured by integrating the current from the Faraday cup. The total dose is 5×10^{15} cm^2 for 4 hour operation with the uniform area of 30×30 mm^2 under the normal beam service condition.

A proton beam is delivered to the neutron beam line, which has two 45 degree bending magnet in vertical direction and 0 degree in horizontal direction in order to locate the neutron target in the center of the neutron experimental room. The beam line also has a doublet between bending magnets and beam profile monitor and Faraday cups. The neutron target is a LiF film deposited on the aluminum plate. There is a room dedicated to the neutron experiment, so called neutron experimental room. There is a shielding door to access the room, which is interlocked to the accelerator control system and the target is located at the center of the room to minimize the effects of the neutron scattering from the wall. The neutron field is under characterization for the purpose of standard neutron source and detector test by using a plastic scintillator, CLYC detector, long counter. The neutron flux with mono-energy is about 200 n/cm^2/s from 1m apart from the target and 0 degree under normal operation condition [4].

3. Upgrade Plan

The external PIXE system was installed at the downstream of the PIXE chamber. The purpose of the external PIXE is for the analysis of the large object or volatile one such as cultural heritage which is difficult to install in the vacuum environment. The ERD system is now under development to analyze the light element. The time-of-flight system for ERD is installed at the RBS chamber. A beam buncher to bunch the beam to a few nano-second is also under development. The purpose of the nano-second proton beam is to measure the neutron energy by using time-of-flight method. It consists of a chopper and a buncher system. A chopper is composed of two parallel plates. A fast switch turns on high voltage on one plate whereas the high voltage is always applied to other plate. When the voltage crosses the same voltage with the other plate, the beam can go straight thus beam chopping can be realized. To make the bunch length more short, a buncher using a pseudo saw-tooth wave is designed. The required RF will be accomplished by using digital signal synthesis board, which makes the overall system compact and simple.

3. Conclusions

After the start of the beam service at 2016, the tandem accelerator is routinely operated not only for beam service but also for the machine study. Several parts are upgraded for efficient operation. 4 beam lines (PIXE, RBS, Irradiation, Neutron production) are under user service and 3 other kinds of beam service (external PIXE, ERD, short pulse neutron) are planned. The tandem accelerator, which has multi-purposes such as 1) ion beam irradiation from 1MeV ~ 3MeV energy range based on proton beam, 2) ion beam analysis, 3) neutron production, is expected to be used actively as one of the main user facilities installed at KOMAC.

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