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PRELIMINARY TEST OF THE BEAM TRANSPORT SYSTEM FOR LI-8 PRODUCTION TARGET ION SOURCE*

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Abstract

A prototype target ion source (TIS) was developed in order to produce a radioactive beam such as ^{8}Li as a part of the goals to establish a platform for secondary particle production at Korea Multi-purpose Accelerator Complex (KOMAC). A beam transport system from the 100-MeV linac to prototype target ion source was designed and constructed. It consists of 8 quadrupole magnets, 2 bending magnets and beam diagnostic devices such as AC current transformers (ACCT), beam position monitors (BPM), beam profile monitors and beam loss monitors. Details on the beam transport system are presented.

INTRODUCTION

A 100-MeV proton linear accelerator has been operating since 2013 for proton beam user service at KOMAC. The layout of the 100-MeV proton beam line is shown in Fig. 1.

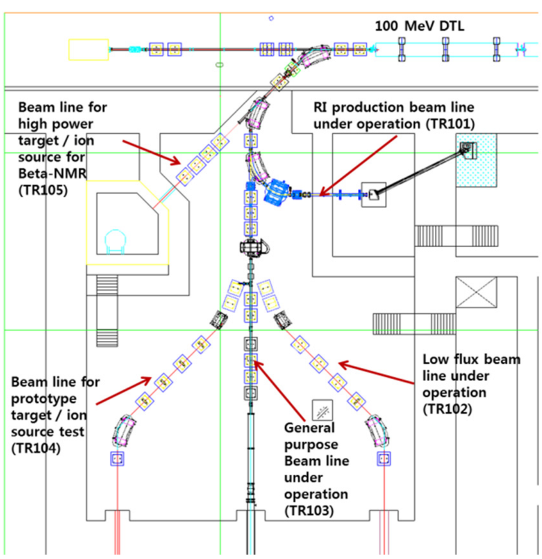

Figure 1: Layout of KOMAC 100-MeV proton beam line.

Recently, four beam lines are under operation for user service, one is a general purpose beam line for 20-MeV beam users (which is not shown in the Fig. 1), another is a general purpose beam line for 100-MeV beam users, both of which have been operating since 2013 [1], the third is the radio-isotope (RI) production beam line using 100-MeV proton beam, which was commissioned in 2016 and started beam service in 2017 [2], and the fourth beam line, whose main purpose is to supply low flux proton beam to users for application fields such as simulation of the space/environment radiation, development of the radiation detector, was developed in 2017 and started formal beam service in 2018 [3]. The total number of projects for beam service was 121 in 2017. Among them, 36% were researches related with the material science including nano-science and semiconductor research, 26% were researches related with the bio-science, 21% were researches related with the basic science including nuclear physics and astrophysics. About 69% of the users come from the universities, 25% come from the research institutes, and 6% come from industries.

Up to now, all the users use proton beam directly irradiated on the target. But it is well known that many kinds of secondary particles such as neutrons and ions are produced from the target when proton beam hits the target. And those secondary particles can be widely used in addition to the primary proton beam. Researches based on the secondary particle are planned at KOMAC. At first stage, two kinds of secondary particles, pulse neutron and radio-isotope beam based on ^{8}Li, are considered. Pulse neutron produced by the high energy proton beam is a main application field of the high power proton accelerator. A system for the production of the pulse neutron is summarized elsewhere [4]. Meanwhile, ^{8}Li radio-isotope beam will be used for beta-NMR research, whose main advantage is its high sensitivity compared with the conventional NMR, but there are few user facilities in the world [5]. A detailed study was carried out on the ^{8}Li production target ion source based on the BeO target, a proton beam transport system from the 100-MeV linac to the target room for ^{8}Li production study, a ^{8}Li beam transport system. A prototype target ion source was developed and finished off-line test [6]. A proton beam transport system was developed and preliminary tests such as vacuum test, electromagnet powering test and control system test were finished. Here, a development of the proton beam transport system will be discussed and ^{8}Li beam transport system will be described too.

PROTON BEAM TRANSPORT SYSTEM

The 100-MeV proton beam transport system to the prototype target ion source which will be installed in TR104 consists of beam focusing and bending elements, vacuum system, beam diagnostics.

Beam Optics and Beam Line Components

The beam transport system shares common elements from the 100-MeV DTL output to AC magnet with other beam lines such as general purpose beam line (TR103) and

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low flux beam line (TR102). The beam optics was calculated by using TraceWin [7]. The output beam from the DTL was used as the input beam parameter to the code. The dispersion after the two 45 degree bending magnets was adjusted to zero by using the two quadrupole magnets between bending magnets. The beam size at the target position was increased by using the dispersion and downstream quadrupole magnets to target size. The beam trajectories along the beam transport system and beam distribution at the target position are shown in Fig. 2 and Fig. 3 respectively.

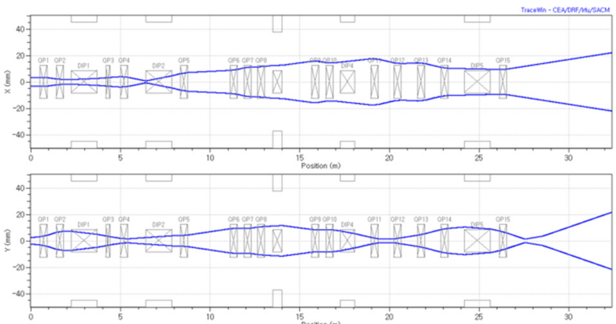

Figure 2: Beam envelope along the beam line.

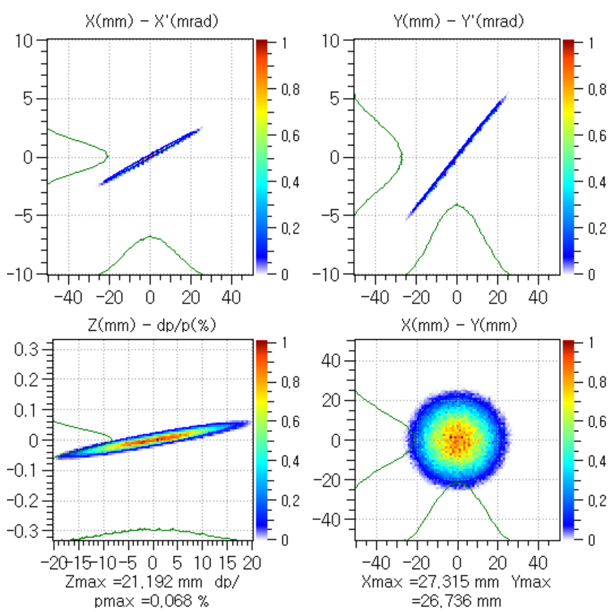

Figure 3: Beam at the target.

Based on the beam optics design, the elements of the beam transport system were designed, fabricated and installed. The installed proton beam transport systems are shown in Fig. 4 and Fig. 5 respectively.

The purpose of the AC magnet is to distribute the beam into three downstream beam lines simultaneously at maximum 7.5 Hz sweep frequency. The 7.5 Hz AC magnet was already installed but the fast sweep power supply is not installed yet. A set of DC power supply and power transfer switch is used to guide the beam into three directions. The bending angle of the AC magnet is 20 degree and another 25 degree bending magnet is installed after the AC magnet and the total bending angle is 45 degrees. The last 45 degrees bending magnet directs the proton beam into the target room. The bending radius of the 25 degrees and 45 degrees bending magnet are the same and both are C-type magnet. The maximum pole tip field is 0.8 T and the pole gap is 90 mm with shim to satisfy the good field requirement of 0.1% within 100 mm width. There are 8 quadrupole magnets from the AC magnet to the target room. The aperture diameter of the quadrupole magnet is 110 mm, the maximum field gradient is 5 T/m and the effective length is 400 mm. Two sets of steering magnets are used. It is a double steering magnet with rib to increase the field uniformity [8]. The kick angle of the 100-MeV proton beam is 4 mrad and aperture of the steering magnet is 136 mm. The field uniformity is 2% within 100 mm width.

Figure 4: Installed proton beam transport system from AC magnet (right) to the vacuum box (left).

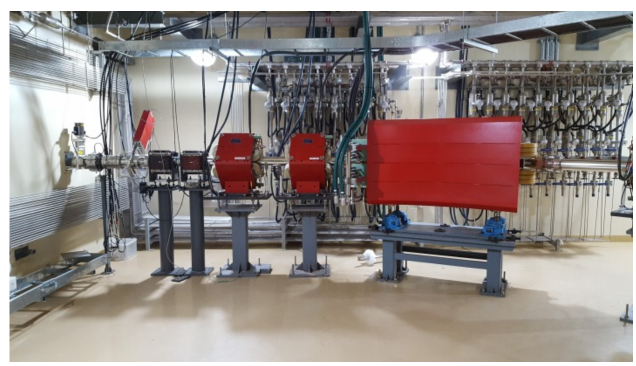

Figure 5: Installed proton beam transport system from 45 degree bending magnet (right) to penetration hole to the target room (left).

The beam pipe is 100mm in diameter. The vacuum requirement of the beam transport line is less than 10^{-6} Torr. A set of turbo molecular pump (TMP) and ion pump (IP) is installed in the common beam line from the DTL output to the AC magnet. Another one set of TMP and IP is installed to evacuate the beam transport line at the middle of the beam line between 25 degrees bending magnet and 45 degree bending magnet. Two gate valves are installed, one is at the downstream of the AC magnet, and the other is in front of the target room penetration. A pressure sensor is installed behind the second gate valve to activate the fast closing valve which is installed in the middle of the two 45 degrees bending magnets at the downstream of the DTL to

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protect the accelerator from the sudden vacuum leak at the target room. Two sets of AC current transformers (ACCT) were installed to monitor beam current, two sets of wire scanners were installed for beam profile monitoring, two sets of strip-line type beam position monitor were installed for fast beam position monitoring and beam phase monitoring, a Faraday cup at the end of the beam line to monitor the beam current in front of the target ion source and two sets of proportional detector were installed beside bending magnet as a beam loss monitor.

^{8}LI BEAM TRANSPORT SYSTEM

A prototype target ion source was developed and finished off-line test as shown in Fig. 6. The target was heated up to 1850 degree by the tantalum heater at the current of 1300 A. The surface ion source made of rhenium was also heated up to 2150 degree at the current of 400 A, both of which satisfied the design conditions [6]. The ^{8}Li beam transport system was designed as shown in Fig. 7. The proton beam comes from the proton beam transport system and hit the target inside the target ion source. The produced ^{8}Li radioisotopes are diffused to the surface of the target and effused to the surface ion source, where they are ionized. The extraction system is a triode type which has a bias electrode to control the extraction beam optics. Two sets of electrostatic steerers are installed to adjust the beam position. An electrostatic einzel lens will be used to focus the beam and a velocity filter called Wien filter is installed to select the ^{8}Li ions. A plastic scintillator will be used to detect the beta particle from the ^{8}Li at the diagnostic box.

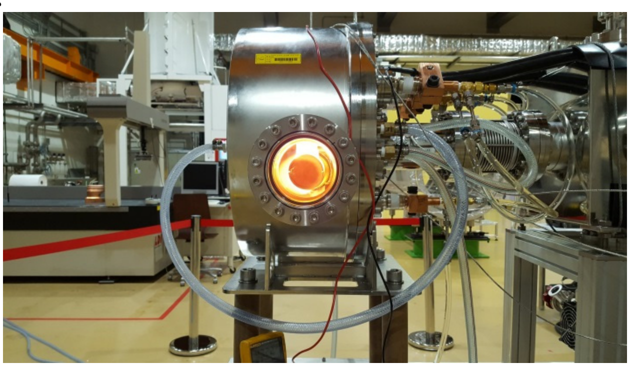

Figure 6: Prototype target ion source off–line heating test.

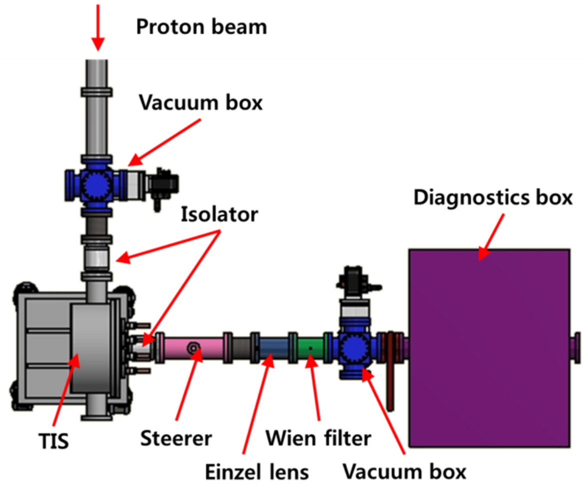

Figure 7: Schematics of the ^{8}Li beam transport system.

CONCLUSION

Two kinds of secondary particle researches are planned at KOMAC to expand the application area of the 100-MeV proton linac. One is the pulse neutron and the other is ^{8}Li RI beam. A proton beam transport system was designed, installed and preliminarily tested. The system inspection test will be done in June 2018. The off-line test of the prototype target ion source was done and the ^{8}Li beam transport will be installed in the target room. The ^{8}Li beam production and transport test will be done in 2018.

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