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FABRICATION OF ON-LINE TEST FACILITY OF LI-8 BEAM AT KOMAC*

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Abstract

A Li-8 beam facility has been developed at KOMAC. A target/ion source (TIS) was fabricated, and a heating experiment of a target heater and a surface ion source was conducted at an offline test site. Additionally, beam optical components were developed. They are utilized in the Li-8 beamline that an electrostatic steerer to adjust a misalignment of the beam, an Einzel lens to focus the beam and a Wien filter to separate the Li-8 beam from other particle beams. Furthermore, a high-energy beta-ray telescope detector was developed as a dedicated beta-decay spectrometer for a diagnostics of the Li-8 beam. The TIS, the beam optics and the beam diagnostics are installed in a target room of the 100 MeV proton linac. An experiment of the proton beam transportation into the target room and the TIS heating experiment were conducted separately. The online test of TIS is going to be conducted to generate Li-8 beam and examine the beam optics and the diagnostics, successively.

INTRODUCTION

The Korea Multi-purpose Accelerator Complex (KOMAC) has developed a secondary particle facility driven by a 100 MeV proton linac. The fast neutron and Li-8 beam will be served at this utilization facility. The fast neutron is utilized in space/environment radiation test, and Li-8 beam is supplied to a beta-detected nuclear magnetic resonance (β-NMR) device. Thus, a target/ion source (TIS) has been developed to generate Li-8 beam. A heating experiment of the TIS was conducted at an offline test site. Then TIS was installed in the target room of the 100 MeV proton linac. Also, Li-8 beamline optics are designed and fabricated. Details on the TIS target room and Li-8 beam optics will be presented in the following sections.

HEATING EXPERIEMENT OF TARGET/ION SOURCE

Numerical study for the design, the fabrication and the offline test of the TIS were conducted [1]. The TIS consists of beryllium oxide (BeO) disk targets, a target container made by graphite, a target heater, a surface ionization ion source (SIS) and ion source alignment instruments as depicted in Figure 1. The dimensions of the disk target are 48 mm in diameter and 1 mm thickness. Twenty-six targets are installed in the target container. In order to prevent the dissociation of the BeO at high operation temperature [2], a rhenium target holder is placed between the target and the target container. The target heater made by tantalum will be heated up to 2000 K by electrical resistive heating. The Li-8 generated at the target is guided to the SIS via a transfer tube. The SIS is made by the rhenium and heated up to 2400 K by the electric current. The temperatures of the target heater and the SIS were measured by a pyrometer during the offline test. In addition, the vacuum pressure of the TIS was sustained lower than 10^{-4} Pa.

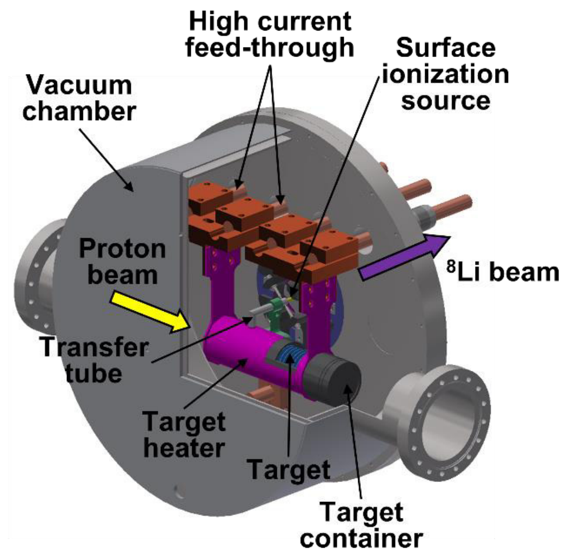

Figure 1: Configuration of target/ion source developed by KOMAC.

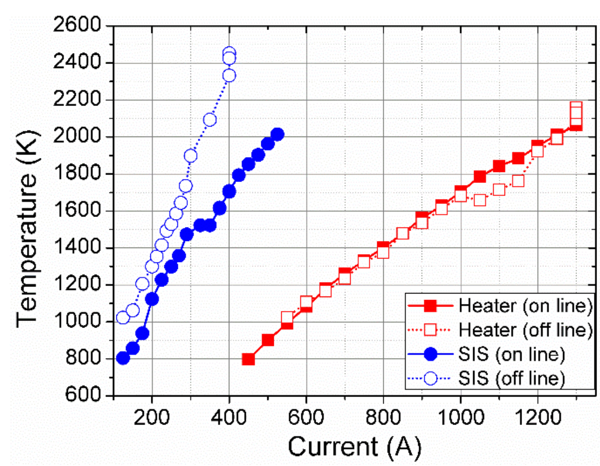

Figure 2: Heater and SIS temperatures measured at offline and online test.

The TIS was moved and installed at the target room of 100 MeV proton linac after the offline test. An online heating experiment was conducted again. The temperatures of the target heater measured at the offline and online test are

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similar. However, the temperature of the SIS at the online test was lower than that of the offline test, as shown in Figure 2. The lower temperature is presumed to be due to a difference in the TIS configuration of the online test. There was a vacuum duct next to the SIS at the offline test. On the other hand, a cooled blank wall was installed after the SIS at the online test. That is, the wall is located closer to the SIS at online test. Thus, the radiative cooling of the SIS was enhanced and SIS temperature was reduced. The vacuum pressure of the TIS was lower than 10-3 Pa.

LI-8 BEAM OPTICS

In order to establish the online test facility, the Li-8 beam optical components are developed such as a beam steerer, a focusing lens and a mass separator. The beam steerer is introduced to adjust a misalignment of the TIS and the beamline. The design goal of the steerer is to correct an angle of 5 degrees. The electrostatic steerer with two parallel electrodes was considered. The geometry of the electrode was determined based on the electrostatic field analysis by using the POISSON code as shown in Figure 3. The length and width of the electrode are 70 mm and 90 mm, respectively. The gap distance between the electrodes is 60 mm. This steerer design can satisfy criteria on the good field region (GFR) and the electric field strength. In this work, the GFR is defined as a circular area where the difference between the maximum and minimum value of the electric field strength is 1% or less. The second criterion is enough electric field to correct the misalignment. When the 5 kV is biased on two electrodes, the average value of the electric field inside the GFR is 1.65 kV/cm and this value is corresponding to 8.3 degrees. Two pairs of the electrodes are employed for the horizontal and vertical steering. The field clamps were introduced to define an effective electric field boundary [3].

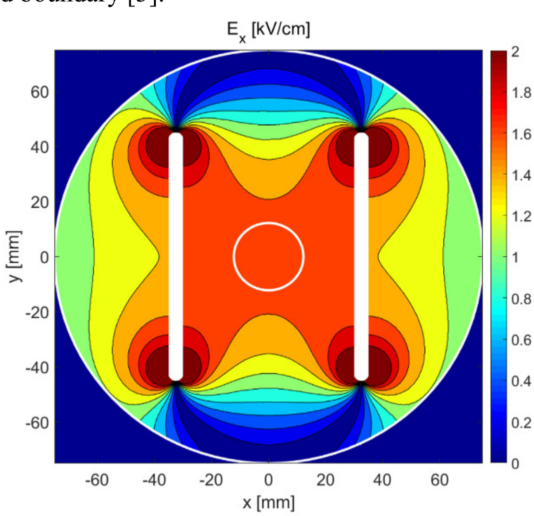

Figure 3: Electric field calculated by POISSON code. The circle at the center is GFR.

The Einzel lens is developed to focus and deliver the Li-8 beam to a mass spectrometer. The design and parameters of the Einzel lens, such as diameter and length of the electrode, a gap distance between the electrodes and potential of the electrode, were determined based on results of the numerical study by using TRAK code. In order to secure a short focal length, a deceleration-acceleration configuration was utilized, which biases a positive potential on the middle electrode. The potential is estimated as 12 kV when the focal length is 250 mm that is the distance to an exit slit of the mass spectrometer. The TRAK calculation result with this optimum case is depicted in Figure 4.

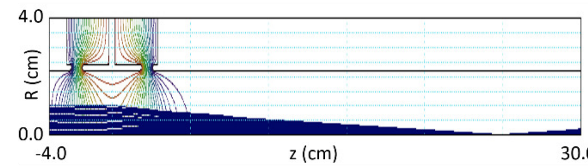

Figure 4: Equipotential line of the Einzel lens and Li-8 beam ray calculated by TRAK.

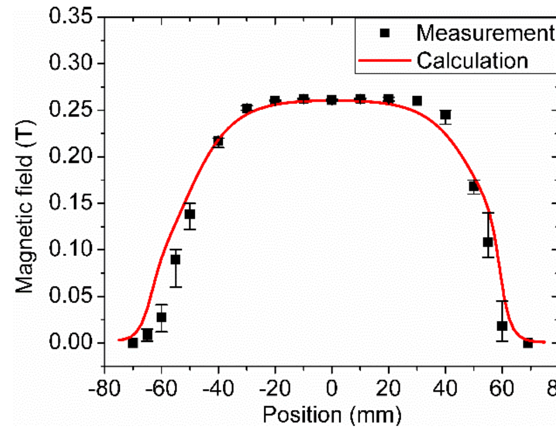

Figure 5: Magnitude of the magnetic field in the Wien filter.

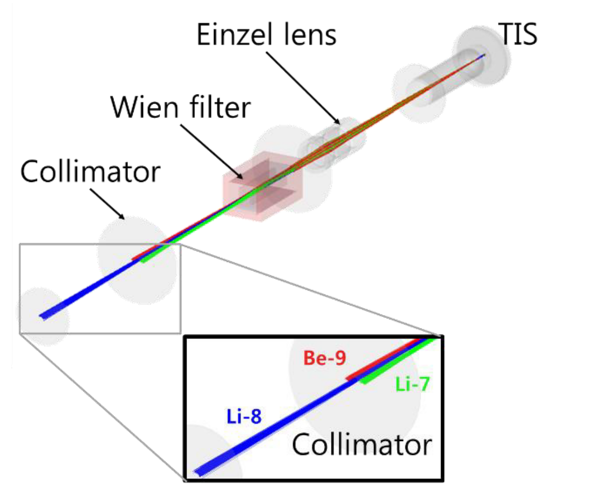

Figure 6: The beam path simulation result based on the online test facility.

The final beam optical component is the mass spectrometer. The resolving power of the mass spectrometer should be higher than eight because the Li-7 produced in the TIS should be separated. The compact Wien filter satisfying the resolving power is developed. The magnetic field of the Wien filter is measured and compared with the simulation by using the magneto-static solver of the CST STUDIO SUITE, as shown in Figure 5.

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Additionally, a particle tracking simulation was conducted with the consideration on every beam optics and their optimum operation parameters. The Li-7 and Be-9, as well as Li-8, were considered in the simulation as depicted in Figure 6. It was confirmed that the Li-8 beam could be selectively transported to the diagnostic chamber located at the end of the online test beamline. Then, the Li-8 beam optics were fabricated based on the numerical study results. The vacuum test and high voltage insulation test were carried out.

ONLINE TEST FACILITY

The online test facility of the TIS has been established in the target room of the 100 MeV linac. As written in the previous section, the TIS was installed in the online test site and the heating experiment was carried out. In addition, the proton beam transportation into the target room was tested. The Li-8 beam optics and the diagnostics will be installed in the target room as shown in Figure 7. In addition, a ΔE-E telescope has been developed for the high-energy beta-ray detector which can be operated under an intense radiation field. A 1.5 mm thick plastic scintillator (EJ-212) is utilized for ΔE detector and a 60 mm thick plastic scintillator (EJ-200) is utilized for E detector. The characterization of the ΔE-E telescope was conducted with Na-22 and Cs-137 standard RI source. This telescope is estimated to measure up to 107 betas per second.

The online test of TIS is going to be conducted to generate Li-8 beam and examine the beam optics and the diagnostics, successively.

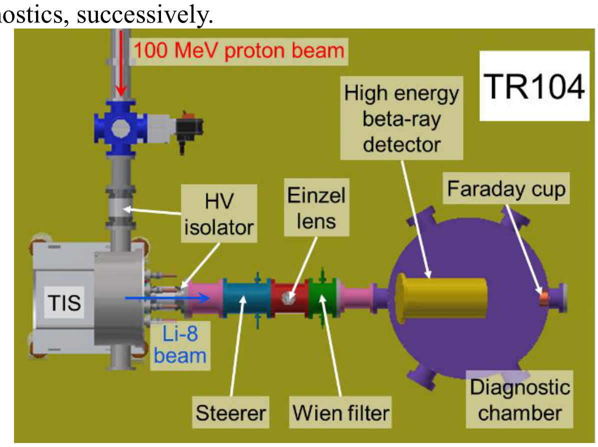

Figure 7: Layout of TIS online test facility in the target room of 100 MeV linac.

CONCLUSION

The target/ion source and beamline for Li-8 have been developed for β-NMR at KOMAC. The TIS was fabricated and installed at the online test facility in the target room of the 100 MeV proton linac. The heating experiment of the target heater and the surface ionization ion source was conducted. The temperature of the TIS was approximately 2000 K and the vacuum pressure was sustained lower than 10^{-3} Pa.

The Li-8 beamline optics were developed. The vertical and horizontal steerers, the Einzel lens and the Wien filter were designed and fabricated based on the numerical study results. Also, the ΔE-E telescope has been developed for the high energy beta-ray detector to identify Li-8. The 100 MeV proton beam irradiation on the TIS will be conducted to generate Li-8 beam and examine the beam optics and the diagnostics.

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