DESIGN OF THE 100-MeV PROTON BEAM LINE FOR LOW FLUX APPLICATION*

Hyeok-Jung Kwon†, Han-Sung Kim, Seok-Geun Lee, Seunghyun Lee, Chorong Kim, Sang-Pil Yun, Yong-Sub Cho
KOMAC, KAERI, Gyeongju, Republic of Korea

Abstract

Korea Multi-purpose Accelerator Complex (KOMAC) has been operating two beam lines for user service since 2013. A new beam line was completed in 2015 for radio-isotope (RI) production and has a plan to be commissioned in 2016. Another beam line was proposed to supply low flux beam to users. The maximum energy and average current are 100-MeV and 10-nA. The beam line consists of collimator, energy degrader, dipole magnet for energy separation and octupole magnet for uniform beam production. In this paper, the design of the beam line and its components is presented.

INTRODUCTION

Two beam lines are operating for user service at KOMAC, one is for a 20-MeV beam and the other is for a 100-MeV beam. Both of them are used for general purpose [1]. The third beam line, which is for RI production, is under commissioning [2, 3]. The fourth beam line is ready to be developed in 2016. The main purpose of the fourth beam line is for the low flux application such as a simulation of the space radiation, a development of the radiation detector. The users in this field want a beam which has low flux but high duty factor because almost CW low flux beam is advantageous for such applications. Therefore the design characteristic of the beam line is to operate the beam in high duty factor with a peak current as low as possible. The beam transport system of the beam line will be constructed in 2016 and commissioned in 2017.

BEAM LINE DESIGN

The design specifications of the low flux beam line are summarized in Table 1. We consider that 1-mA is a minimum possible peak current, which can be accelerated stably. Therefore, we designed the beam line to operate with maximum duty of 8 % and installed a collimator to reduce the flux to 1/10,000. Wedge type energy degraders are designed to adjust the beam energy which is requested by the user. Two sets of octupole magnets are designed to supply the beam to the sample with the ± 5% uniformity. In addition to the collimator, energy degrader and octupole magnets, 25° and 45° bending magnets, quadrupole magnets, a beam window, a fast gate valve are the main components of the beam transport system of the beam line. The designed beam transport line is shown in Fig. 1. The beam spreads out into the collimator to reduce the local heat load and efficiently reduce the current and the beam from the collimator spreads out at the target to satisfy the uniformity conditions. The beam envelop of the beam line is shown in Fig. 2.

Table 1: Specifications of the Low Flux Beam Line

Parameters	Values
Energy at target	20 ~ 100 MeV
Maximum current from accelerator	1 mA peak
Maximum duty	8 %
Maximum power at collimator (peak / average)	100 kW / 8 kW
Beam current at target	10 nA in average
Maximum beam power at target	1 W
Target size	100 mm × 100 mm
Beam uniformity at target	± 5 %
Maximum energy spread at target at 100-MeV	± 2 %

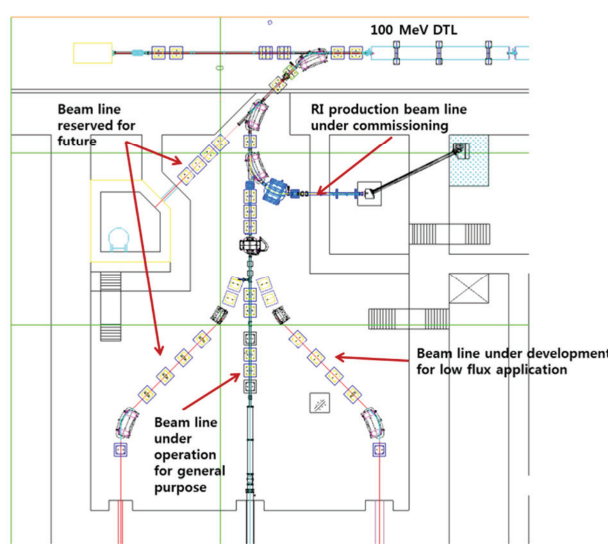

Figure 1: Layout of the low flux beam line.

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† hjkwon@kaeri.re.kr

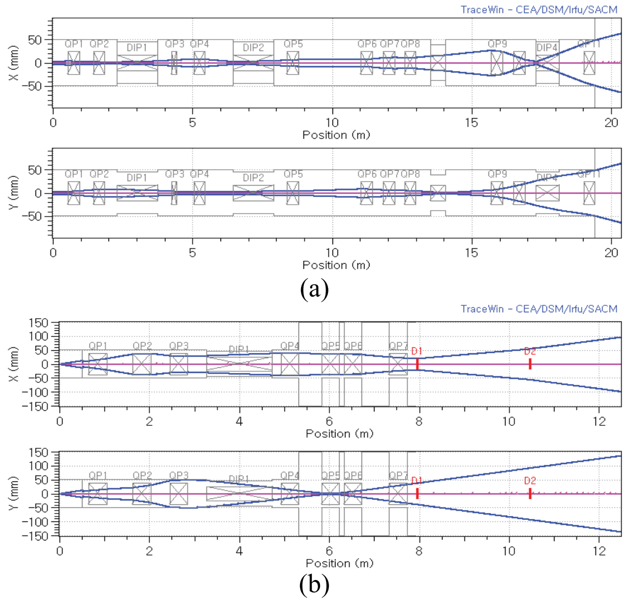

Figure 2: Beam envelop: (a) From an accelerator to a collimator, (b) From a collimator to target.

Collimator

A collimator is an essential part of the beam line which reduces the beam current to 1/10,000 and dissipates maximum 8 kW beam power in average. The beam from the accelerator spreads out to 100 mm in diameter. A hole of 10 mm in diameter is located in the centre of the collimator and the beam is guided to the collimator in off axis direction. And the edge beam is transmitted to the downstream through the hole. If the beam centre is diverted 50 mm from the centre of the collimator, the beam current reduces to 1/1,000 when the beam has a Gaussian profile. The collimator is located downstream of the 25° bending magnet, therefore we are able to adjust the direction of the beam centre into off axis direction. Maximum 8-kW beam power is deposited in the collimator and it is very important to cool it efficiently. The shape of the collimator is shown in Fig. 3. The inclined angle is 15° and it has a spiral cooling channel. The heat analysis using ANSYS showed that the maximum temperature was limited below 96°C when the beam is directed to off axis and has 8 kW power as shown in Fig. 3 [4].

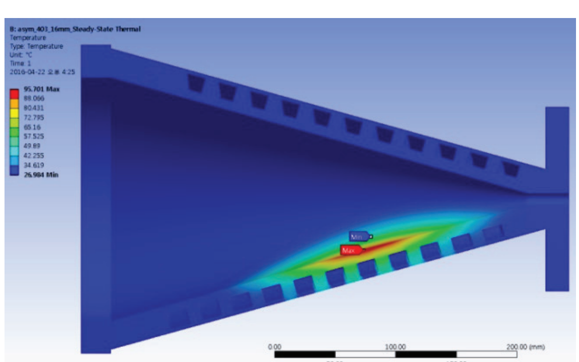

Figure 3: Collimator shape and thermal analysis.

Energy Degrader

The KOMAC DTL from 20-MeV to 100-MeV consists of 7 tanks and can produce a discrete beam energy depending on the number of RF turn-on tank. The energy between two discrete energy gaps is planned to be adjusted using energy degrader. To adjust the beam energy as continuous as possible, we considered two sets of wedge type energy degraders. The energy spread was estimated using MCNPX after the energy degrader made of aluminium. The energy spread was within 2 % when the beam energy reduces from 100–MeV, which is the case of turning on every DTL tanks, to 87-MeV, which is the case of turning off the last DTL tank, whereas the energy spread reaches up to 5 % when the beam energy reduces from 33-MeV to 20-MeV. In this case, we are going to use a downstream bending magnet as an energy collimator.

Octupole Magnet

Two sets of octupole magnets are used to produce spatially uniform beam at the 100 mm × 100 mm target area. Two octupole magnets are installed in the beam waist positions of each transverse direction to facilitate the beam size adjustment in each direction respectively. The beam profile at the target is shown in Fig. 4. The uniformity is within ± 5% inside the target area. The specification of the octupole magnet is 200 mm in effective length and the maximum octupole strength is 500 T/m3. The beam transmission from the collimator to the target was around 20 %.

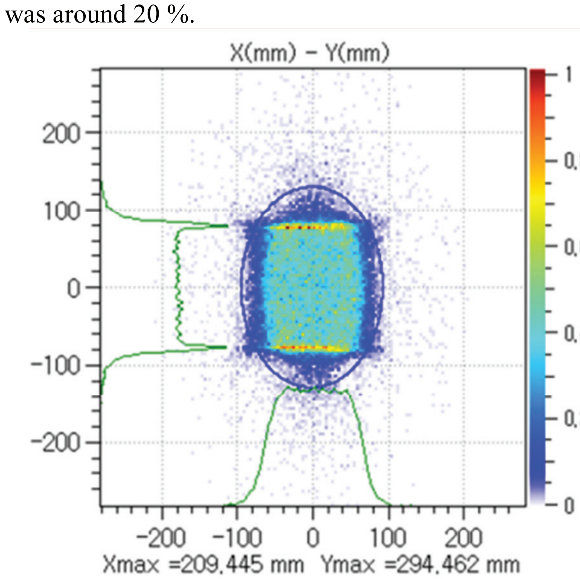

Figure 4: Beam profile at the target position.

Beam Window

An aluminium, beryllium alloy (AlBeMet) is used as a beam window. The thickness of the beam window is 0.5 mm. The beam window is formed to concave shape to reduce the stress due to the pressure difference between atmosphere outside the beam line and vacuum inside the beam line. The diameter of the beam window is 300 mm and the curvature radius is 1 m. The energy loss in the beam window is less than 1 % of 100-MeV proton beam.

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A helicoflex seal was used as a vacuum seal of the AlBe-Met, on which KOMAC has an experience. In addition to the beam window, we are going to install a vacuum sensor to detect and transmit the signal to the fast closing valve to protect the accelerator when there is a rupture accident of the beam window. The closing time of the fast closing valve is 20 ms and the sensor will be installed as close as beam window.

Development Plan

The beam transport system including dipole, quadrupole, octupole and steering magnets, vacuum chamber and beam pipe, vacuum system, beam diagnostics and beam window will be installed in the 2016 summer maintenance period. Also all the power supplies, cooling system and electrical system will be installed in summer maintenance period. After that, overall control system will be developed and implemented in the main accelerator control system. System integration and part test will be completed at the end of 2016. The beam commissioning will start at the early of 2017.

CONCLUSION

A beam line is designed for low flux proton beam application. It is the fourth beam line at KOMAC. The characteristics of the beam line are its low flux with high duty factor. A high power collimator was designed with the conjunction of the beam dynamics results. A double wedge energy degrader was proposed to supply continuously variable beam energy. Two sets of octupole magnets are used to produce a uniform beam at the target. The beam line is going to be integrated until the end of 2016 and the commissioning start at the early of 2017.

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