Design Study on the Beam Scanning System of the KOMAC RI Production Beam Line

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1. Introduction

A beam line for radioisotope (RI) production is developed at Korea Multi-Purpose Accelerator Complex (KOMAC). The specification of the beam line is summarized in Table 1 [1]. The beam energy is 100 MeV, maximum beam power is 30 kW and maximum irradiation diameter is 100 mm. The layout of the beam line for RI production is shown in Fig. 1. The beam from the 100 MeV linear accelerator is bent to 90 degree to deliver the beam to users. The existing beam line is a straight one which is perpendicular to the linac. A proposed RI production beam line is bent to 90 degree again to deliver the beam to TR101 target room as shown in the Fig. 1. A beam scanning system is required to distribute the heat load in the beam window and to use the target efficiently. The beam scanning system was proposed that the Halbach dipole array is rotating to scan the beam into the target. In this paper, we investigate the beam optics from the existing 100 MeV proton linear accelerator to the RI production target to get the beam information and compare the scanning system configurations in the view point of the heat load.

Table 1: KOMAC RI production beam line

Particle	Proton
Beam energy	100 MeV
Peak beam current	20 mA
Peak power	2 MW
Max. average power	30 kW
Max. energy per pulse	1,000 J/s
Max. irradiation diameter	100 mm

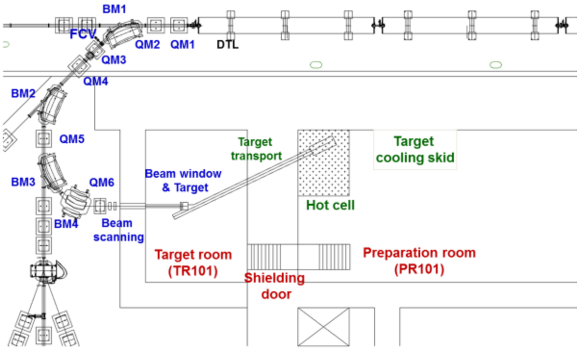

Fig. 1: Layout of the RI production beam line

2. Beam Scanning System

2.1 Beam Optics

The beam envelope was calculated using the TRACE3D code [2]. The location of the input beam was at the end of the 100 MeV linac. There are 4 bending magnets which have bending angles of 45 degrees in the beam line. We adjust three quadrupole magnets (QM3, QM4, QM5 in Fig. 1) to minimize the dispersion at the target. The result of the beam envelop is shown in Fig. 2.

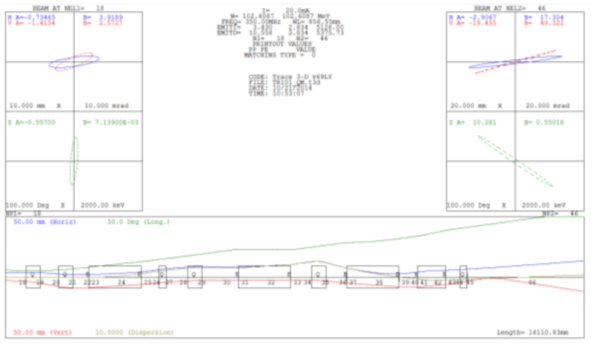

Fig. 2: Beam optics in the RI production beam line (blue: horizontal envelope, red: vertical envelope, green: longitudinal envelope, yellow: dispersion)

2.2 Beam Scanning System

The simple model of the beam scanning system is shown in Fig. 3.

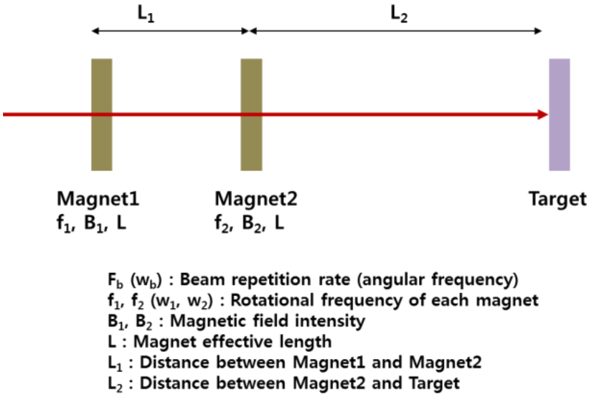

Fig. 3: Schematics of the beam scanning system

We used a transfer matrix [3] to transport the particle from the scanning magnet to target to investigate the behavior of the particle position at the target. Equation (1) and (2) were derived from the transfer matrix when we assumed a thin lens approximation. The variables r and Θ are the radial and azimuthal position of the particle at the target. As shown in the equation, the position depends on several parameters of the scanning system such as the integrated magnetic field, rotating frequency, the distances between two rotating magnets and the distance from the last magnet to target.

$$r = k\sqrt{(A^2+B^2+2AB\cos(w_1-w_2)t)} \qquad \text{Eq. (1)}$$

$$\theta = -atan\left(\frac{A\cos(w_1 t)+B\cos(w_2 t)}{A\sin(w_1 t)+B\sin(w_2 t)}\right) \qquad \text{Eq. (2)}$$

where,

$$A = B_1(l_1+l_2),\ B = B_2 l_2,\ k = \frac{L}{Magnetic\ rigidity}$$

With these conditions, the modulation frequencies in radial and azimuthal direction are the same and are the difference between f_1 and f_2. And the rotational frequency of the beam spot at the target is the larger one between the f_1 and f_2. The beam spots at the target is shown in Fig. 4 under the condition that L1 is 100 mm, L2 is 5,000 mm, L is 15 mm, f1 is 0.1 Hz, B1 is 0.2 T, f2 is 1.1 Hz and B2 is 0.6 T. The independent number of beam spots is 600 when the beam repetition rate is 60 Hz.

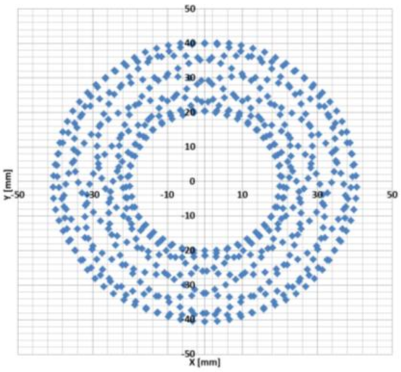

Fig. 4: Beam spots at the target

We compared the relative heat loads at the target under the condition that case 1) there is no scanning, case 2) there is only one scanning magnet and case 3) there are two scanning magnets with different rotational frequencies. In these cases, we assumed Gaussian beam with 6mm rms beam radius. The relative magnitude of the maximum heat loads of each case are such that case 1 is 21.9, case 2 is 1.7 and case 3 is 1. The heat load distribution for case 3 is shown in Fig. 5 using the same condition to that of Fig. 4.

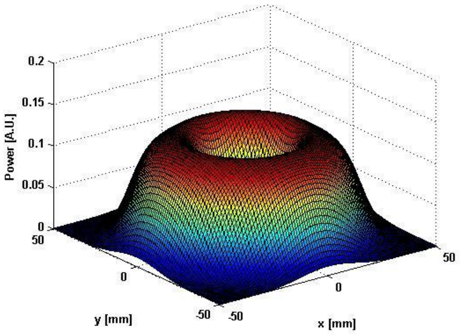

Fig. 5: Heat load distribution at the target

3. Conclusions

The beam scanning system was proposed to reduce the local heat load at the target and to use the target efficiently. The general equation to describe the beam spot position at the target was derived by using the transfer matrix. The beam spot positions and heat load at the target were calculated with the Gaussian beam profile. The maximum heat load in the case by using two scanning magnets could be reduced to 1/22 compared with the case without beam scanning.

ACKNOWLEDGEMENT

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