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Error Analysis of the Low Flux Beam Line at KOMAC

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1. Introduction

A low flux beam line has been operating since 2017 at Korea Multi-purpose Accelerator Complex (KOMAC). The purpose of the low flux beam line is to supply a low flux proton beam (1/100 ~ 1/1000 of the nominal beam current) with uniform beam profile in large area. The specification of the beam line is summarized in Table. 1.

Table 1: Specification of the low flux beam line

Proton beam energy	33 ~ 100 MeV
Average current	min. 0.1 nA
Beam uniformity	< 10% (100 mm × 100 mm)
Fluence per pulse	$5\times10^5 \sim 1\times10^8$ /cm^2/pulse

The characteristics of the beam line is that it is possible to access the target room easily because of the low activation of the target room, and electronics can be installed at the target preparation room. Recently, low flux beam line is the most popular one among users. The beam line is mainly used for the space radiation test, detector research and development, biology research and so on which requires very low flux proton beam. The proton beam flux is reduced through the collimator in the beam line, and the uniform beam can be obtained by using two octupole magnets [1]. The beam line layout is shown in Fig. 1. The collimator which is used to reduce the flux and two octupole magnets which are used to control the uniformity of the proton beam are shown in Fig. 1 too.

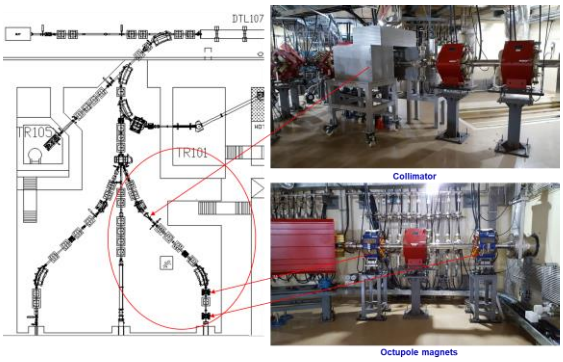

Fig. 1. Low flux beam line layout is shown in the red circle (left). The collimator and two octupole magnets which are installed in the beam line are also shown (right).

Recently, space part tests with proton beam has been studied in the low flux beam line. It is important to reproduce the proton beam parameter at the target position. Unfortunately, there is no beam steering magnet in the beam line from collimator to the target. Therefore, it is not easy to adjust the beam orbit if there are some errors in the beam line components. It is planned to study the error effects of the beam line components on the beam parameters and to prepare the method to adjust those effects in order to supply high quality beam to users.

2. Error Analysis

2.1 Beam Line Layout

The low flux beam line layout is shown inside of red circle in Fig. 1. The beam line components after the collimator are consists of 5 sets of quadruple magnet, 1 set of bending magnet and 2 sets octupole magnet, which are designated in Fig. 2 in detail. The beam envelope from collimator to target without errors is shown in Fig. 3. The envelope was calculated using TRACEWIN code [2]. The input beam parameters and the design parameters of the magnets are listed in Table 2 and Table 3 respectively. In the calculation, the design parameters of the magnets are the quadrupole magnet gradient which result in the beam envelope in Fig. 3.

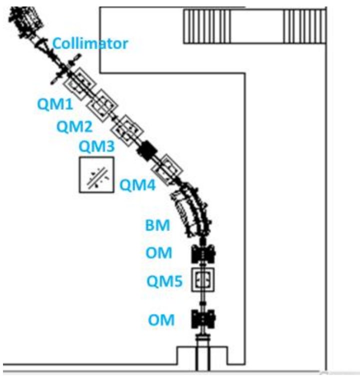

Fig. 2. Low flux beam line components after the collimator, focusing quadrupole (QF), defocusing quadrupole (QD), bending magnet (BM), octupole magnet (OM) are shown.

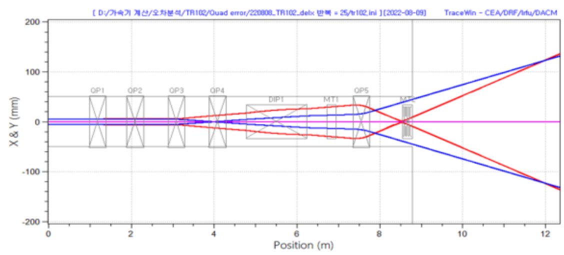

Fig. 3. Beam envelope of the low flux beam line without errors. The start point is the exit of the collimator and the end point is the beam window position. The red line is the envelope in x direction, the blue line is in y direction.

Table 2: Input beam parameters

Proton beam energy	102.6 MeV
Emittance (normalized, rms)	0.2 π mm mrad
α	0
β	13.3 mm / π mrad
No. of particles	10,000

Table 3: Operation parameters of the quadrupoles

Magnet designation	Quadrupole gradient [T/m]
QM1	-0.72
QM2	1.22
QM3	-5.00
QM4	0.26
QM5	5.00

2.2 Error Source

The errors of the quadrupole and dipole bending magnet are considered. The error source and ranges used in the calculation are summarized in Table 4, and the meaning of the errors is shown in Fig. 4.

Table 4: Error source and their ranges

Error source	Range
Displacement in x, y	< 100 μm
Pitch angle	< 1 °
Roll angle	< 1 °
Gradient	< 1 %

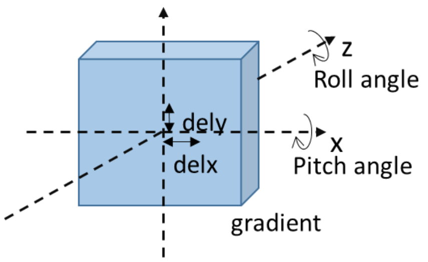

Fig. 4. Meaning of errors in Table 4.

2.3 Results and Discussion

The calculation results are shown in Fig. 5. The results are obtained with the random error sets of 25 cases of the error ranges in Table 4 respectively. As shown in the Fig. 5, the displacement error of the quadrupoles in x direction gives the largest displacement of the orbits. The operation parameters of the quadrupoles in Table 3 show that the QM3 is the largest defocusing effect in x direction and the QM4 is low focusing effect. In addition, the dipole bending magnet is a rectangular shape which has a drift effect in horizontal direction and focusing effect in vertical direction. Because of these magnet arrangement, the motion of the particle in x direction has a long drift section after the strong defocusing effect in QM3 which results in such a large displacement of orbit in horizontal plane (x-direction). In order to adjust the orbit in horizontal plane, a preliminary study was done with two beam position monitors and one corrector magnet as shown in Fig. 6. The orbit before and after the correction are shown in Fig. 7. The orbit deviation is reduced from 3 mm to less than 1 mm in horizontal plane. The optimization of the positions of the corrector magnet and beam position monitors is will be done in future.

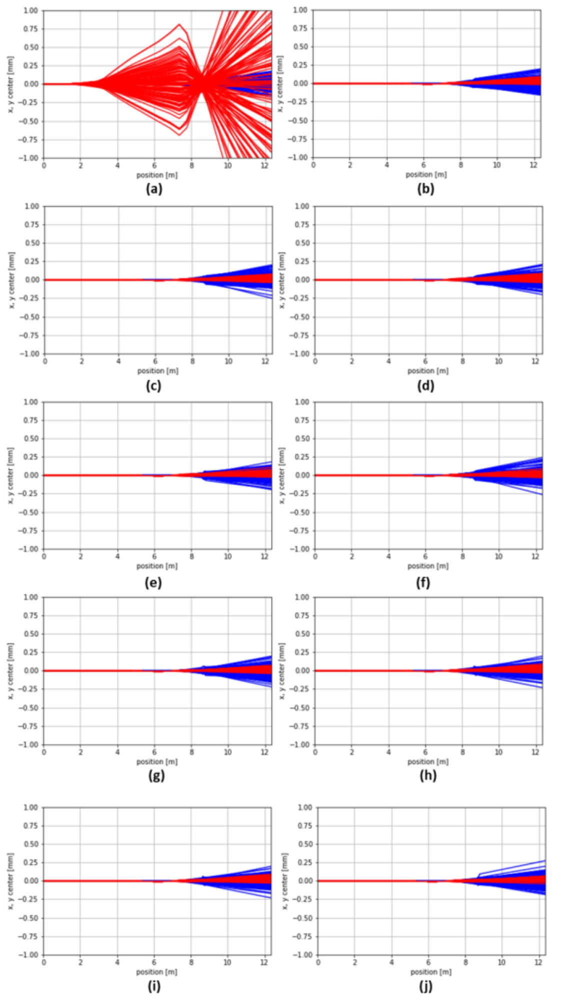

Fig. 5. The beam orbit with errors. (a) quadrupole displacement error in x, (b) quadrupole displacement error in y, (c) quadruple pitch angle error, (d) quadrupole roll angle error, (e) quadrupole gradient error, (f) dipole displacement error in x, (g) dipole displacement error in y, (h) dipole pitch angle error, (i) dipole roll angle error, (j) dipole gradient error. Red color is in x-direction orbit, blue color is in y-direction orbit.

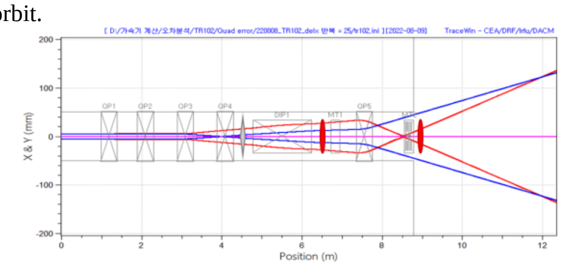

Fig. 6. The position of the correction magnet (diamond shape) and beam position monitors (red ellipse shape) in preliminary study.

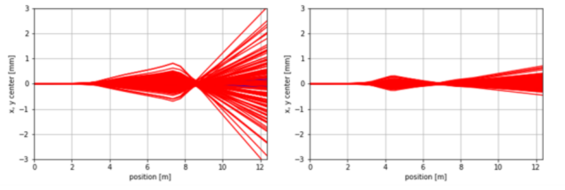

Fig. 7. Orbit due to the quadrupole displacement error in x-direction, (a) before correction, (b) after correction.

3. Conclusions

The error analysis was done in the low flux beam line in order to supply high quality beam to users. The quadruple displacement error in horizontal plane is the most harmful error which results in largest orbit deviation. The optimization of the adjustment of the orbit deviation will be done by using corrector magnet and beam position monitors in future.

ACKNOWLEDGEMENT

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