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PRELIMINARY STUDY ON THE IMPLEMENTATION OF THE ORBIT CORRECTION TO THE 100 MeV PROTON LINAC AT KOMAC

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Abstract

At KOMAC (Korea Multipurpose Accelerator Complex), we have been operating a 100 MeV linac consisting of 11 DTLs (Drift Tube Linacs) with several BPMs (Beam Position Monitors), WSs (Wire Scanners) and SMs (Steerer Magnets) installed for the orbit correction of the proton beam. The orbit correction can be performed through the response matrix between the position measurements from the BPMs/WSs and the field strength of the steering magnets. In this work, we will show the calculated response matrix from the simulation results, and describe the detailed plans for the implementation of the orbit correction in the real linac system at KOMAC.

INTRODUCTION

The performance of the high current linac greatly depends on the alignment of the linac and the performance of the orbit correction. At KOMAC, we have a 100 MeV proton linac consisting of 11 DTLs. Using information on beam center at various BPM and WS locations in the linac, we can guide the proton beams to avoid beam loss. For this, SVD (Singular Value Decomposition) technique [1–3] is performed to calculate the steering angles to apply by building a response matrix relating between the beam centers at BPM/WS and the steering angles applied by SMs from the beam dynamics simulations. Here, we show some of the preliminary results of the orbit correction and future plans for the implementation of the orbit correction in the real system at KOMAC.

METHOD

In this section, we will describe how the orbit correction is implemented based on the beam dynamics simulation.

Layout for Beam Position Monitor, Wire Scanner and Steerer Magnet

For the orbit correction, there are 10 BPMs, 2 WSs and 8 SMs(including 3 additional SMs to be installed in future) in the linac and the dump beamline as shown in Fig. 1a. Depending upon the size of the free space, 2 types of steerer magnets, a and b are installed and also shown in Fig. 1a. The steering angle $\Delta\theta$ applied by the steerer magnet of size L and magnetic field B is given as

$$\Delta\theta = \frac{qBLc}{mc^2\beta\gamma} \tag{1}$$

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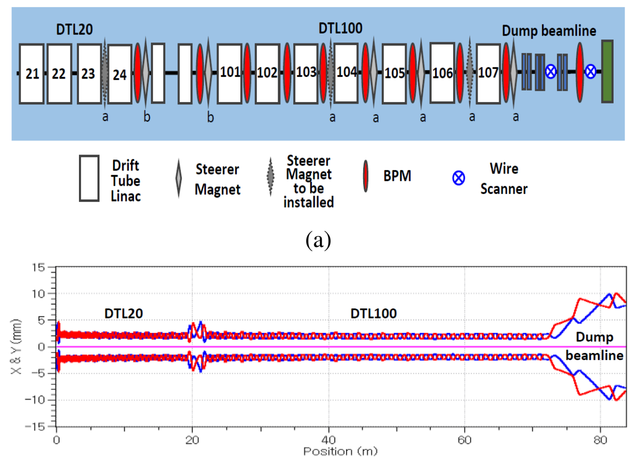

(a)

(b)

Figure 1: (a) Layout for Beam Position Monitor, Wire Scanner and Steerer Magnet. (b) Beam envelope graph shows x and y envelopes in blue and red respectively. Beam x, y centers are shown in magenta.

In Fig. 1a, we label DTL21~24 and DTL101~107 as DTL20 and DTL100 sections. Beam envelope for our 100 MeV proton linac is calculated and shown in Fig. 1b.

Scheme for Orbit Correction

The orbit correction is carried out utilizing a SVD which inverts a response matrix. We construct a response matrix, R_{ij} relating M BPMs and WSs, and N SMs used for the orbit correction of the 100 MeV proton linac,

$$R_{ij} = \frac{\Delta x_i}{\Delta\theta_j} \tag{2}$$

where x_i is beam center at i^{th} BPM and $\Delta\theta_j$ is a steering angle applied by j^{th} SM. This means that the change in the beam center by the steering angle is

$$\Delta x = R \cdot \Delta\theta \tag{3}$$

Response matrix, R can be written as a product of three matrices, U, Σ and V as

$$R = U \cdot \Sigma \cdot V^T \tag{4}$$

where U and V are $M \times M$ and $N \times N$ unitary matrix respectively. Σ is an $M \times N$ diagonal matrix with diagonal elements s. This decomposition is unique only to a certain extent, not in every case. To calculate the steering angle to apply the orbit correction,

$$\Delta\theta = R^{-1} \cdot \Delta x \tag{5}$$

where R^{-1}, an inverse of R matrix. This is written as below,

$$R^{-1} = V \cdot \Sigma^{-1} \cdot U^T \tag{6}$$

and Σ^{-1} = all non-zero diagonal terms $1/s$.

The response matrix R is a (10+2)×8 non-square response matrix with 8 eigen values and is obtained from the beam dynamics simulation similar in [4, 5]:

$$R_{12\times8} = \begin{bmatrix} -0.1158 & 0.0000 & 0.0000 & \cdots & 0.0000 \\ -0.0862 & 0.1268 & 0.0000 & \cdots & 0.0000 \\ 0.3169 & -0.4540 & 0.2917 & \cdots & 0.0000 \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ -2.4994 & 3.6002 & -0.9544 & \cdots & -3.9723 \end{bmatrix}$$

The inverse of R is used for the orbit correction. Given the layout of BPM, WS and SM, we tested a certain case by setting certain errors that would show some weak points in the current BPM/WS-SM layout in Fig. 1a. The set errors are x displacement of DTL101, DTL103 and DTL106 by +0.1 mm, +0.5 mm and −0.2 mm respectively, assuming that quadrupole magnets inside the DTL are well aligned to the DTL tank. When the errors are applied, the simulated beam envelope is shown as in Fig. 2. x center is increasingly shifted along the linac, till the dump beamline with the maximum shift of 12 mm. Steering angles are calculated using Eq. (5) and set to steerer magnets.

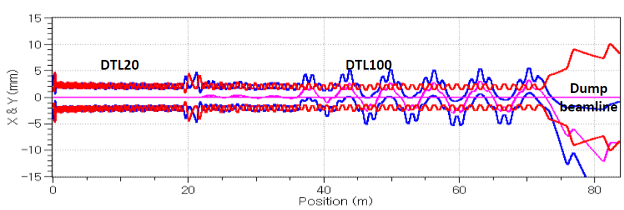

Figure 2: X, Y beam envelope in blue and red lines and x center in magenta when the orbit correction is applied to the x displacement errors of DTL101, DTL103 and DTL106.

RESULTS

Beam envelope is simulated after applying the steering angles for the orbit correction, shown in Fig. 3. Beam centers in the latter half of the DTL100 and the entire dump beamline are greatly improved as they gather close to the linac center. However, even though there is no error set in DTL20, the steerer magnets in DTL20 act to correct the orbit in DTL100. That is because there is no steerer magnet installed in DTL102 and DTL103 due to space limitation.

This test study is not real but helps us to visualize how SM-missing places are affected to over-compensate errors. We will continue our simulation study to improve our diagnostics system based on the error studies and orbit correction. We also intend to modify the SM design to be accommodated in the congested spaces. In parallel, to apply the orbit correction in the real linac system, real-time beam position monitoring GUI using BPMs are set in the 100 MeV linac control room.

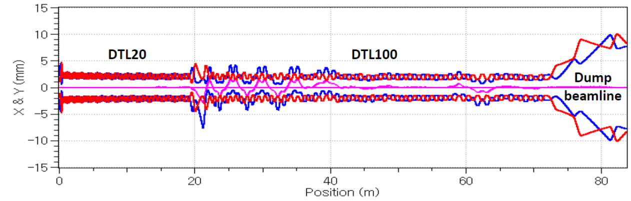

Figure 3: Orbit-corrected X, Y beam envelope in blue and red lines and x center in magenta when the orbit correction is applied to the x displacement errors of DTL101, DTL103 and DTL106.

CONCLUSION

From the beam dynamics simulations, response matrix is obtained, relating between beam centers at BPM/WS positions and steering angles applied by steering magnets. With certain and known errors, the orbit correction is applied using SVD. As there is no steerer magnet to correct the orbit in the DTL102 and 103, the steering magnets in the DTL23, DTL24 and MEBT II are acted for the orbit correction even though there were no error set in DTL20 and MEBT sections. As a result, beam center is corrected in the latter part of DTL100 and the dump beamline. And from the result, we visualize effects on the SM-missing places in the linac. In coming studies, we will work on improvement of beam diagnostics based on error studies and orbit correction.

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