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Study on Beam Steering in the PEFP 20 MeV DTL

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1. Introduction

The Proton Engineering Frontier Project (PEFP)[1] is developing a proton linac which accelerate 20 mA proton beams up to 100 MeV. The accelerator consists of an ion souce, a low energy beam transport (LEBT), a 3 MeV radio-frequency quadrupole (RFQ), a 100 MeV drift-tube linac (DTL). The DTL structure divides into two parts. One is a DTL (called DTL1) whose energy range is from 3 MeV to 20 MeV. It is designed to operate with 24% beam duty. The other is another DTL (called DTL2) for 20 ~ 100 MeV with 8% beam duty[2]. There is a MEBT between two DTL structures which will be operated with different beam duties. The main purposes of the MEBT are extracting 20 MeV proton beams to the user group and matching proton beams into the DTL2.

This brief report related to the steering properties of the PEFP DTL tanks. For the beam dynamics study related with the steering magnets, we concentrated on the displacement error of the 20 MeV DTL tanks which consists of 4 tanks.

2. Displacement Error Effects

The displacement errors of the DTL tanks and quarupole magnets generate a betatron oscillation of beam center in the lattice structures of the linac. The oscillation is a source of the emittance growth and the beam quality is getting worse. The particles in the proton beam can be lost if the oscillation amplitude becomes larger. Figure 1 (a) shows the behavior of the matched input beam in the DTL1. The beam oscillation in Figure 1 (b) is generated by the 1 mm displacement of DTL21, which is the first tank in PEFP DTL1, in the horizontal direction. In this work we neglected the space charge effects because the main purpose is to check the steering concept.

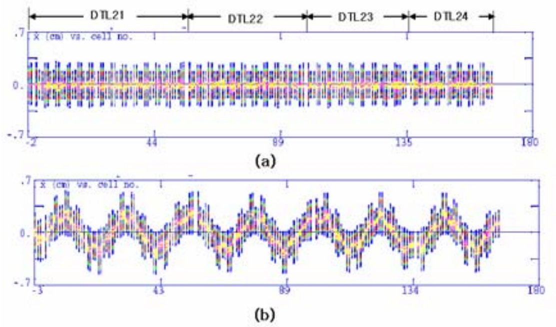

Figure 1. Configuration plots of proton beams in the PEFP DTL1: (a) for matched input beams and (b) for 1 mm displacement of DTL21 in the horizontal direction.

3. Beam Steering

3.1 Steering Methods

We can control the beam oscillation by using steering magnets which are small dipole magnets. The magnets have two roles. One is shifting beam center to the accelerator axis at a specific point. The other is changing the derivative of the trajectory of the beam center to be zero at the same point. These purposes can be achieved by four steering magnets, two for the horizontal direction and the others for the vertical direction. The information of the beam trajectory is obtained by four beam-position monitors (BPMs) in both transverse directions.

The lattice of the PEFP DTL1 is a FFDD structure and each drift tube includes a quadrupole magnets. Hence the steering magnets and BPMs can be installed before and after DTL tanks. We studied two steering schemes. In the first method, the BPMs are installed after DTL23 and DTL24 (scheme-a). In the other scheme, they are installed after DTL24 where two BPMs are separated by a drift space of 700 mm (scheme-b). Figure 2 shows the schematic plot of the setups for two beam steering schemes in the horizontal direction. The same method can be used for the vertical direction.

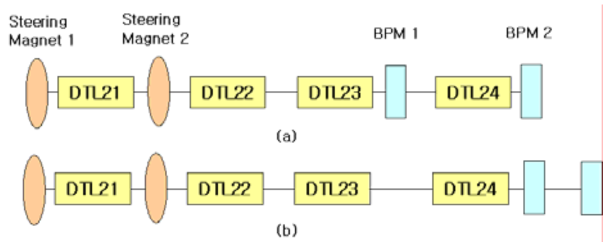

Figure 2. Schematic plot of the steering setup in a transverse direction. It consists of two BPMs and two steering magnets.

3.2 Beam Steering Result

First of all, we calculated the beam dynamics under the condition that one of the four DTL1 tanks is displaced from the designed position by 1 mm in the horizontal direction. Figure 3(a) ~ Figure 3(d) show the beam oscillation corresponding to the displacement errors of DTL21 ~ DTL24, respectively.

Table 1 summarized the shift-values of the beam center at the BPM positions in the scheme-a and scheme-b steering methods. From this information we can calculate the bending angle of the two bending magnets. The result is given in Table 2.

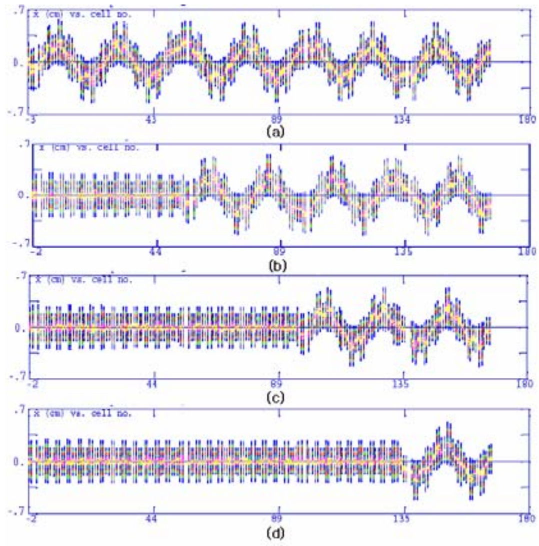

Figure 3. Configuration plot of proton beams in the PEFP DTL1 under displacement errors of (a) DTL21, (b) DTL22, (c) DTL23 and (d) DTL24.

Table 1. Position data of beam center measured by two BPMs in two steering schemes. The first column corresponds to from Figure 3 (a) to Figure 3 (d), respectively.

Tank with displacement error	Scheme-a		Scheme-b	
	BPM1 (mm)	BPM2 (mm)	BPM1 (mm)	BPM2 (mm)
DTL21	-2.17	1.26	1.25	5.64
DTL22	1.95	-1.52	-1.52	-3.53
DTL23	0.15	-0.46	-0.47	1.17
DTL24	0.004	0.34	0.33	3.72

Table 2. Bending angles obtained by two steering magnets(SMs) in two steering schemes.

Tank with displacement error	Scheme-a		Scheme-b	
	SM1 (mrad)	SM2 (mrad)	SM1 (mrad)	SM2 (mrad)
DTL21	-6.99	-2.61	-6.69	-2.18
DTL22	3.96	-4.40	3.90	-4.45
DTL23	-1.71	-6.21	-1.68	-6.21
DTL24	2.03	5.87	-4.61	-5.41

Figure 4 and Figure 5 show the resulting configuration plot of proton beams after turning on the steering magnets in two schemes, respectively. From Figure 4 (d), we found that the scheme-a cannot correct the displacement error of DTL24 because the first BPM is located before the error source. That is why we studied the scheme-b. From Figure 4 and 5, we found that the kicks of steering magnets cancel the displacement effect of a DTL tank and the beam oscillation disappears after the error source.

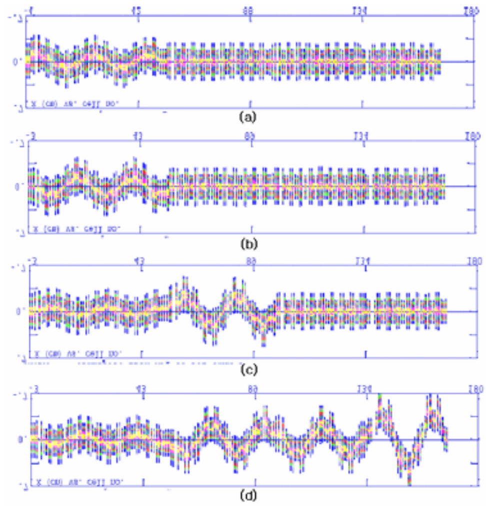

Figure 4. Configuration plot after turning on the steering .magnets in the scheme-a.

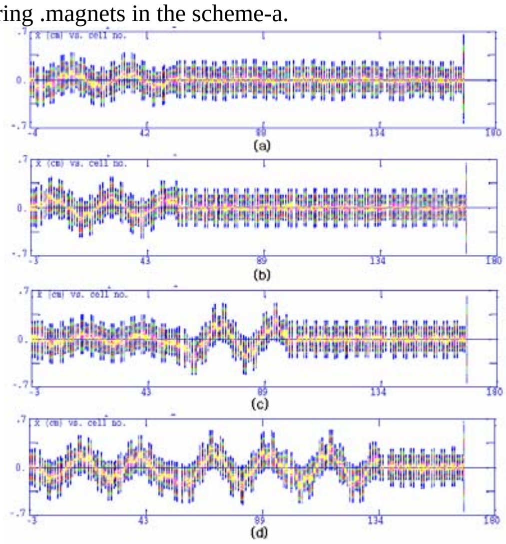

Figure 5. Configuration plot after turning on the steering .magnets in the scheme-b.

In conclusion, we studied the steering magnet effects under the condition that there is a displacement error in one of PEFP DTL1 tanks and space charge effects can be neglected. We found that the steering magnets works very well and this study is a starting point of the study on the beam steering in PEFP linacs.

5. Acknowledgement

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[2] J.H. Jang, Y.S. Cho, H.J. Kwon, “Beam Dynamics Design of the PEFP 100 MeV Linac”, HB2006, Tsukuba, May 2006.