Transactions of the Korean Nuclear Society Spring Meeting
Chuncheon, Korea, May 25-26 2006

Beam Dynamics in the PEFP Linac

Ji-ho Jang[a,b], Yong-sub Cho[a], Hyeok-jung Kwon[a], Kui-young Kim[a], Yong-hwan Kim[a]
a Proton Engineering Frontier Project, KAERI, P.O. Box 105, Yusong, Daejeon, Korea, b jangjh@kaeri.re.kr

1. Introduction

The linac of the Proton Engineering Frontier Project (PEFP) consists of a 50 keV proton injector, a 3 MeV radio-frequency quadrupole (RFQ), a 20 MeV drift tube linac (DTL)[1], a medium energy beam transport (MEBT), and the higher energy part (20 MeV ~ 100 MeV) of the 100 MeV DTL. The MEBT is located after the 20 MeV DTL to extract 20 MeV proton beams[2]. The lower and higher energy parts of the PEFT linac was designed to operate with 24% and 8% beam duties, respectively. This brief report discusses the beam dynamics properties of the PEFP 100 MeV linac.

2. Matching between LEBT and RFQ

First of all, we have studied the beam matching from a low energy beam transport (LEBT) into the RFQ. In order to obtain the matched input beam, we have programmed a simple routine using MATHMATICA.

Table 1 shows the twiss parameters of the matched input beams in the transverse directions. Even though the peak beam current of PEFP linac is 20 mA, we studied the matching condition up to 40 mA. In the calculation, we assumed that the beam emittances are independent of input currents: $\varepsilon_x = \varepsilon_x = 0.2$ mm-mrad in the normalized rms unit. The transmission rates in the RFQ are given in Figure 1. We found that the transmission rate in the RFQ decreases for the larger beam current.

Table 1. Twiss parameters of matched input beams into the 3 MeV RFQ depending on the peak beam current.

Current (mA)	α	β(cm/rad)
0.1	0.77	4.09
1	0.77	4.09
10	0.80	4.23
20	1.00	5.20
40	1.09	5.56

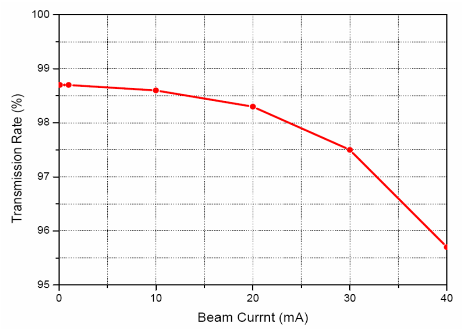


Figure 1. Transmission rates of the RFQ depending on beam currents.

3. Matching between RFQ and DTL1

3.1 Matching Methods

We studied three different schemes of the beam matching between the RFQ and the lower energy part (DTL1) of the PEFP DTL. The first case is that there is no matching tool in the drift space (Figure 2(a)). The second is using one quadrupole magnet for easy control of the transverse matching (Figure 2(b)). In these cases, the transverse beam matching is achieved by initial four quadrupole magnets in the first tank of the DTL1. The last one is using the four quadrupole magnets and two buncher cavities to match the beams in the transverse and longitudinal directions, respectively (Figure 2(c)).

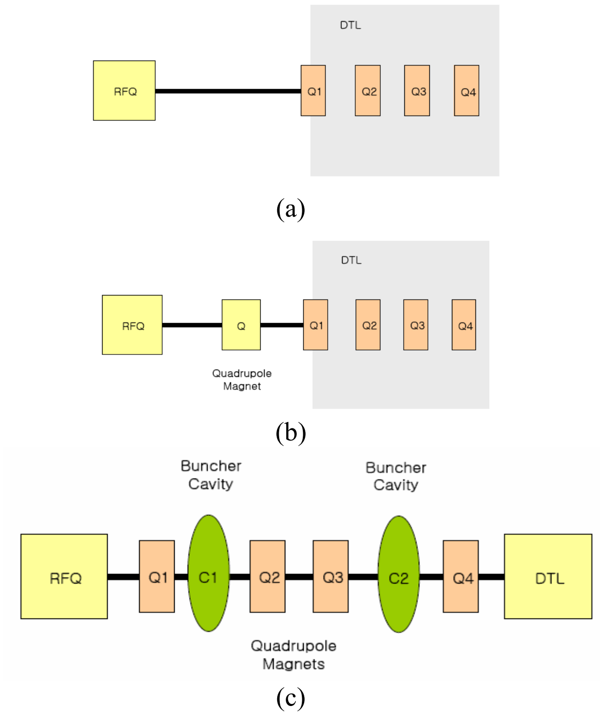
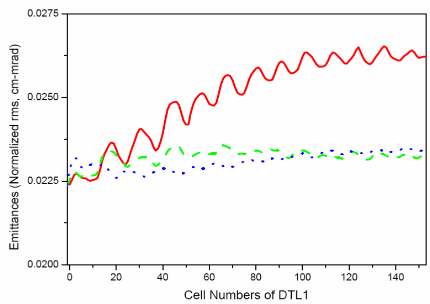


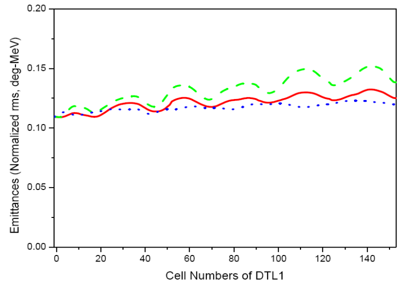
Figure 2. Matching schemes between RFQ and DTL1: (a) with drift space only (b) with one quadrupole magnet (c) with four quadrupole magnets and two buncher cavities.

3.2 Beam Dynamics in PEFP DTL1

In the first case, we found that there is no solution for the transverse beam matching within the designed value of the quadrupole magnets. Hence the additional quadrupole in the second case is essential for the matching. Figure 3 (a) shows the trend of transverse emittances in DTL1 tanks for three cases.



(a)



(b)

Figure 3. Transverse (a) and Longitudinal (b) emittances in DTL1: real (red), green (dashed), blue (dotted) lines for first, second, and third cases, respectively.

In the first case, the transverse emittance increases dramatically since beams are not matched in the design limit of the quadrupole magnets. The longitudinal emittance is given in Figure 3(b). Because the length of the drift space between RFQ and DTL1 is smaller in the first case than the second, the longitudinal emittance oscillation reduces in the first case. The emittances in the full matching of the third case remain to be relatively flat in both transverse and longitudinal directions.

4. Beam Dynamics in the MEBT and DTL2

The PEFP higher energy part (DTL2) of the PEFP linac accelerates proton beams from 20 MeV to 100 MeV. Since the beam duty of DTL2 is 8%, the accelerating gradient increases from 1.3 MV/m in DTL1 to 2.58 MV/m. It is another reason of the MEBT to be located after DTL1 for beam matching.

4.1 MEBT: Beam Matching between DTL1 and DTL2

The PEFP MEBT consists of 8 quadrupole magnets and 2 buncher cavities. The initial 4 magnets are controlling the beam size in a 90-degree bending magnet for the beam extraction. The following quadrupoles are matching 20 MeV proton beams into the DTL2. The buncher cavities are for the longitudinal matching and they are realized by 2 DTL tanks with 3 cells. Figure 4 shows the beam size in the MEBT and DTL2.

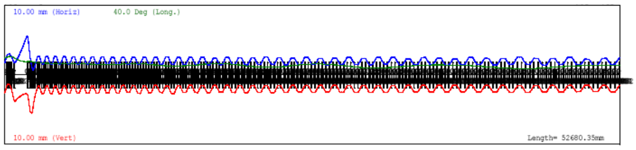


Figure 4. Beam sizes in the MEBT and DTL2: blue line in upper half plane, red line in lower half plane, green line between blue and green lines for horizontal (cm), vertical (cm), and longitudinal (degrees) beam sizes.

4.2 Beam Dynamics in DTL2

We found that the transverse emittances oscillate and increase even though we used the MEBT for beam matching. The origin of the oscillation is the missing RF between DTL tanks. The effects can be removed by ramping 3 cells before and after the drift space between tanks. The figure 5 shows the transverse and longitudinal emittances in the MBET and DTL2 after the inter-tank matching.

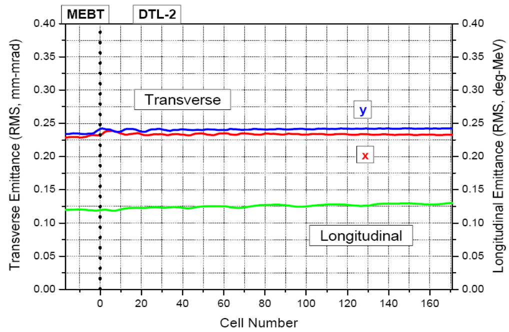


Figure 5. Transverse and Longitudinal Emittances in the PEFP MEBT and DTL2.

5. Conclusion

The PEFP 100 MeV linac includes two important matching points. The first one is the matching between RFQ and DTL1 where the transverse mismatch is more serious than the longitudinal one. The second matching is in the MEBT where there is a long drift space for beam extraction. The beam dynamics study including these matching shemes shows that the PEFP linac can accelerate 20 mA proton beams to 100 MeV without serious problems.

6. Acknowledgement

This work is supported by the 21C Frontier R&D program in Ministry of Science and Technology of the Korean Government.

REFERENCES

[1] J.H. Jang et. al., "Beam Dynamics Design Study of 20 MeV DTL for PEFP", ICOPS 2003, Jeju, 2003.

[2] J.H. Jang et. al., "Design of the PEFP MEBT", PAC 2005, Knoxville, USA, 2005.