BEAM DYNAMICS STUDY OF THE LOW ENERGY PROTON ACCELERATORS FOR PEFP

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Abstract
The low energy part of the high current proton accelerators for Proton Engineer Frontier Project (PEFP) includes a 3MeV RFQ and a 20MeV DTL. This work is related with the combined beam dynamics study of the RFQ and DTL in order to test the beam transportation through the whole structure and gather the preliminary information of the MEBT.

INTRODUCTION
The low energy linear accelerators for PEFP consists of a 3 MeV RFQ under testing and a 20 MeV DTL under construction. They are the first part of the PEFP linear accelerators designed to accelerate 20 mA proton beam to 100 MeV.

The beam matching between the RFQ and DTL becomes serious since the RFQ is a relatively strong focusing structure than the DTL in the transverse direction. On the other hand, the longitudinal zero current phase advances between the accelerators are so similar that the longitudinal matching problem becomes relatively manageable.

The main purpose of this work is the combined beam dynamics study of the RFQ and DTL in order to find a simple solution of the transverse mismatch problem without introducing the complex MEBT.

In the next section, we have summarized the physical designs of PEFP RFQ and DTL. The following section includes a possible solution of the mismatching problem between the RFQ and DTL.

RFQ AND DTL FOR PEFP
PEFP RFQ is four vane type with 4 sections [1]. They consists of a radial matching section of 4 cells, a shaper, a gentle buncher, an accelerator, and a fringe field region. The whole structure is separated into two segments which are resonantly coupled for the field stabilization [2]. The RF power is fed into the cavity through two iris couplers in the third section. The main design parameters are given in Table 1 and Figure 1.

The beam dynamics is calculated by PARMTEQM code. The result is given in Figure 2 for the configuration plots of the beam in the RFQ structure. The transmission rate has been improved to be 99.3% by applying the matched beam for the RFQ.

Table 1: The PEFP RFQ parameters.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency</td>
<td>350 MHz</td>
</tr>
<tr>
<td>Input / Output Energy</td>
<td>23 mA / 20 mA</td>
</tr>
<tr>
<td>Input / Output Current</td>
<td>50 keV / 3 MeV</td>
</tr>
<tr>
<td>Peak Surface Electric Field</td>
<td>1.8 Kilpatrick</td>
</tr>
<tr>
<td>Power</td>
<td>417.9 kW</td>
</tr>
<tr>
<td>Transmission Rate</td>
<td>95.4 % †</td>
</tr>
<tr>
<td>Length</td>
<td>324 cm</td>
</tr>
</tbody>
</table>

†99.3% for the matched input beam.

Figure 1: PEFP 3MeV RFQ Design Parameters: synchronous phase (φs), accelerating efficiency (A), focusing efficiency (B), mid-cell aperture radius (r0), minimum radius curvature (a), modulation (m), and particle energy (W).

Figure 2: Configuration plots of the beam in the original RFQ.

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PEFP DTL consists of 4 tanks which accelerates the 20 mA proton beam from 3 MeV to 20 MeV [3]. The total length is about 20 m and a 1 MW klystron will be used to supply the RF power. The lattice structure is FFDD with the magnetic field gradient of 5 kG/cm and the effective field length of 3.5 cm.

The simulation result obtained by PARMILA is given in Figure 3 for the configuration plots, and Figure 4 for the matched input and output beam.

**MATCHING BETWEEN RFQ AND DTL**

The zero current phase advances per unit length are given as 4.15 deg/cm at the high energy end of the RFQ and 2.55 deg/cm at the low energy end of the DTL. It implies that the output beam from the RFQ is over-focused than the desired input beam for the DTL. If we push the RFQ output beam directly into the DTL, the additional betatron oscillation occurs and the beam loss comes to 0.13 % as shown in Figure 5. It is beyond the designed limit of the particle loss, 1 ppm. The input and output beam in the trace space are given in Figure 6.

We have modified the last section of the RFQ in order to close it with weaker focusing efficiency. The new design parameters are given in Figure 7. The main change is the larger aperture radius for the reduced focusing efficiency. The configuration plot of the beam in the modified RFQ is given in Figure 8.
CONCLUSION

This work is related with the combined beam dynamics study of PEFP RFQ and DTL. In order to get the matched input beam for the DTL under the constraint of limited strength of the quadrupole magnets, we have modified the last section of the RFQ and selected some specific values for the field gradient of the first four magnets in DTL and the effective field length of the first magnet. However the longitudinal matching is not fixed in this framework.

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REFERENCES