BEAM COMMISSIONING PLAN OF PEFP 100-MeV LINAC *

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Abstract

Proton engineering frontier project (PEFP) is developing a 100-MeV proton linear accelerator. The lower energy part of the linac up to 20-MeV is operating at KAERI site. The remaining part of the 100-MeV linac was fabricated and tested at Gyeungju site. The movement of 20-MeV linac and the installation of the 100-MeV accelerator will start in November 2011. The beam commissioning is scheduled for 2012. This work summarized the beam commissioning plan of the proton linear accelerator.

INTRODUCTION

One of the main purposes of the PEFP is developing a 100-MeV proton linear accelerator [1]. It consists of a 50keV proton injector, a 3-MeV RFQ (radio frequency quadrupole), a 20-MeV part of a DTL (drift tube linac), a MEBT (medium energy beam transport), and a higher energy part (20~100MeV) of the DTL. The distinguishing characteristic of this facility is extracting 20-MeV proton beams in the middle of the linac and providing the beams to users. The MEBT was designed to satisfy this special purpose. It comprises one bending magnet for beam extraction and two small DTL-type tanks for beam matching in both transverse and longitudinal directions.

The PEFP linac operates at 350MHz and the peak beam current is 20 mA. The beam duties of the linac are 24% up to 20-MeV and 8% for 100-MeV acceleration. The beam power becomes 160kW at the end of the linac with the designed beam specification which is given in Table 1.

BEAM COMMISSIONING PLAN

The layout of the beam diagnostic equipment in PEFP 100-MeV linac is given in Figure 1. The beam commissioning will be a two-staged process. One is testing up to the 20-MeV linac and the MEBT. The other is the beam commissioning for 100-MeV linac. The 1-kW beam bump will be installed at the end of the 100-MeV linac. A beam stop which is located in the MEBT will be used for the 20-MeV beam commissioning. The commissioning goal is the beam power of 100W with the peak beam current of 20 mA, the pulse width of 50μs in 1 Hz operation .

20MeV Linac and MEBT

The 20MeV part of the linac has been installed and tested at KAERI site [2]. It will be moved to Gyeungju site at the end of 2011. It is located about 220 km below from the KAERI site. The commissioning of the 20-MeV linac is basically retesting process of the linac after moving and reinstalling the machine.

The PEFP injector consists of a 50-keV microwave ion source and an LEBT (low energy beam transport). The ion source uses 2.45 GHz magnetron. The design value of the beam emittance is 0.2 π mm-mrad in the normalized rms unit. There are two solenoid and two steering magnets in the LEBT for beam matching into the RFQ.

Table 1: Design specification of PEFP 100-MeV linac

Parameters	Low energy	High energy
Output Energy	20 MeV	100 MeV
Peak beam Current	20 mA	20 mA
Beam Duty	24%	8%
Pulse Width	2 ms	1.33 ms
Repetition Rate	120 Hz	60 Hz
Average Beam Current	4.8 mA	1.6 mA
Average Beam Power	96 kW	160 kW

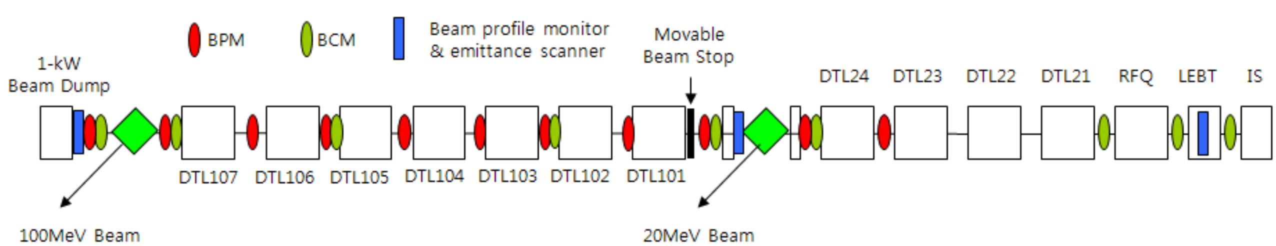

Figure 1: Layout of beam diagnostics in PEFP linac.

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The PEFRP RFQ was designed the proton beam up to 3 MeV [1, 3]. One of the important processes of the beam commissioning of the RFQ is finding the RF operating point by comparing the calculation and experimental results of beam transmission. The PARMTEQ [4] result for the beam transmission through the PEFP RFQ is given in Figure 2. The blue and red lines respectively show the transmission rate and beam energy as a function of the voltage factor.

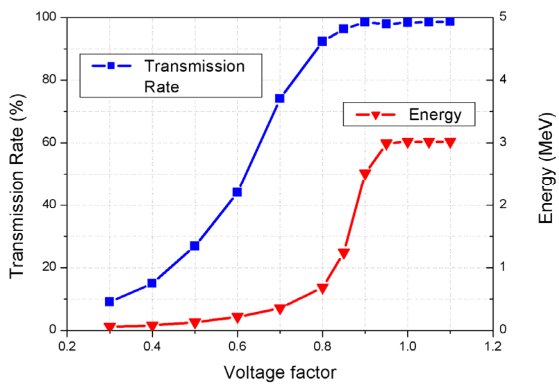

Figure 2: PARMTEQ result of the beam transmission in the PEFP RFQ.

The 20-MeV DTL consists of four tanks that accelerate 20 mA proton beams from 3 MeV to 20 MeV [1]. The twiss parameters, α and β, of the matched input beam to the DTL21 tank are 2.08 and 0.26 mm/mrad in the horizontal direction and -3.06 and 0.45 mm/mrad in the vertical direction, respectively. For the beam matching, we will use initial 8 quadrupole magnets in the first DTL tank. Table 2 shows the input and output energies of 4 DTL tanks. A 1-MW klystron supplies RF power into the four tanks. The relative phase between DTL tanks will be adjusted by phase shifters as shown in Figure 3. Then we can obtain the operating condition of the 4 tanks by adjusting them like a single cavity. The RF set point will be determined by the phase scan method [5].

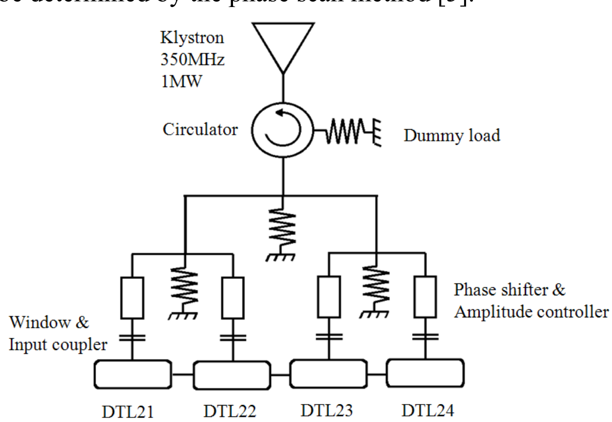

Figure 3: RF operation scheme of the PEFP 20-MeV DTL.

Table 2: Input and Output Energies of 20-MeV DTL tanks

	Input Energy (MeV)	Output Energy (MeV)
DTL21	3.0	7.2
DTL22	7.2	11.5
DTL23	11.5	15.8
DTL24	15.8	20.0

The MEBT includes a long drift space for a 45-degree bending magnet in order to extract 20-MeV proton beams [1, 6]. Two small DTL-type tanks will be used to match proton beams into the following DTL tank. The quadrupole magnets and RF of the cavities are used for beam matching in transverse and longitudinal directions as shown in Figure 4 which was obtained by TRACE3D code [7]. The PARMILA [8] result of beam simulation is given in Figure 5 from 20 MeV to 100 MeV through the MEBT. A beam stop will be installed in the MEBT system for 20-MeV beam commissioning as shown in Figure 1. In this commissioning stage, the peak beam current is 1 mA with pulse width of 50 μs and repetition rate of 1 Hz. The beam position monitors and current transformer will be installed in the MEBT for beam diagnostics. The beam energy can be measured by using the time of flight method two BPMs.

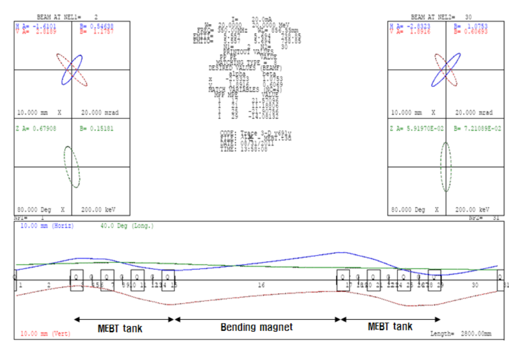

Figure 4: TRACE3D result for beam matching in the PEFP MEBT.

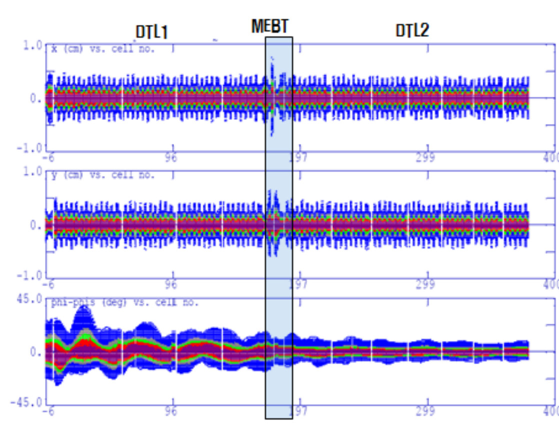

Figure 5: PARMILA result of beam simulation.

DTL(20MeV ~ 100MeV)

The higher energy part of DTL consists of 7 tanks which accelerate proton beams from 20 MeV to 100 MeV [1]. Each tank will be derived by a 1.3-MW klystron. The twiss parameters, α and β, of the matched input beam to the first DTL tank are -2.87 and 1.10 mm/mrad in the horizontal direction and 1.88 and 0.60 mm/mrad in the vertical direction, respectively. The input and output energies of each tank are summarized in Table 3. The commissioning goal is the 100 W proton beams at the end of DTL. In this case, the pulse width and repetition rate are 50 μs and 1 Hz with the peak beam current of 20 mA which will be achieved after several steps from 1 mA peak current.

Table 3: Input and Output Energies of the DTL (20MeV ~ 100 MeV) tanks

	Input Energy (MeV)	Output Energy (MeV)
DTL101	20.0	33.1
DTL102	33.1	45.3
DTL103	45.3	57.3
DTL104	57.3	69.1
DTL105	69.1	80.4
DTL106	80.4	92.0
DTL107	92.0	102.6

The operation condition of the RF for each tank will be determined by the phase scan method which gives the information of the RF amplitude, phase, and input beam energy of the tank. Figure 6 shows the PARMILA result of the beam phase as a function of the RF phase for DTL101 which was calculated by PARMILA. Each curve represents the case of different RF amplitude where 0.96 means 96% of the design amplitude. The beam phase will be measured by the BPM located between tanks. Because there is no empty drift tube in PEFP DTL tanks, beam

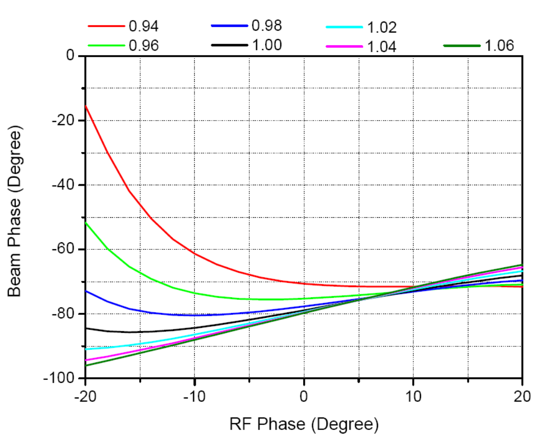

Figure 6: Beam phase of DTL101 as a function of RF phase.

diagnostic instruments will be installed in the space between two DTL tanks. The operating point of the RF phase will be determined by either selecting the overlapped position of several experimental results or comparing the simulation and experimental results for the beam phases depending on the RF phases [9, 10, 11].

CONCLUSION

The installation of the PEFP 100-MeV linac will starts in November 2011. The commissioning consists of 2 stages, 20 MeV and 100 MeV beams, and is scheduled for 2012. The beam commissioning goal is the proton beam power of 100 W at the end of 100-MeV linac. The pulse width and repetition rate are 50 μs and 1 Hz with the peak beam current of 20 mA. The commissioning process will begin with the peak current of 1 mA.

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