RF SET-UP SCHEME FOR PEFP DTL*

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Abstract

The proton engineering frontier project (PEFP) is developing a 100-MeV proton linac which consists of a 50 keV injector, a 3-MeV radio frequency quadrupole (RFQ) and a 100-MeV drift tube linac (DTL). The installation of the linac was started in December 2011. The beam commissioning is scheduled for 2012. The phase scan signature method is a common technique to determine the rf set point including the amplitude and phase in DTL tanks. This work summarized the rf set-up scheme for PEFP DTL tanks by using the phase scan signature method.

INTRODUCTION

The main purposes of the PEFP are developing a 100-MeV proton linear accelerator and supplying 20-MeV and 100-MeV proton beams to users [1]. The linear accelerator consists of a 50keV proton injector, a 3-MeV RFQ, and an 100-MeV DTL. One of the characteristics of the facility is extracting 20-MeV proton beams in the middle of the linac and providing the beams to users. The medium energy beam transport (MEBT) was designed to satisfy this special purpose with one bending magnet for beam extraction and two small DTL-type tanks for beam matching in both transverse and longitudinal directions [2].

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 [1, 3].

The installation of the linac started on November 2011 and the accelerating cavities were installed until March 2012 in the accelerator tunnel. The temporary operation of the 20-MeV part of the linac was finished on November 2011 at Daejeon site, and moved to the project site at Gyeongju city. It was installed as a low energy part of the 100-MeV linac [4].

BEAM COMMISSIONING PLAN

The beam commissioning will be a two-staged process. One is testing up to the 20-MeV 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 for the commissioning. A beam stop which is located in the MEBT will be used for the 20-MeV beam commissioning. The initial goal is the beam power of 100W with the peak beam current of 20 mA, the pulse width of 50μs in 1 Hz operation. The layout of the beam diagnostic equipment in PEFP 100-MeV linac is given in Figure 1 [3].

The commissioning of the 50-keV injector including a microwave ion source and LEBT (low energy beam transport) will start from the operating condition of the machine at Daejeon site. The RFQ commissioning is the process to find the RF operating point by comparing the calculation and experimental results of beam transmission. A 1-MW klystron drives 4 DTL tanks which accelerate proton beams up to 20-MeV. The RF set point of tanks will be determined by the same procedure as that for a DTL tank [3] .

RF SET POINT OF DTL TANKS

In order to determine the RF set point of the PEFP DTL tanks, we will use the well-known phase scan signature method [5]. The beam phase of a DTL tank will be measured as function of RF phase by using the beam position monitor (BPM) which will be installed downstream of each DTL tank as shown in Figure 1. Figure 2 is the schematic plot of the beam phase measurement of a DTL tank.

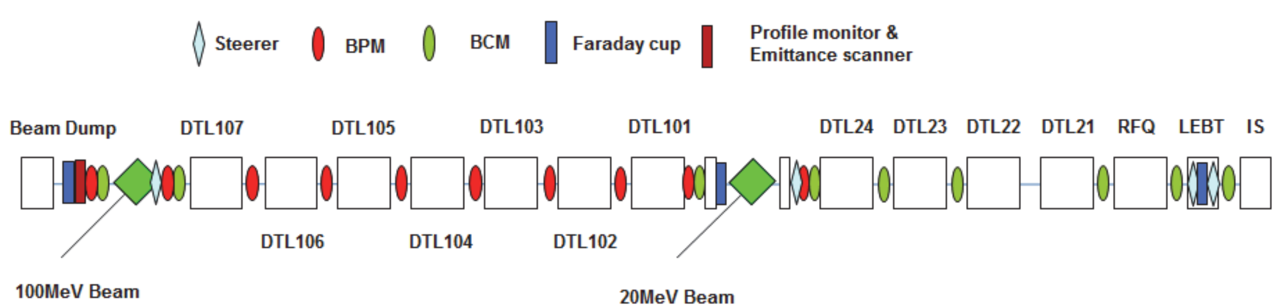

Figure 1: Layout of beam diagnostics in PEFP linac.

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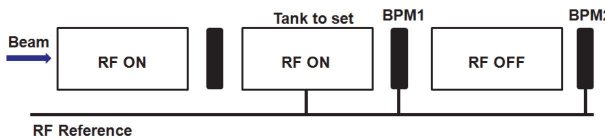

Figure 2: Schematic plot for beam phase measurement of a DTL tank.

Table 1: Input and Output Energies of the PEFP DTL 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 beam energy can be also determined by using the time of flight method from the phase measurement via 2 BPMs, BPM1 and BPM2 in Figure 2, downstream of the DTL tank. The RF of the tank is on for phase measurement. The RF of the next DTL tank is off to determine the output energy of the tank as shown in Figure 2. The design values of the input and output are summarized in Table 1.

In the next step, we calculated the beam phase as a function of RF phase for DTL101 tank by using PARMILA code [6]. The result is given in Figure 3 [2]. In this simulation, we varied the relative value of the RF amplitude from 0.94 to 1.06. The value 1.02 represents 2% larger value of the RF amplitude than the design value. From the simulation data, we obtained the polynomial function of the beam phase as a function of RF phase, $\phi_{\text{beam}} = f(\phi_{\text{rf}})$. We used the 10-th order polynomial in the fitting process.

In order to study the validity of the procedure, we used artificial experimental data generated by using PARMILA code for the relative RF amplitude of 1.0. We assumed that the input energy of the tank is same as the design value. It can be achieved by adjusting the RF adjustment of 20-MeV DTL tanks. For the other DTL tanks such as DTL102~DTL107, the input energy can be selected to the design value through the RF set point determination of the previous tank. In order to compare the artificial data with the fitting function, we moved the fitting function as follows,

$$\phi_{\text{beam}} = b + f(\phi_{\text{rf}} - a).$$

The parameters a and b can be determined by minimizing χ^2 which is defined as follows,

$$\chi^2 = \frac{1}{N}\sum_{i=1}^{N}\left[f_{\text{ex}}(\phi_i) - (b + f(\phi_i - a)\right]^2,$$

The number N and function $f_{\text{ex}}(\phi_i)$ represent the number of different RF phase measured in the (artificial) experiment and their beam phases, respectively. From the quadratic fitting of the χ^2, we can determine the RF amplitude set value. Figure 4 shows the result. The obtained amplitude was 1.001 which is very close to the artificial experiment with the relative amplitude of 1.0

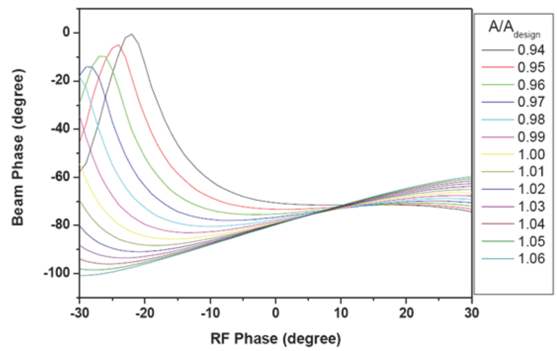

Figure 3: Beam phase as a function of RF phase for DTL101.

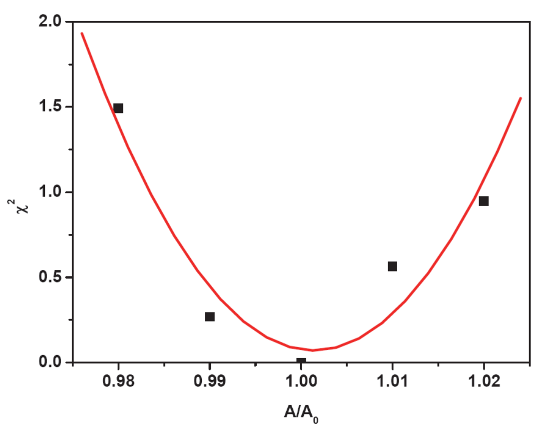

Figure 4: Amplitude determination by comparing the simulation results with the artificial experimental result for the relative amplitude of 1.0.

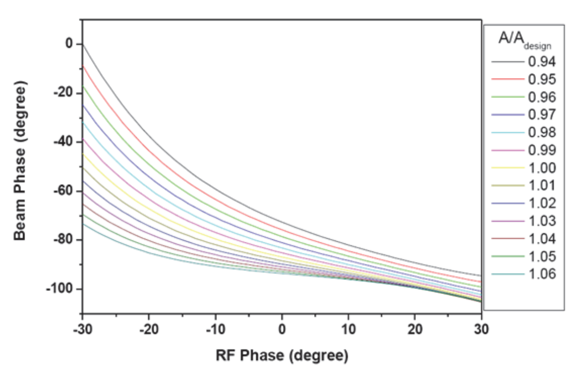

Figure 5: Beam phase as a function of RF phase for DTL102.

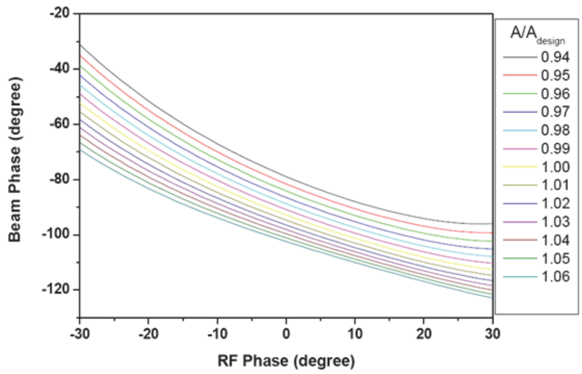

Figure 5: Beam phase as a function of RF phase for DTL103.

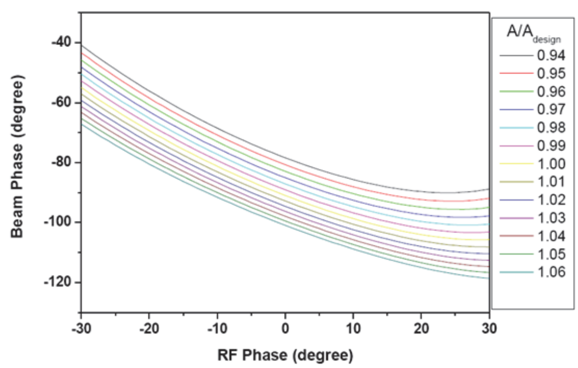

Figure 7: Beam phase as a function of RF phase for DTL104.

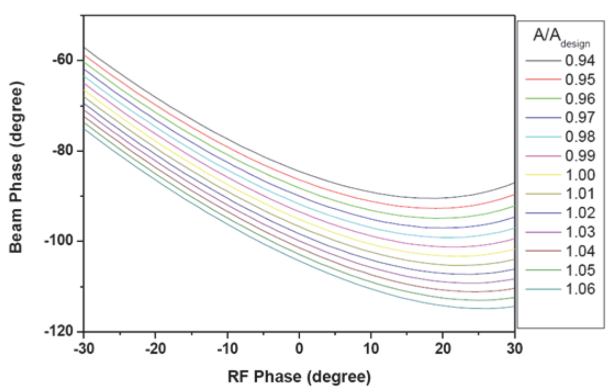

Figure 8: Beam phase as a function of RF phase for DTL105.

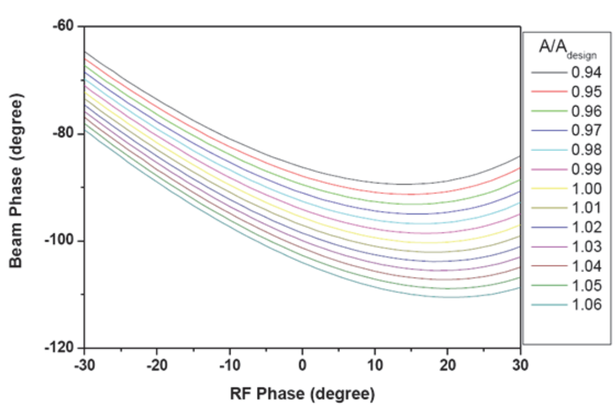

Figure 9: Beam phase as a function of RF phase for DTL106.

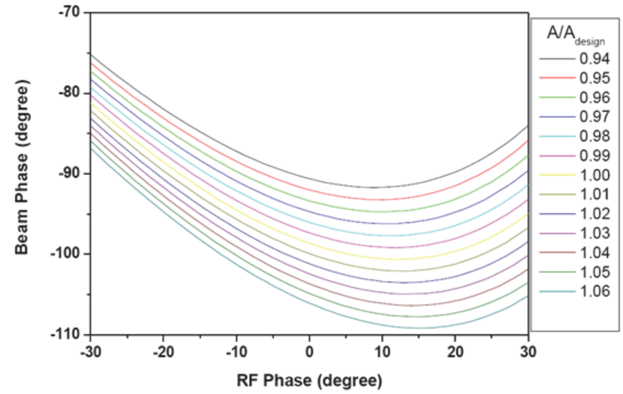

Figure 10: Beam phase as a function of RF phase for DTL107.

We also obtained the beam phases as a function of RF phase for the other DTL tanks, DTL102~DTL107. We found that the beam phase behaviour is almost similar between higher energy tanks. The results are given in Figures 5 to Figure 10. The same method to determine the RF amplitude for DTL101 can be applied to the other tanks.

CONCLUSION

We studied on the determination of the RF set point based on the phase scan signature method. The beam phase on DTL tanks were obtained as a function of RF phase by using PARMILA code. The validity of the procedure was studied by using artificial experimental data for DTL101. The procedure will be applied to the upcoming beam commissioning at the end of this year.

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