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DESIGN AND FABRICATION OF THE BEAM POSITION MONITOR FOR THE PEFP LINAC

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The beam position monitor (BPM) is an essential component for the PEFP 100-MeV linac's commissioning. A prototype stripline-type linac BPM was designedfor this purpose. The electrode aperture is 20 mm in diameter, and the electrode is 25 mm long, so it can be installed between Drift Tube Linac (DTL)101 and DTL102, which is the shortest distance. One end of the electrode is connected to the Sub Miniature Type A (SMA) feed through for signal measurement, and the other end is terminated as a short. The signal amplitude of the fundamental component was calculated and compared with that of the second harmonic component. The designed BPM was fabricated and a low-power RF test was conducted. In this paper, the design, fabrication and low power test of the BPM for the PEFP linac are presented.

KEYWORDS : Proton, Accelerator, Commissioning, Beam Position Monitor

1. INTRODUCTION

One of the goals of the Proton Engineering Frontier Project (PEFP) is to construct a 100-MeV proton accelerator [1-3]. The fabrication of the PEFP 100-MeV DTL tanks finished in 2010, the installation starts in 2011, and the commissioning is planned to start in June 2013. A phase scan method will be used to adjust the RF set points, such as the amplitude and the phase, during the commissioning stage [4]. A beam position monitor (BPM), which is used to measure the beam phase, is a crucial component for the phase scan method. The beam diagnostics layout of the 100-MeV proton accelerator is shown in Fig. 1. The BPMs will be used not only for measuring the beam phase but also for measuring the beam position to adjust the steering magnets.

Button-type BPMs were installed for the 20-MeV accelerator, which has been operating since 2007. A stripline-type BPM is being considered for the remaining higher energy part, which accelerates the proton beam from 20-MeV to 100-MeV, because the 100-MeV accelerator has enough space to accommodate a stripline-type BPM.

The goal of this study is to design, fabricate, and test a prototype BPM for the PEFP 100-MeV accelerator. The design of the BPM is described in Section II, the fabrication is described in Section III, and the low-power test results are described in Section IV. Finally, Section V discusses the test results and future plans for the prototype BPM.

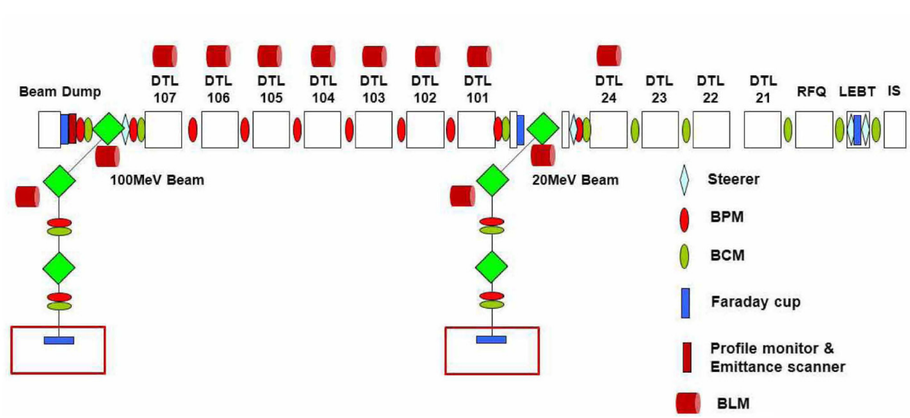

Fig. 1. Beam Diagnostics Layout

2. DESIGN

The design parameters of the PEFP linac BPM are summarized in Table 1. The beam parameters for the BPM design are such that the energy ranges from 20 MeV to 100 MeV with a peak beam current from 1 mA, which will be used at the early commissioning stage, to 20 mA, which is the accelerator's design value. The minimum beam pulse width is 50 us which was selected in consideration of the Low Level RF (LLRF) control margin. Schematics of the stripline-type BPM are shown in Fig. 2. The stripline-type BPM consists of four electrodes to measure the RF power induced by the proton beam, four pick-up feedthroughs to deliver the RF power induced in the electrode to the electronics in order to calculate the beam position, and a vacuum pipe. At first, we should consider the BPM length because the available space is limited. The BPMs will be installed between Drift Tube Linac (DTL) tanks, and the shortest inter-tank gap is 124.6 mm between the DTL101 and the DTL102 endplates, which includes a BPM, a gate valve, and a bellow. The net available space for the BPM is 48.2 mm. With this constraint, the electrode aperture is 20 mm in diameter, which is the same as the drift tube's inner diameter. The electrode width is 60º, which is used in many BPM designs because the signal power is larger with less inter-electrode coupling. The electrode thickness is 2 mm, considering the mechanical stiffness. The gap size between the electrode and the outer vacuum pipe is 3.5 mm in order to give the 50Ω impedance calculated by using the POISSON/SUPERFISH code. One side of the electrode is connected to the SMA feedthrough for signal measurement, and the other side is terminated as a short. A simulation using the MWS code showed that the gap size between the electrode and the vacuum pipe transition had little influence on the electromagnetic properties, such as the matching and the coupling between electrodes, of the BPM.

The signal amplitude was estimated by using an analytic formula that included high frequency effects such as the transit time factor and the Bessel factor [5]. Beam parameters, such as the beam bunch size, were obtained from the PARMILA code and are summarized in Table 2. The beam was assumed to have a Gaussian profile. The signal amplitudes, expressed as rms values, were calculated by varying the electrode length for the fundamental and the second harmonic frequencies. The 700-MHz signal amplitude was higher than the 350-MHz signal amplitude because the electrode length was much shorter than the quarter wavelength for a 350-MHz frequency. The signal power increased as the electrode length was increased, as shown in Fig. 3. From Fig. 3, an electrode length of 25 mm was selected, which will be able to produce enough signal amplitude and fit in the given space.

Table 1. Design Parameters of the PEFP linac BPM

Beam energy	20MeV ~ 100MeV
Peak beam current	1mA~20mA
Pulse width	50us~1.33ms
Position accuracy	2% of beam pipe radius
Position precision	0.2% of beam pipe radius
Position measurement range	40% of beam pipe radius
Electrode aperture radius	10mm
Total length	< 49mm
Electrode angle	60 degree
Signal frequency	350MHz or 700MHz

Table 2. Beam Parameters for BPM Design

Beam energy	20MeV	100MeV
Beam bunch length (RMS)	0.033ns	0.018ns
Beam current	20mA	20mA
Beam bunch frequency	350MHz	350MHz

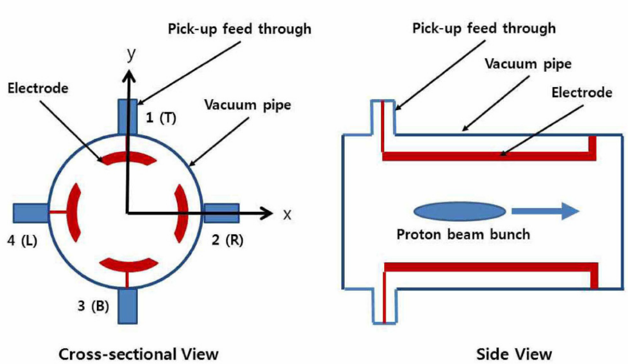

Fig. 2. Schematics of Strip Line BPM

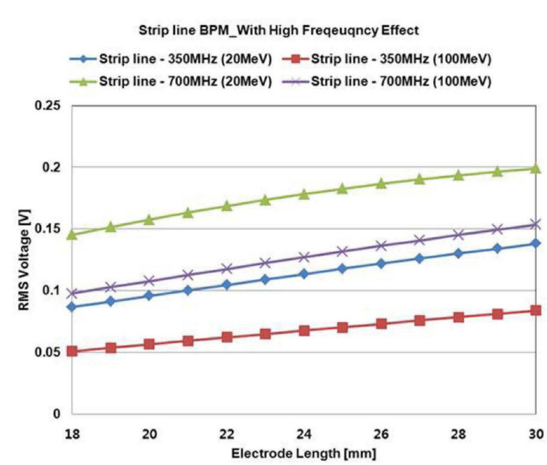

Fig. 3. BPM Signal Amplitude Depending on the Electrode Length