DEVELOPMENT OF BEAM POSITION MONITOR FOR PEFP LINAC AND BEAM LINE*

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Abstract

The development of the beam position monitor (BPM) is in progress for the linac and beam lines of the proton engineering frontier project (PEFP). We chose a strip line BPM for the PEFP 20-MeV and 100-MeV beam lines in order to increase the sensitivity of the relatively long bunches in the beam lines. We also selected the same type BPM for the proton linac in the energy range between 20 MeV and 100 MeV. The prototype BPM was designed, fabricated and tested at the Daejeon site of Korea atomic energy research institute (KAERI). This paper summarized the status of the BPM development.

INTRODUCTION

The PEFP 100-MeV Linac consists of a 50 KeV 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 (20~100-MeV) of DTL [1]. The PEFP accelerator also has 20MeV beam lines and 100MeV beam lines, which have five target rooms to supply the proton beam for users. It is required to monitor the position of the proton beam during the 100MeV accelerator operation. Ten BPMs for the linac will be installed from the 20MeV DTL to the 100MeV DTL including the front of the beam dump. Two BPMs for the beam line will be also installed at the 20MeV beam line and 100MeV beam line respectively. The layout of the BPMs for the PEFP 100-MeV linac and beam-line is given in Figure 1. The BPMs for the PEFP 100MeV accelerator have been developed and the BPMs for the linac and beam line have been fabricated. Their electrical performance was measured with the low power RF signal and it was applied in the beam experiment of the 20-MeV PEFP linac.

BPM DESIGN

The BPM was designed with the MWS code and SUPERFISH code and the design parameters of the BPM are summarized in Table 1 [2]. The strip line BPM was chosen for the 100MeV linac and the beam lines. The linac BPM and the beam line BPM were fabricated. The fabricated BPMs are shown in Figure 2. There are four pickup ports with electrodes in the BPMs and those have a symmetrical structure.

Figure 2: Photo of the beam line BPM (left) and Linac BPM (right).

Table1: Design parameters of the BPMs.

BPM type	Beam-line BPM	Linac BPM
Electrode inner diameter	100 mm	20 mm
Electrode thickness	2 mm	2 mm
Electrode angle	45 degree	60 degree
Electrode length	70 mm	25 mm
Electrode gap	15 mm	3.5 mm
Feed through	SMA type	SMA type
Signal frequency	350 MHz	350, 700 MHz

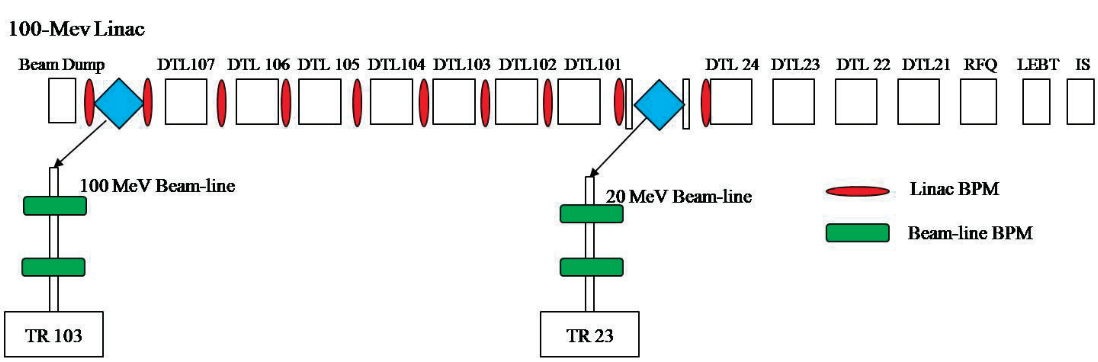

Figure 1: Layout of BPMs in PEFP 100-MeV Linac and Beam-line.

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The beam bunch rms length was calculated by using the PARMILA code. During the calculation, the high frequency effects such as transit time factor and Bessel factor were considered. The parameters of 20-MeV, 100-MeV proton linac are summarized in Table 2. The BPM is used to measure not only the beam position but also the beam phase. The BPM is a crucial component for phase scan method.

Table 2: Parameters of 20-MeV, 100-MeV proton accelerator beam.

Beam energy	20 MeV	100 MeV
Beta (β)	0.2	0.43
Beam bunch rms length	0.033 ns	0.018 ns
Beam bunch frequency	350 MHz	350, 700 MHz
Transit time factor	0.99	0.99
Bessel factor (Beam-line / linac)	0.5/0.96	0.87/0.99

LOW POWER RF TEST OF THE BPM

Measurement of the coupling between electrode and antenna.

We checked their electrical performance in the low power test at the test stand. It was measured with electrode-center coupling to check whether the electrical center is located at the geometrical center. We used the 350 MHz RF signal radiated from a 3-mm-diameter copper instead of the beam. The copper wire is located at the geometrical center of the BPM.

The four electrodes of the pickup detect the radiated signal of the copper wire. The result of measurement value was -18.2~20.3 dB at the beam-line BPM. When compared to designed value -20 dB, the measurement value at port 2, 3, 4 was little small due to the difference between electrical center and physical center. The measurement results of electrode-center coupling at the Linac BPM are summarized in Table 3. The signal at 700 MHz was higher than that of 350MHz. The results of measured electrode-center coupling values in 4 ports were almost same because the difference was less than 3 %.

Table 3: Measured electrode-center coupling of the Linac BPM.

Electrode	Measurement [dB]	
	350 MHz	700 MHz
Port 1 (+X)	-30.2	-23.2
Port 2 (+Y)	-29.6	-23.7
Port 3 (-X)	-29	-23.1
Port 4 (-Y)	-29	-22.7

Measurement of the inter-electrode coupling

We also measured the inter-electrode coupling by putting the 350-MHz RF signal to the port4 and measured the response signals at port 1, 2, 3. The same signal amplitude was measured at port 1 and port 3 because they are equally separated from port 4. The schematic of the BPM is shown in Figure 3.

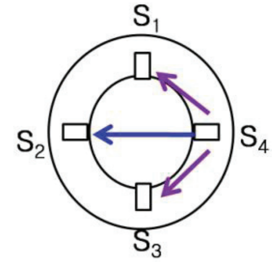

Figure 3: Schematic of ports for inner electrode measuring.

The smallest signal was measured in the longest distance port 2. The inter-electrode coupling results are given in Table 4. We found that the measurement results are well agreed with the calculations.

Table 4: Measurement of inter-electrode coupling.

Electrode	Measurement	Simulation
Beam line BPM		
S_{14} [dB]	-32.3	-32.1
S_{24} [dB]	-41.1	-42.5
S_{34} [dB]	-32.2	-32.1
Linac BPM		
S_{14} [dB]	-27.9	-28.2
S_{24} [dB]	-37.0	-37.0
S_{34} [dB]	-28.1	-28.2

Measurement of the position sensitivity of the BPM

Figure 4 shows 2-D Mapping of the beam-line BPM and linac BPM. The position sensitivity to convert the output voltage signal from the oscilloscope into the position is theoretically defined by equation (2) [3].

$$S = \frac{160}{\ln 10} \frac{\sin\left(\frac{\phi}{2}\right)}{\phi} \frac{1}{b} \qquad (2)$$

Where ϕ is the angular width and b is the electrode inner radius. The theoretical position sensitivity of the beam line BPM is 0.67 dB/mm and the position sensitivity of the linac BPM is 3.3 dB/mm.

BEAM TEST OF THE BPM

The prototype BPM was installed and tested at the 20-MeV proton accelerator beam-line. The 20-MeV beam-line sequentially consists of gate valve, quadrupole triples with two faraday cup and exit window and dump. We installed the BPM in just before exit window. The output signals from four ports were measured by using the oscilloscope, 350 MHz band pass filter, and RF detector.

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The cables were used for the transmission line. During the test, the quadrupole triplets in the beam line were set to transport the proton beam without loss. The current setting values were such that 107.0A for the 1st one, -75.0A for 2nd one and 71.4A for the 3rd one.

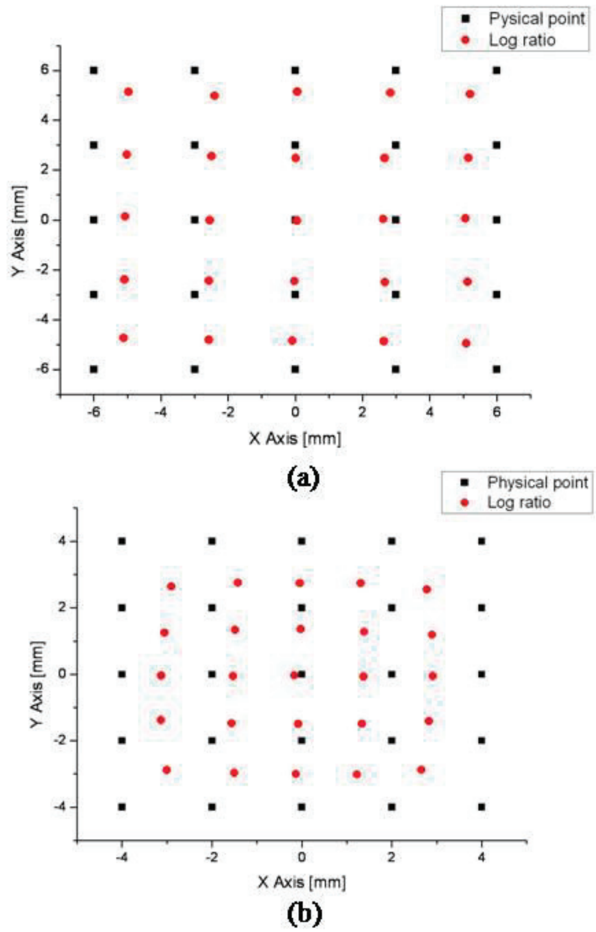

Figure 4: 2-D Mapping of the beam-line BPM (a) and Linac BPM (b).

The output signals from each port are shown in figure 5. The vertical axis (X axis) measured signal ratio were 111.2% and horizontal axis (Y axis) is 90.4%, finally total ratio is 100.8% in case of the beam-line BPM [4]. The signal from the Linac BPM was little different from that of the beam-line BPM. The channel 3(-x) signal is measured very large. Therefore we should check the inner structure of linac BPM.

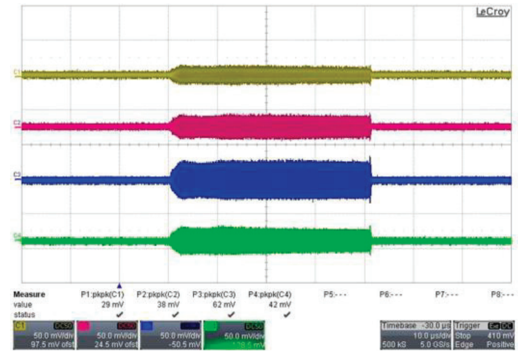

Figure 5: Output beam signal from the PEFP 20-MeV linac by using the beam-line BPM

CONCLUSION

The BPM is important a diagnostic equipment for beam commissioning. The strip line BPMs were designed and fabricated for the PEFP 100MeV linac. Their performance was measured with the low power signal, and was operated with the 20MeV linac at the KAERI site. The BPMs will be installed in the linac and beam lines, and the position of the proton beam will be monitored during the 100MeV accelerator operation.

ACKNOWLEDGEMENTS

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