Preliminary Test of the KOMAC Linac BPM at the Test Bench for Upgrade

Kyumin Choe*, Young-Gi Song, Hae-Seong Jeong, Han-Sung Kim, Hyeok-Jung Kwon
Korea Multi-purpose Accelerator Complex, Korea Atomic Energy Research Institute,
Gyeongju, Gyeongbuk 38180, Korea
**Corresponding author: kyuminchoe@kaeri.re.kr*

1. Introduction

Beam Position Monitor (BPM) is one of important beam diagnostic devices. It is basically used to measures the beam phase and the beam position which is the displacement from the center of a beam line. In the 100 MeV proton linear accelerator of the Korea Multi-purpose Accelerator Complex (KOMAC), Gyeongju, 7 linac BPMs [1] are installed. Since the commission stage in 2013, the BPMs have played a crucial role in RF tuning of the DTL accelerators, as beam phase monitors [2]. Originally, it was designed and has already tested to measure the beam position as well as the beam phase [1]. Due to some reasons, however, it does not measure the beam position yet. So, currently the upgrade is in process for the BPMs to be able to measure not only the beam phase but also the beam position and current. In this paper, we will show the system setup for the upgrade of the linac BPM, and some experimental results of the tests for the upgrade.

2. Experimental Setup

The test setup consists of the BPM test stand, the BPM analog box, and the BPM digital electronics. In this section, we will briefly describe each part.

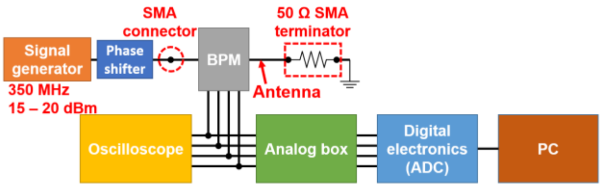


Fig. 1. Schematic diagram of the test setup

2.1 BPM Test Stand

Since beam characteristics cannot be controlled at the accelerator, experiments should be performed while adjusting the position and phase in a device that simulates the beam.

Fig. 2 shows the BPM test stand. A straight wire, which is called antenna, is positioned in the center of the BPM aperture, and can move by a motion stage precisely on the transverse plane of the BPM aperture. The 350 MHz RF signal is given to the antenna, so the antenna wire is considered as 350 MHz beam bunch. By moving the motion stage, the position of the beam can be adjusted. A phase shifter between the signal generator and the antenna wire can adjust the phase of the simulated beam. The 350 MHz RF signal comes from a signal generator, and the signal induced in the electrodes of the BPM can be checked on an oscilloscope.

(a) (b)

Fig. 2. BPM test stand: (a) total setup, (b) the BPM transducer and the antenna wire.

2.2 BPM Analog Box

350 MHz beam signal is converted to 50 MHz sine wave signal to analyze the signal easily in the BPM analog box. The real beam signals from the BPM are not good sine shape. Firstly, through the band pass filters (BPF), the 350 MHz sine wave signals are selected. These signals are mixed with external 300 MHz LO (local oscillation) signals and converted to 50 MHz IF (intermediate frequency) signals through the low pass filters (LPF).

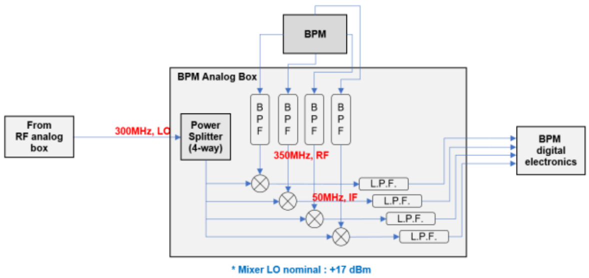


Fig. 3. Schematic diagram of the BPM analog box

2.3 BPM Digital Electronics

The 50 MHz IF signals from the BPM analog box are converted to the digital value by the ADC (analog to digital converter) of the BPM digital electronics. The BPM digital electronics consists of MVME3100 baseboard, PENTEK7142 FPGA board which includes 4 channel 14 bits ADC, and vxWorks 6.8 operating system. By EPICS, the digital values are connected to the computer. The 50 MHz IF signals from the BPM analog box are processed by using digital IQ demodulation [3]. The acquired IQ values are transferred to the computer and the beam characteristic values are calculated.

3. Result and Discussion

By moving the motion stage of the BPM test bench, and adjusting the phase shifter, we acquired the beam characteristic data and calculated the beam position, phase and current. Through this process, we validated the system feasibility.

3.1 Beam Position

The beam position is calculated using the 4 signal IQ values from the 4 BPM electrodes (x_+, x_-, y_+, y_-). The amplitudes of the signals are calculated as Eq. (1).

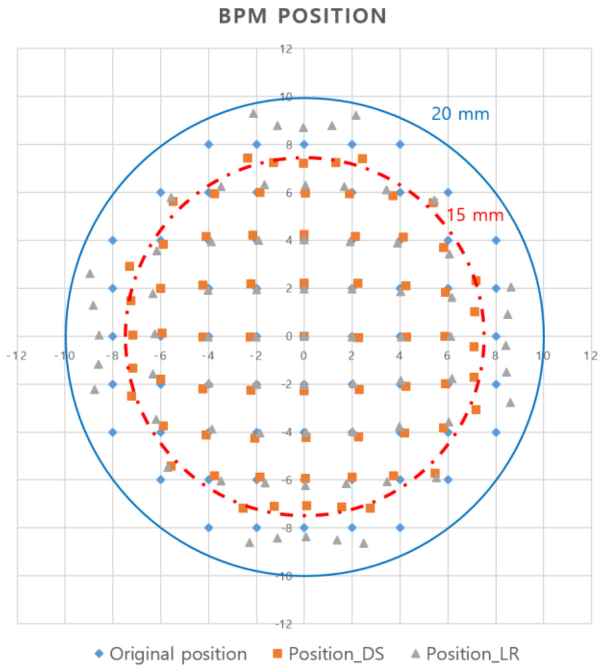
$$V_i = \sqrt{I_i^2 + Q_i^2}\ , \qquad i = x_+, x_-, y_+, y_- \tag{1}$$

There are 2 methods to calculate the position, 'difference over sum (DS)' and 'log ratio (LR)'. The equations are as below.

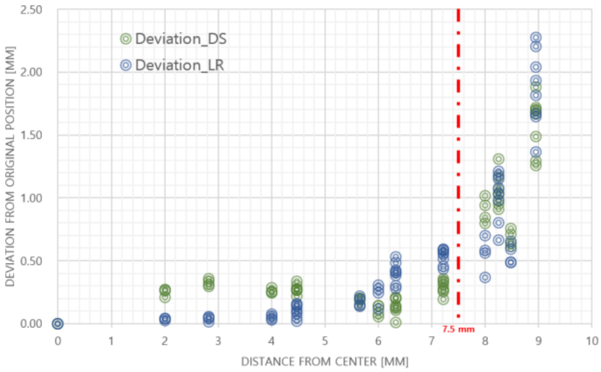
$$(x,y) = \left(R_{DS}\cdot\frac{V_{x_+}-V_{x_-}}{V_{x_+}+V_{x_-}},\ R_{DS}\cdot\frac{V_{y_+}-V_{y_-}}{V_{y_+}+V_{y_-}}\right), \qquad \text{difference over sum} \tag{2}$$

$$(x,y) = \left(R_{LR}\cdot 20\log\frac{V_{x+}}{V_{x-}},\ R_{LR}\cdot 20\log\frac{V_{y+}}{V_{y-}}\right), \qquad \text{log ratio} \tag{3}$$

Fig. 4 is the calculated result. The beam aperture diameter of the BPM is 20 mm. Within the 15 mm diameter, the calculated beam position is generally correct. In Fig. 4(b), the accuracy is about 0.5 mm within 7.5 mm radius (15 mm diameter). The objective of accuracy is 2%, so more precise data acquisition and calculation is required. We used just linear fitting in calculation. To acquire more accurate position results, various fitting methods like the polynomial fitting can be tried.



(a)



(b)

Fig. 4. Beam position difference between the original position and the measured position: (a) the position distribution on the transverse plane, (b) the position deviation vs. the distance from center.

3.2 Beam Phase

The beam phase is calculated by taking the arc tangent value of Q and I ratio shown as Eq. (4).

$$\phi\ (\text{Beam phase}) = \arctan\left(\frac{Q}{I}\right) \tag{4}$$

To measure and to compare the change of the beam phase, the phase of input signal is adjusted by tuning the phase shifter between the signal generator and the antenna wire. The LLRF system trigger is used as the reference. Fig. 5 shows the change of the phase and the measured value of the phase. Well agreement between the input signal and the measure value can be seen.

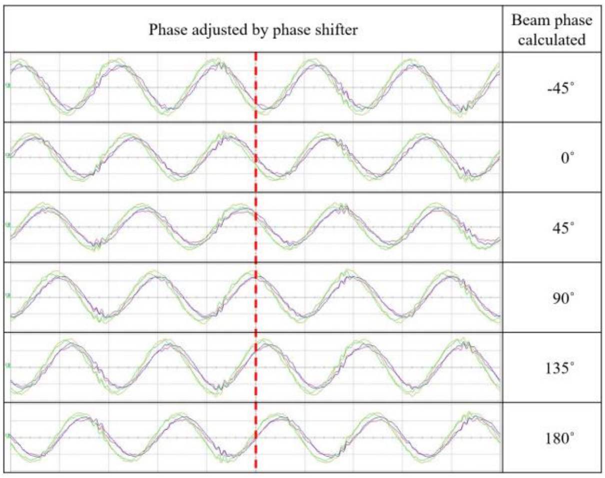


Fig. 5. Beam phase measurement by adjusting through the phase shifter.

3.3 Beam current

Generally, BPM measures beam position and phase. However, from the amplitude of BPM signal the beam current can be decided.

$$I\ (\text{Beam current}) \propto \sum_{i=1}^{4}|V_i| = \sum_{i=1}^{4}\sqrt{I_i^2+Q_i^2}$$
$$= \mathrm{K}\sum_{i=1}^{4}\sqrt{I_i^2+Q_i^2}\ , \qquad i = x_+, x_-, y_+, y_- \tag{5}$$

The beam current is calculated as Eq. (5). The proportional factor K depends on the beam energy, the bunch length, and the beam position. Fig. 6 shows the normalized beam current by the beam position. When the K is set constant, beam current value changes by the beam position. The delicate decision of the K value is required.

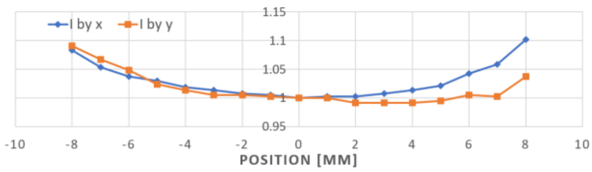


Fig. 6. The normalized beam current value by the position of the simulated beam (antenna wire)

4. Summary

The preliminary test for the KOMAC linac BPM upgrade is conducted at the BPM test bench. Through the test, we can confirm that the signal processing system works well, and it can be used for the real accelerator system. We measured the beam characteristics which the BPM can decide, the beam position, the beam phase, and the beam current. In general, it also works well, but to acquire more precise and accurate result, we have to get more data and manipulate the data delicately. The upgrade is in progress. After more test and system improvement, the upgraded system will be applied to the accelerator operation.

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