R&D OF A BEAM POSITION MONITOR FOR RISP

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Abstract

We have investigated on the R&D of stripline beam position monitor for the heavy-ion accelerator at RISP. We present the detailed design and fabrications on the beam position monitor in superconducting linac that the beam is accelerated to 200 MeV/u.

INTRODUCTION

The superconducting linac which accelerates uranium beam to 200MeV/u from ion source is on the design stage for the heavy-ion accelerator project in Korea. Beam diagnostic devices are usually used to check normal operation of each accelerating device on beam, to correct electromagnet, and to protect them by feedback. Stripline beam position monitor (BPM) among such devices was developed for monitoring the beam position and for correction of beam orbit [1].

The diameter of beam pipe is designed as 40mm for stripline BPM since the aperture of beamline for the linac is 40mm. The velocity for each linac section is shown in Table 1. The design was mainly focused on the first section of linac in this study. We selected the frequency of 162.5MHz, which is the second harmonics, for BPM and assumed the longitudinal beam size is less than 200ps for 99% of particles in each bunch. We have considered as follows;

- The strip should have well matched impedance with SMA connector (50ohm).
- BPM should minimize beam instability.
- In time domain, the signal has to be well separated: the reflected signal and signals from other bunches.
- The design has to be flexible for future readout electronics, wideband vs. narrowband processing.
- Position resolution of 100μm has to be achieved.

Table 1: The Parameters of Each Linac Section

Linac section	Velocity(beta)	RF Freq. (MHz)
1st (QWR)	0.0328~0.0728	81.25
2nd (HWR)	0.0728~0.2000	162.50
3rd (SSR1)	0.2000~0.3720	325.00
4th (SSR2)	0.3720~0.5680	325.00

DESIGN

The beam passes through beam pipe as shown in Fig. 1. When the beam passes through upstream of beam pipe, then the half signal is detected and the other travels on the stripline and goes to ground. When the beam passes through downstream of stripline, the half signal travels to upstream and is detected by antenna and the other goes to ground. Finally we get each half signal as shown in Fig. 1, which are detected, while two signals, which gose to the ground, are cancelled [2].

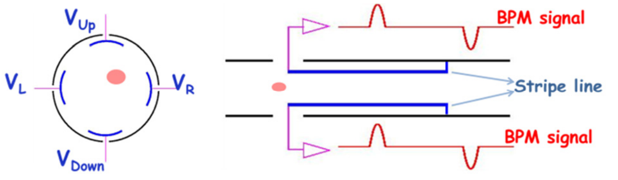


Figure 1: Conceptual diagram.

We can convert the detected signal to position like as next equation:

$$X = k_x \frac{V_L - V_R}{V_L + V_R}, Y = k_y \frac{V_T - V_B}{V_T + V_B} \qquad (1)$$

where, V_L, V_R,V_T,V_B are the detected signal from left, right, top, bottom side, respectively. And K_x, K_y are the calibration constants.

Since the signal for each bunch has to be well separated, the signal spacing was drawn for the each beta as shown in Fig. 2. When the strip length of 40mm is used, it was confirmed the signal are separated well [3].

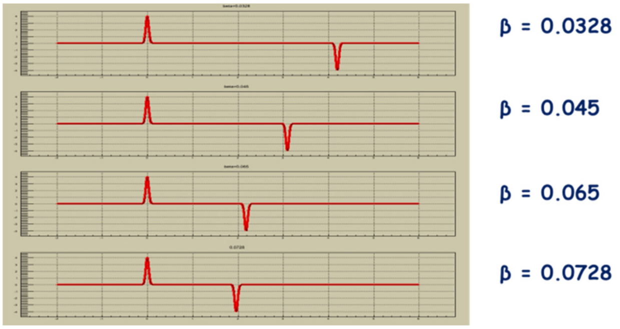


Figure 2: The signal spacing for each beta.

Fig. 3 shows the strength of signal with strip length of 40mm at design frequency of 162.5MHz. The average strength of the signal is about 70mV which can detect by normal device.

Fig. 4 shows the resolution of stripline BPM. We assumed the particle is with charge of +1 or +5 and the plot was drawn in cases of when only thermal noise is considered or with 6dB noise figure or with 10dB. The resolution is distributed from 260μm to 0.15μm for each case. Therefore we need to design the electronics carefully to achieve the aim resolution.

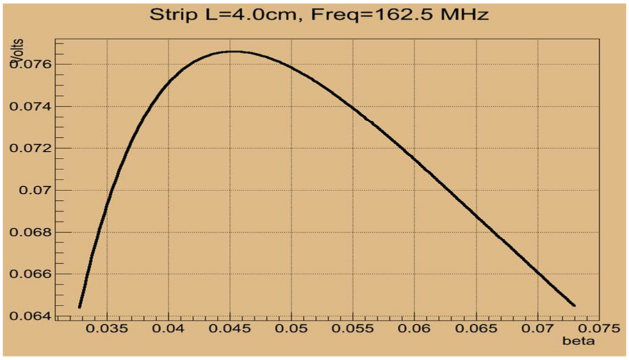


Figure 3: The strength of signal at 162.5 MHz.

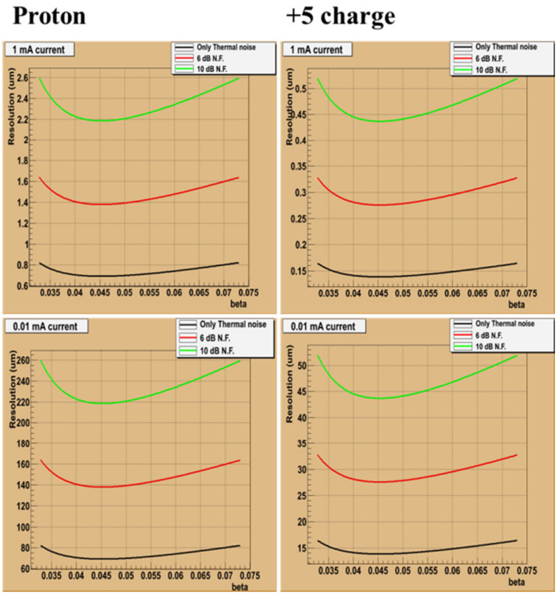


Figure 4: The resolution of stripline BPM.

The impedance matching was performed based on the numerical calculation. It was mainly carried out by adjusting the gap size between strip and the wall of beam pipe and it was decided as 3mm to match impedance (50ohm) well. Fig. 5 shows cross section of stripline BPM with dimension.

MEASUREMENT

We fabricated two BPMs and measured the performance by network analysis. Fig. 6 shows the fabricated BPM and the setup for RF measurement. The result is shown in Fig. 7. The reflection parameter (S11, S22) is designed as 0.993 and the transmission are 0.002 (Port 1 to 2), 0.001 (Port 1 to 3). In measurement, the reflection and transmission are 0.986 (average) and 0.00159 (Port 1 to 2, average), 0.00075 (Port 1 to 3, average), respectively.

The result of TDR measurement to confirm impedance of each strip was measured as shown in Fig. 8. One port of each BPM has non-balance and their impedance is higher than normal ports. It seems the antenna and the strip are misconnected in the welding procedure. We are now trying to confirm the reason. And the impedance at three ports is lower than design (50ohm). This is why the TDR device measures the impedance at the frequency of broad range and average out them. However the stripline BPM was designed at the specific frequency and matched impedance. Therefore we need to fix this difference by analysis.

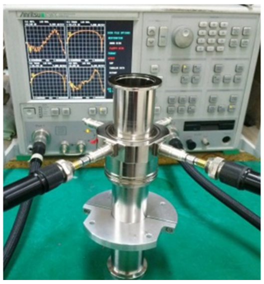


Figure 6: BPM and the setup for measurement.

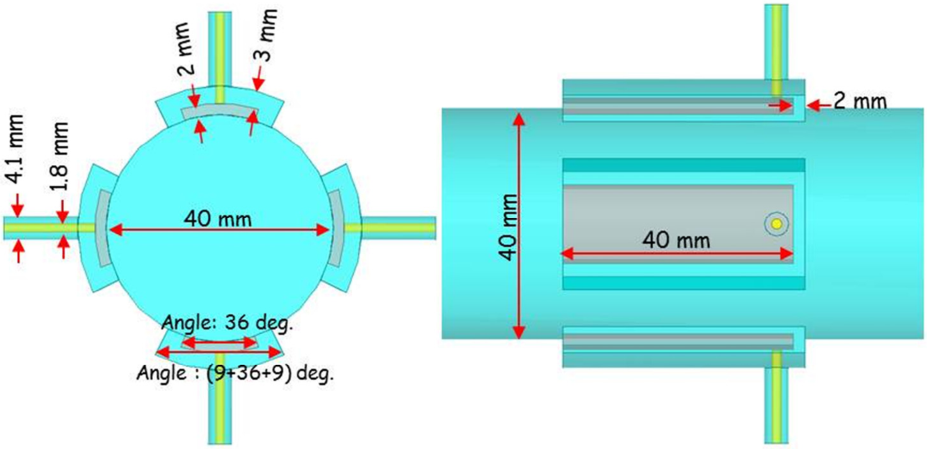


Figure 5: The cross section of BPM with dimension.

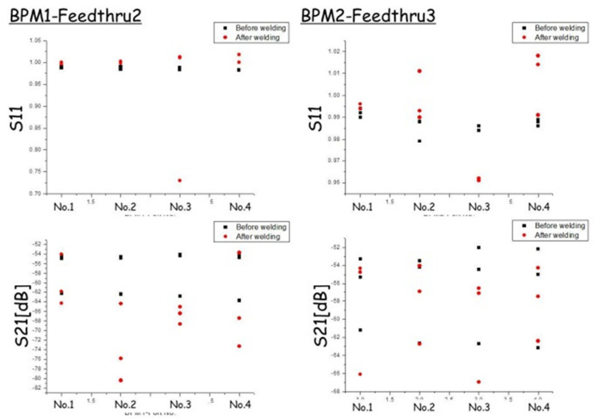
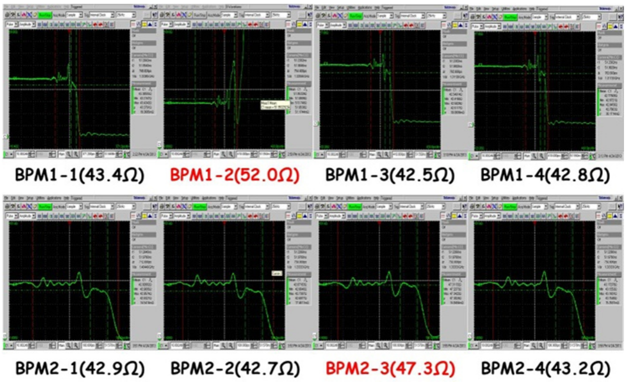


Figure 7: The result of RF measurement.


BPM1-1(43.4Ω) BPM1-2(52.0Ω) BPM1-3(42.5Ω) BPM1-4(42.8Ω)

BPM2-1(42.9Ω) BPM2-2(42.7Ω) BPM2-3(47.3Ω) BPM2-4(43.2Ω)

Figure 8: The result of TDR measurement.

We carried out the calibration using by tungsten wire on the test bench at J-PARC. The procedure is follows [4]:

- Install the tungsten wire (D: 100μm) in the center of beam pipe of BPM
- Detect the signal moving the wire within radius of 17mm by x, y stage mover
- Convert each signal into position information data (Eq. 1)
- Find out the calibration constants K_x, K_y by fitting method
- Apply the calibration constants to each position information data
- Draw 2-D mapping plot (Fig. 9)

We finally got the 2-D mapping plot through this procedure as shown in Fig. 9. The physics position and reconstructed position are matched well on the x and y axes while the cyan points of the diagonal area of outside do not correspond well with the black points. We need to analyse more and to find out fine fitting function.

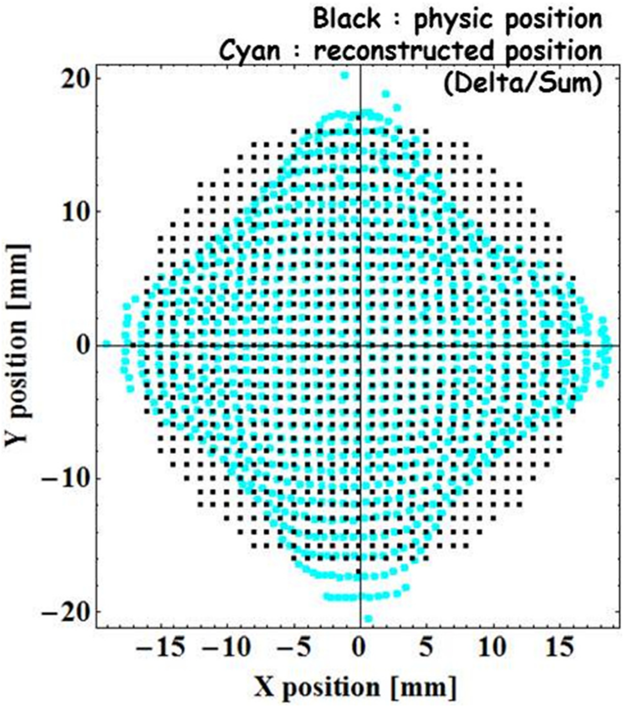


Figure 9: The 2-D mapping plot.

SUMMARY

We have designed the stripline BPM for superconducting linac for heavy-ion accelerator and two BPMs were manufactured and performed the measurement to confirm their performance. More data analysis is needed to fix some problems. Then we are going to carry out beam test at RCNP in Japan and the electronics will be developed to process the signal of BPM.

REFERENCES

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[2] John Byrd, Presentation Material, “Stripline Pickups and Kickers”, Jun. 2009

[3] R. E. Shafer, 1992 American Institute of Physics, pp601-636, “Beam Position Monitor”

[4] S. Sato et al., Proc. PAC07, pp4072-4074, “Beam Position Monitor and its Calibration in J-PARC linac”