BEAM POSITION MONITORS FOR THE ACS SECTION OF THE J-PARC LINAC

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Abstract

We are aiming at the energy upgrade of J-PARC Linac from 181MeV to 400MeV. In order to have the energy upgrade, we need to develop beam instruments including beam position monitors (BPMs). Then, we designed them and employed a stripline-type as their electrodes. The BPMs are required to be calibrated to the accuracy of beam orbit within 100μm. To achieve the requirement, we did some calibrations. First, we decided a width of stripline whose characteristic impedance can be calibrated to 50 ohm with electric field simulations. Second, we also measured characteristic impedance of 4 different striplines per a BPM corresponding with BPM simulations. Last, we measured an electrical center position of BPMs with a simulated beam signal at 324MHz, 6dBm. A BPM will be installed at each quadrupole magnet in the ACS section to be used for a beam commissioning. Systematic calibration of developed BPMs is described in this paper.

ENERGY UPGRADE

A first acceleration (181MeV H^- beam) is done by the J-PARC Linac in 2007. Beam position monitors in the Linac, which are consisted of striplines as pickup electrodes are placed inside the beam transporting chambers. At present there are 102 BPMs in the Linac (Fig. 1 [1]). For energy upgrade (181MeV to 400MeV), we will install the Annular Coupled Structure (ACS) as the acceleration cavities at A0BT section, in addition, we will install 48 BPMs, including MEBT-2 section. In the ACS section, we will install two BPMs into quadrupole magnet per one acceleration unit. One is between A-cavity and B-cavity, the other is the exit of B-cavity (Fig. 2). We will install 48 BPMs, including MEBT-2 section (between the SDTL and the ACS section).

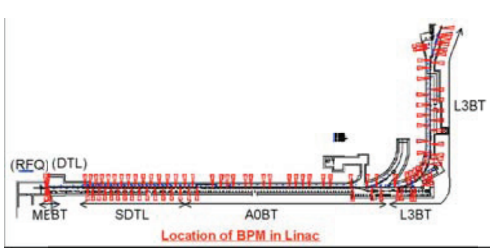

Figure 1: Present location of BPMs at the Energy of 181MeV. In the future, we will install them at the A0BT section.

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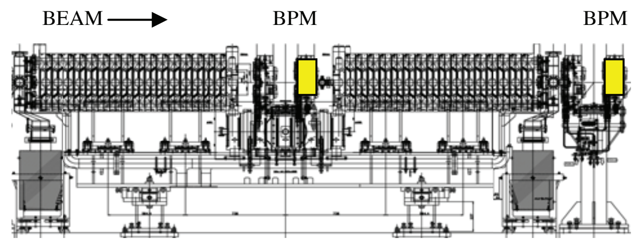

Figure 2: BPM installation at the ACS section. The cavity is called A-cavity and B-cavity from beam direction, respectively.

FABRICATION OF THE BPM

In the ACS section, BPMs are also required to be calibrated to the accuracy of the beam orbit within 100μm. Then, we designed BPMs. Basic design is taken over from the present one. Figure 3 shows the design of BPM. The pickup electrode employs the stripline type. This diameter is 37.7mm, so that the beam aperture can be the same length. As the beam energy increases, we change the size of BPM (Table 1).

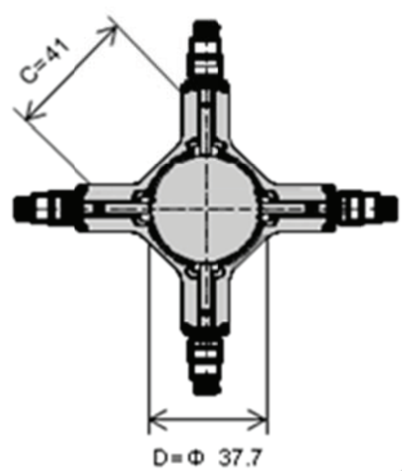

Figure 3: The design of BPMs.

Table 1: The Size of Designed BPMs

	D (mm)	C(mm)	Length(mm)
1	37.7	41.0	192
2	40.0	45.0	192
3	40.0	45.0	222
4	40.0	45.0	232

TWO-DIMENSIONAL CALCULATION OF STRIPLINE IMPEDANCE

After we designed the BPMs, we decided the width of the BPM. In order to define the width of the stripline and the depth inside the electrode part, the impedance of the stripline is calculated using the two-dimensional Poisson equation calculation code “Poisson Super Fish” [2]. In this code, an electrical field is obtained assuming the inducted electrical charge at the surface of the stripline due to the beam particles. Calculated electrical field is shown Fig. 4. As there are symmetries of the shape in each of 4 (up, down, right, left) electrodes, only a quarter of cross section is shown. At the narrow space which is a gap between the stripline and the body, the big gradient of the electrical field can be seen. When the width of the stripline is shifted as a parameter, the gradient is getting larger or smaller. After the electrical gradient is obtained, the impedance of the stripline can be easily calculated. Calculated impedance is described in Fig. 5. The remarkable shift of the impedance is obtained by the small change of the stripline width. About 2 ohm of the impedance is changed by the shift of the 1.0 mm width. Even the small shift is essential for the adjustment to the impedance of 50 ohm system. When the body around the connectors is bored, the bored holes are playing role in the co-axial cables. The impedance dependence of the hole depth is also calculated using “Poisson Super Fish”. As the result, the dependence is saturated over 5.0mm depth. If there is no bored hole, the impedance is decreased about 20 %. .Because the impedance should be kept 50 ohm with over 5.0 mm depth, the structural depth (20mm) is chosen.

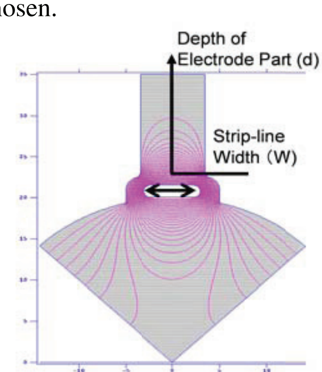

Figure 4: Cross sectional distribution of electric fields around stripline

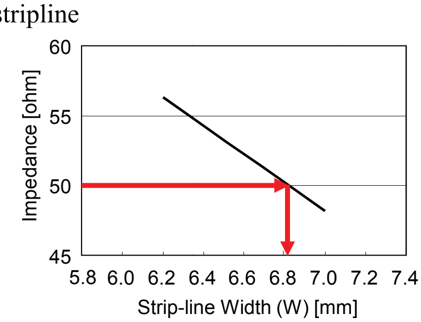

Figure 5: Impedance dependence of stripline width. The width of stripline which is obtained 50ohms impedance is 6.86mm.

CALIBRATIONS OF BPMS

Calibration of BPMs is taken by two steps. First, we decided a width of stripline by measuring characteristic impedance. We measured it with a prototype of BPM. T he prototype of BPM is also taken over by the present one. This aspect is the striplines and the connectors of BPM are removable (Fig. 6).

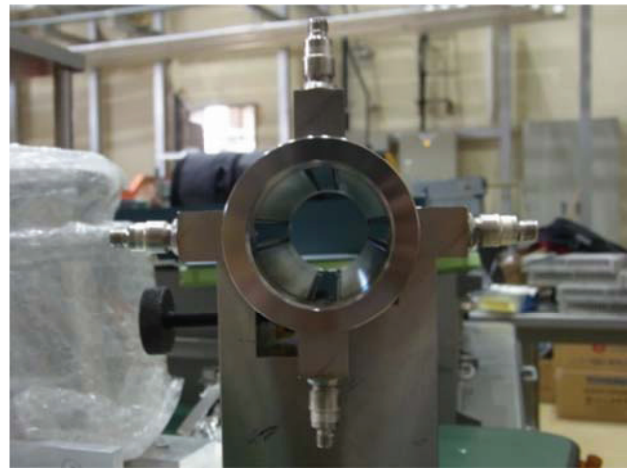

Figure 6: The prototype of BPM.

As for the stripline electrodes, we used from 6.70mm to 7.30mm by 0.05mm step , respectively. Figure 7 shows the relationship with width of stripline and impedance, where blue points are simulation results and green points are measurement values of stripline impedance. From linear fitting of the result, we estimated 6.86 mm, while a width of stripline we measured 50 ohm was 6.80 mm. Measurement value corresponds approximately to simulation result. But, stripline electrodes were all removable, when we measured. Of course, Electrodes must be welded by electron beam. After the electrodes are welded, the impedance was increased. So we decided a width of stripline which is 6.85 mm.

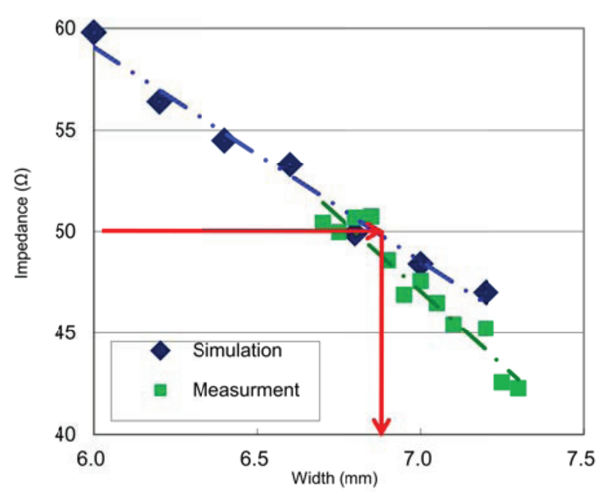

Figure 7: Relationship between the width of stripline electrode and impedance. Blue and green lines are taken by the measurement, dashed line are fitted curves. Optimized width of stripline whose impedance is 50 ohm is obtained was 6.85mm

Second, we measure an electrical center position of BPMs with a simulated beam signal induced by a wire. This wire consists of stainless coated by gold. To relate physical position and its reconstructed position via electrical readout, the following scheme is used in the test bench. The accuracy of measurement is aiming for a half hundred micrometers:

- Scanning the wire hanging through the cross section of BPM, horizontally and vertically, and put 324 MHz RF on the wire during scan to simulate the beam. The 324 MHz is a frequency used for the RF cavity of the LINAC.
- Amplifying logarithmically the induced voltage on 50 ohm, and take the ratio, between the left stripline and the right stripline for horizontal position, and between the top and the bottom for vertical position. The voltage is digitized by 16bits ADC.
- Interpolating (analytically fitting) the position among Scanned points. As seen in Fig. 6, as outer the wire goes (especially for off-XY-axis position) the discrepancy gets larger. The fitting functions need to be optimized especially around the center of the beam duct.

Figure 8: The aspect of BPM calibration with a wire.

Figure 9 shows the relationship with mechanical center position and electrical center position. The large circle represents the mechanical center and red point does the electrical center. This BPMs' 4striplines impedances are all 50 ±0.5 ohms. In addition, horizontal and vertical differences of impedance are less than 0.5 Ω. For the mechanical center, the electrical center differs (X,Y) = (30μm , -50μm). Therefore we could achieve the accuracy of beam orbit within 100μm. In the future, we will install at each quadrupole magnets, and use for a beam commissioning.

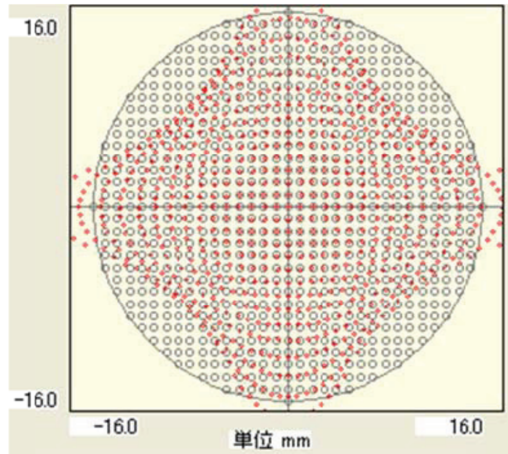

Figure 9: Result of electrical center of BPM by using simulated signal (324MHz, 6dBm). We could achieve the accuracy within 100μm. This BPM has 37.7mm diameter and scan is done by 1 mm step.

SUMMARY

Calibration of BPM has just started. This work will be continued. We measured the stripline impedance which is 50 ohm. This value agrees with the simulated one. At the test bench, we measured the electrical center position of BPMs, and could achieve the accuracy within 100μm compared with mechanical center position. In the future, we will need to measure the electrical center position compared with quadrupole magnetic center position using a beam. After the largest earthquake which occurred at Tohoku on March 11, we observed the fabricated BPMs carefully, but fortunately they had no serious damage.

REFERRENCES

[1] S. Sato et al., "DEVELOPMENTS OF THE CALIBATION TOOLS FOR BEAM POSITION MONITOR AT J-PARC LINAC", proceedings of LINAC 2004.

[2] A. Miura et al., "DESIGN AND FABRICATION OF BEAM MONITORS IN ENERGY UPGRADED J-PARC LINAC", DIPAC2011, MOPD08, May, 2011, Proceeding of this conference.

[3] Poisson Superfish Announcement by LANL Home Page:http://laacg1.lanl.gov/laacg/.