ISBN: 978-3-95450-132-8 doi:10.18429/JACoW-IPAC2014-THPME147

THE HIGH POSITION RESOLUTION CAVITY BPM DEVELOPMENTS AND MEASUREMENT FOR ILC FINAL FOCUS SYSTEM

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Abstract

An ultra high position resolution cavity BPM was developed for the final focus system of ATF2, which is a accelerator test facility for ILC final focus system [1]. The main purpose of ATF2 are achievement of 37 nm beam size and nano-meter beam orbit stability at IP(Interaction Point). For these purposes, a few nano meter beam position resolution was required for this cavity BPM, which is called the low-Q IP-BPM [2]. Three low-Q IP-BPMs were fabricated, the first block consists of two cavities in one block and second block consists of single cavity. Low-Q IP-BPM can measure beam position in vertical and horizontal independently by using rectangular shape single cavity. Three low-Q IP-BPMs were installed at ATF IP region inside IP-chamber, and its position resolution was measured. We will present the detailed results on the beam tests.

INTRODUCTION

The low-Q IP-BPM system for beam position resolution of 2nm was checked at IP-region of ATF2 during beam operation. In this period, we performed IP-BPM system installation, IP-chamber re-alignment, operation checks for entire low-Q IP-BPM electronics, the ADC system check, the simple resolution beam test by using three YI signals. Due to this system checking process, we performed the first beam study of beam position resolution with entire low-Q IP-BPM system.

LOW-Q IP-BPM SYSTEM INSTALLATION

All of the low-Q IP-BPM system was installed inside tunnel near the IP-region. The electronics, LO signal splitter, and variable attenuators(x8) are installed. The cable connection scheme was shown in the Fig. 1.

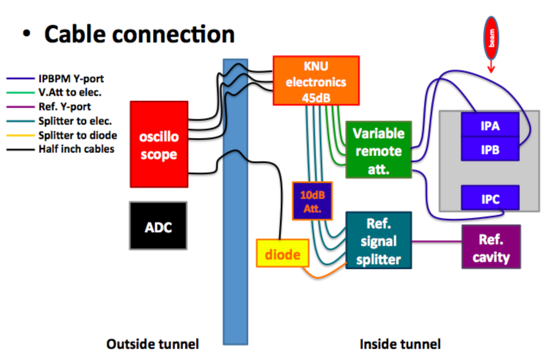

Figure 1: Low-Q IP-BPM cable connection scheme.

The new aluminum reference cavity BPM has been modified to set the fine resonance frequency for y-port. The sensor cavity resonance frequency of y-port was 6.4095GHz so that we changed the cavity size for y-port from 36.65mm to 38.65mm. After the modification, the resonance frequency was set to near the 6.4095GHz by using frequency tuner. The feed-through of the reference cavity BPM was sealed by indium. After the indium sealing, the Ref. cavity BPM was installed just after IP-chamber. Figure 2 shows the installed reference cavity BPM.

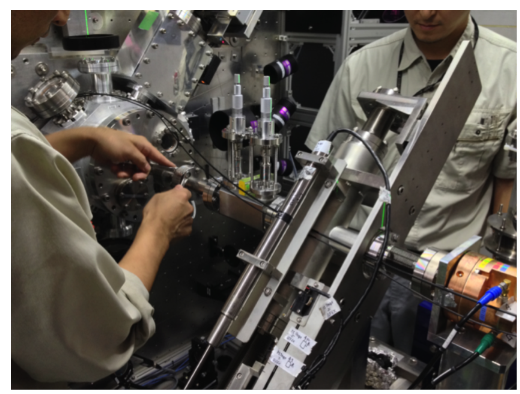

Figure 2: Installation of reference cavity BPM.

LOW-Q IP-BPM ELECTRONICS RF TEST

Before installation of the electronics in the beam tunnel, we performed RF test of low-Q IP-BPM electronics. The main perpose of RF test was to check the input RF signal working range and LO signal working rnage. The measured test results were shown in the Fig. 3 and Fig. 4. The electronics total conversion gain was measured to 45dB.

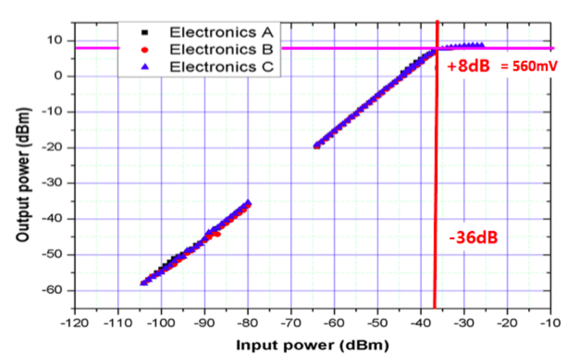

Figure 3: RF signal working range test of electronics.

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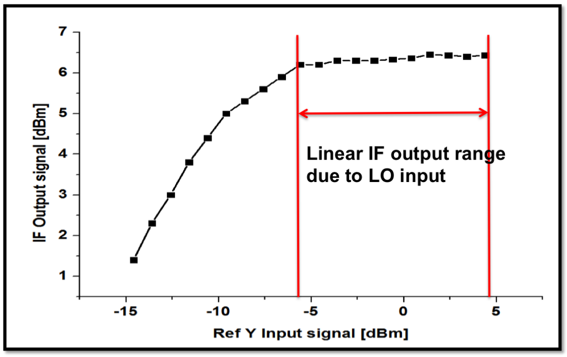

Figure 4: LO signal working range test of electronics.

IP-CHAMBER REALIGNMENT

The misalignment check of low-Q IP-BPMs is one of most important procedure for the beam test. The misalignment of low-Q IP-BPM was checked by beam test by using low-Q IP-BPM system. After the beam test, the IP-chamber was re-aligned for the alignment of low-Q IP-BPM center positions. By the beam test for misalignment check, IPBPM-C vertical position was 430 um lower than IPBPM-A vertical position which means the IPBPM chamber pitch angle was 1.8mrad. For the pitch angle re-alignment, the IP-chamber pitch tuning was performed by removed shims 3mm. After the pitch tuning, the BPM center position of low-Q IP-BPM A and C shows simultaneously with almost center mover position. Figure 5 shows how to pitch correction of IP-chamber.

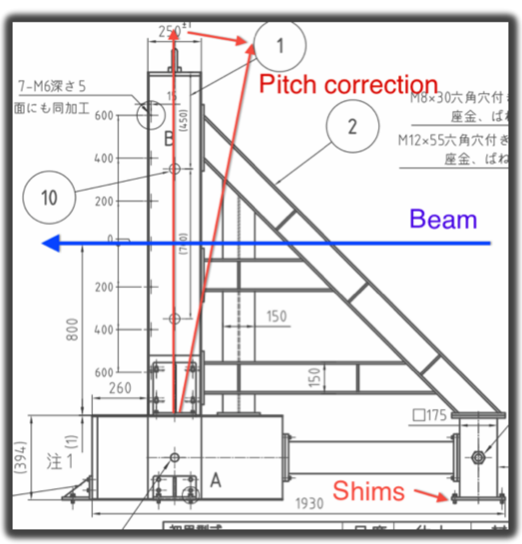

Figure 5: Pitch angle correction of IP-chamber.

ADC SYSTEM CHECK WITH I-Q TUNING

The ADC data was checked by using YI signals of IPBPM-A. The mover position was changed from 1V to 7V with 1V step and 40dB att. case. The gate time length for low-Q IP-BPM and ICT signal was set to 150ns. After the ADC signal check, we performed IQ tuning for all Y-port signal to set minus voltage signals from center position to most far away offset position. ADC pedestals for Channel YI and YQ of IPA were measured with 50ns gate time. An available measure range of ADC is -500mV square signal with 50ns. Which signals correspond to -500pC of limit of ADC. The pedestal of ADC it self is 350 to 370 counts for ch1(YI) and ch2(YQ).

Table 1: ADC Pedestal Measurements by Using IPBPM-A

	Electronics offset	Pedestal of ADC	Corresponded pC of ADC
IPA YI	-50mV	1934 counts	-60pC
IPA YQ	-24mV	982 counts	-30pC

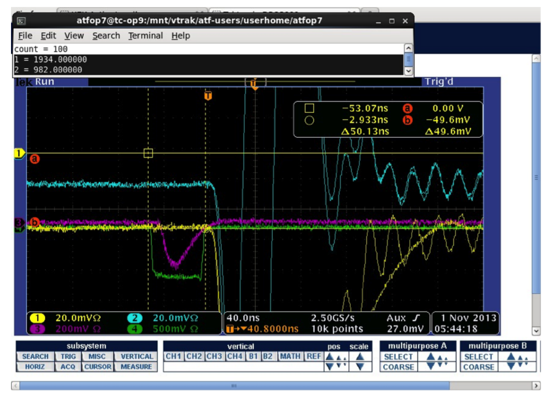

Figure 6: The testing for ADC system.

SIMPLE RESOLUTION TEST BY USING THREE YI SIGNALS OF LOW-Q IP-BPM

We performed simple resolution test to check current low-Q IP-BPM system status. For which test, we used three YI signals of low-Q IP-BPM with ADC. The calibration run was taking 50 data at each mover position with 20dB, 30dB, and 40dB attenuators. The resolution run was taking 500 data at fixed one position with 0dB attenuator case. The calibration slope for 0dB was estimated by extrapolating the results of 30 dB attenuation cases.

The extrapolating method by using geometrical relation between three low-Q IP-BPMs was used. The calculated the geometrical factor for each BPM and it was shown in the Table 2. The Fig. 8 shows the distance between each BPM.

Table 2: Low-Q IP-BPM Geometrical Factor

	IPBPM-A	IPBPM-B	IPBPM-C
Geo. factor	0.5311	0.8026	0.2715

The distance between BPM: Z_{12} = 81mm, Z_{23} = 158.4mm, Z_{13} = 239.4mm. Also, we define BPM_i as the i th cavity, z_{ij} as the distance between BPM_i and BPM_j, Ii as beam position signal BPMi and assuming their resolution R_i are all equivalent, RMS of

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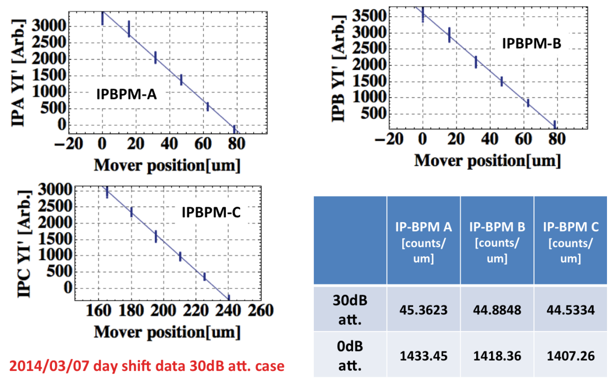

	IP-BPM A [counts/um]	IP-BPM B [counts/um]	IP-BPM C [counts/um]
30dB att.	45.3623	44.8848	44.5334
0dB att.	1433.45	1418.36	1407.26

Figure 7: Low-Q IP-BPM calibration factor for 30dB attenuation.

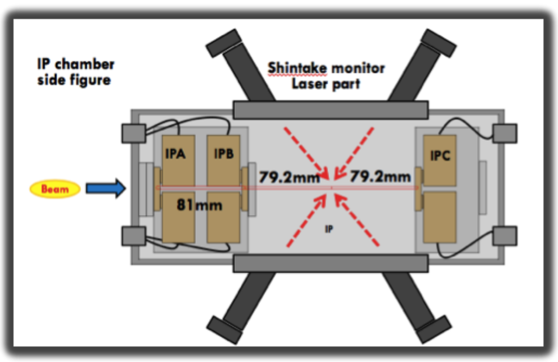

Figure 8: The distances between each low-Q IP-BPM.

$$Z_{12} : (I_2 - I_1) = Z_{13} : (I_3 - I_1)$$
$$\Rightarrow Z_{13}(I_2 - I_1) = Z_{12}(I_3 - I_1)$$
$$\Rightarrow Z_{13}I_2 = Z_{12}I_3 + (Z_{13} + Z_{12})I_1$$
$$\Rightarrow Z_{13}I_2 = Z_{12}I_3 + Z_{23}I_1$$
$$\Rightarrow I_2 = (Z_{12}I_3 + Z_{23}I_1)/Z_{13}$$
$$\therefore f_B(I_1,I_2,I_3) = I_2-(Z_{12}I_3+Z_{23}I_1)/Z_{13} \quad \text{for IPBPM-B}$$
$$f_A(I_1,I_2,I_3) = I_1-(Z_{13}I_2-Z_{12}I_3)/Z_{23} \quad \text{for IPBPM-A}$$
$$f_C(I_1,I_2,I_3) = I_3-(Z_{13}I_2-Z_{23}I_1)/Z_{12} \quad \text{for IPBPM-C}$$

, where the first term of function is the measured I_i value and the second term is the predicted I_i value, which predicted value interpolated by I_j and I_k . Then the Geometrical factor of IPBPM-B is calculated as [3],

$$\frac{R_2}{R_f} = R_2 \Big/ \sqrt{\left(\frac{\partial f}{\partial I_1}R_1\right)^2 + \left(\frac{\partial f}{\partial I_2}R_2\right)^2 + \left(\frac{\partial f}{\partial I_3}R_3\right)^2}$$
$$= 1 \Big/ \sqrt{\left(\frac{Z_{23}}{Z_{13}}\frac{R_1}{R_2}\right)^2 + 1 + \left(\frac{Z_{12}}{Z_{13}}\frac{R_3}{R_2}\right)^2}$$
$$= 1 \Big/ \sqrt{\left(\frac{Z_{23}}{Z_{13}}\right)^2 + \left(\frac{Z_{12}}{Z_{13}}\right)^2 + 1} \qquad (1)$$

Also, we assumed $R_1 = R_2 = R_3$. Therefore, the Geometrical factor for IPBPM-B is approximately 0.8026. By using this geometrical factor, the measured position resolution values of IPBPM-B with 0dB attenuation case correspond to 60.24nm for 0.374 x 1.6nC beam charge. Which beam position resolution corresponds to 22.53nm for 1.6nC of ATF nominal beam charge condition. All of position resolution values of low-Q IP-BPMs are listed in Table 3.

Table 3: The Expected Resolution by Charge Normalization

	IPBPM-A	IPBPM-B	IPBPM-C
A normalized resolution (1.00 ×1.6nC)	22.56nm	22.53nm	22.47nm

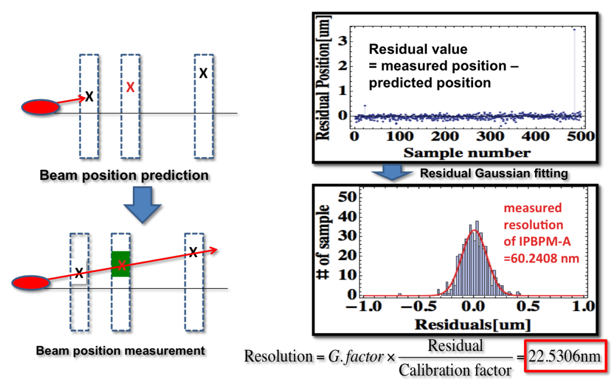

Figure 9: The measured and expected position resolution of IPBPM-B with 0.374 × 1.6nC beam charge condition.

CONCLUSION

During the first beam-commissioning period of low-Q IP-BPM system, we measured beam position resolution by using ADC. The measured resolution shows quite a good and all of system work well. The achieved beam position resolution for charge normalization of three low-Q IP-BPMs was around 22nm for the case of 0.1m large beta optics.

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