# TEST RESULTS ON BEAM POSITION RESOLUTION FOR LOW-Q IP-BPM AT KEK-ATF2

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*Abstract*

We have performed the beam tests on the beam position resolution for the Low-Q IP-BPM (Interaction Point-Beam Position Monitor) at ATF2 which is an accelerator test facility for the International Linear Collider [1]. The main goals of KEK-ATF2 are to achieve beam size of 37 nm and beam resolution of nano-meter for beam stabilization. Resolution tests for the Low-Q IP-BPM were performed with KEK BPM doublet in Jan. 2011. We got the results of beam position resolution 70 nm during the experimental periods and will present the detailed experimental procedures and results.

## INTRODUCTION OF LOW-Q IP-BPM

The second goal of ATF2 is the achieving of a few nano-meter level beam position resolutions for beam stabilization at the IP (Interaction Point). To achieve the second goal of ATF2, High-Q value IP-BPM was developed before Low-Q IP-BPM. However, beam feedback system at the IP needed much shorter decay time. Therefore, new IP-BPM with lower Q value has been developed to achieve nano-meter level beam position resolution and short decay time below than 20ns. The developed Low-Q IP-BPM (See Figure 1) consists of a one sensor cavity and a one reference cavity.

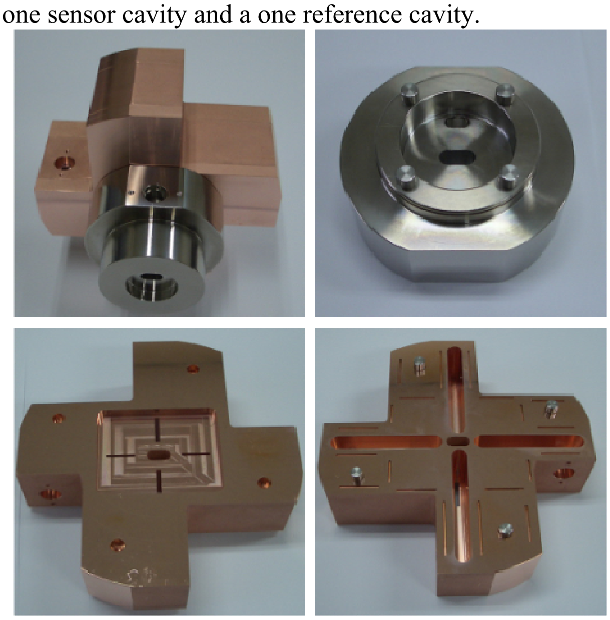

Figure 1: Entire of Low-Q IP-BPM (left up). Reference cavity (right up). Sensor cavity part (left down). Wave guide part (right down).

Detailed characteristics of Low-Q IP-BPM were described elsewhere [2]. Table 1 shows the design parameters of Low-Q IP-BPM.

Table 1: Design Parameters of Low-Q IP-BPM

| | X-port | Y-port | Reference |
|---|---|---|---|
| $f_0$ (GHz) | 5.712 | 6.426 | 6.426 |
| $\beta$ | 8 | 9 | 0.0117 |
| $Q_0$ | 5900 | 6020 | 1170 |
| $Q_{ext}$ | 730 | 670 | 100250 |
| $Q_L$ | 656 | 602 | 1156 |
| $\tau$ (ns) | 18 | 15 | 29 |

## THE SCHEME OF BEAM POSITION RESOLUTION TEST FOR LOW-Q IP-BPM

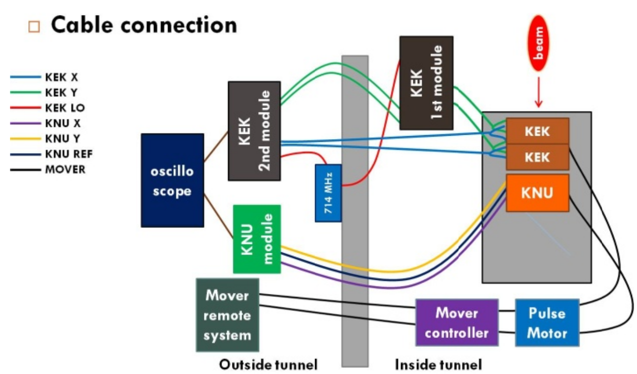


Figure 2: Beam position resolution measurement test scheme for Low-Q IP-BPM.

As shown in Figure 2, a one Low-Q IP-BPM (KNU) and two High-Q IP-BPMs (KEK) in one block were used to measure beam position resolution of Low-Q IP-BPM. Two sets of horizontal movers and vertical movers were installed to align beam centre of each BPMs. The electronics of IP-BPMs were used to convert from raw signal to I-Q signal. The sensor cavity monitor is used to measure the beam position by using dipole mode, while the reference cavity was used to measure the beam charge by using mono-pole mode of same resonant frequency. The output signal from the sensor cavity enters the electronics. We can acquire I signal and Q signals after the phase tuning by using phase shifter in the electronics, which signals are 90 degrees difference in phase. Band-pass filters were used to prevent the contamination of dipole mode with the other modes. Figure 3 and 4 show

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the electronics block diagram of Low-Q IP-BPM and installed appearance of Low-Q IP-BPM and High-Q IP-BPMs.

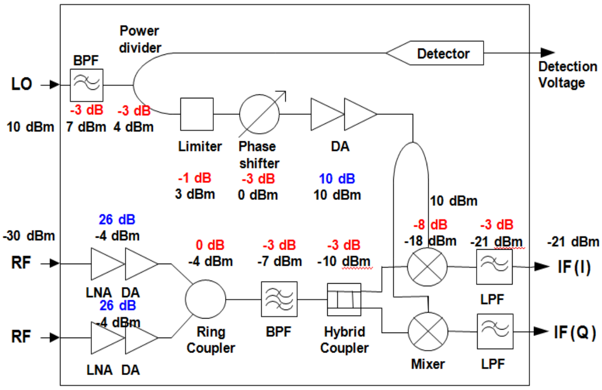


Figure 3: Electronics block diagram of Low-Q IP-BPM.

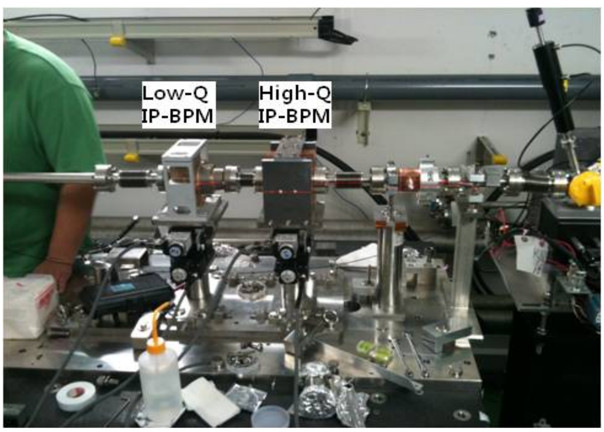


Figure 4: Installed appearance of Low-Q IP-BPM (Left) and High-Q IP-BPMs (Right).

## BEAM POSITION RESOLUTION MEASUREMENT OF LOW-Q IP-BPM

Beam position resolution measurement of Low-Q IP-BPM was performed at ATF2 in Jan. 2011. Beam position resolution was measured in vertical direction of Low-Q IP-BPM, since the second goal of ATF2 is much more strict compared to horizontal.

### *Principle*

We used three cavities for beam position resolution measurement. To determine beam position resolution, at least three cavities are required. The beam position resolution was defined by “RMS of the residual between measured and predicted beam position at the Low-Q IP-BPM” × “Geometrical factor”. Predicted beam position was calculated from the two High-Q IP-BPMs and Geometrical factor was a factor to correct the propagation of the error due to the alignment of the three IP-BPMs to calculate the resolution of a single cavity.

### *I-Q Tuning*

I-Q tuning was performed by using a oscilloscope. When I signal shows the maximum position, Q signal is set to zero position by using phase shifter. For this, I & Q signal means the beam position signal and angle signal, respectively. If we do not performed I-Q tuning, the electronics will be easily saturated by large beam angle signal. Thus we also can’t expect good beam position resolution. Figure 5 shows a one of the examples of the I-Q tuning by using oscilloscope.

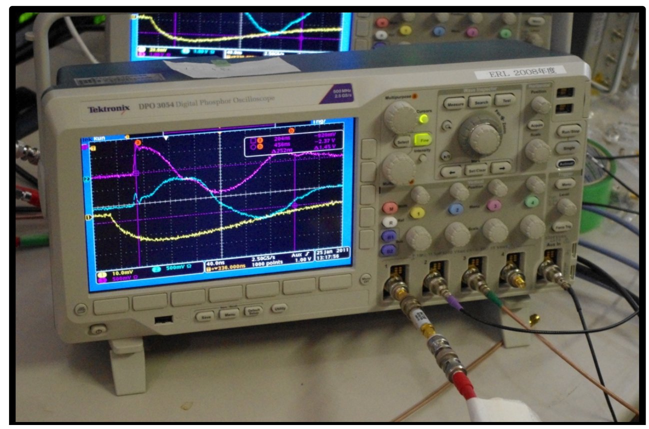


Figure 5: A one of the examples of I-Q tuning. The violet line shows I signal and sky-blue line shows Q signal.

### *Calibration Run*

Calibration run was performed to calibrate the sensor cavity response to actual beam position. To monitor the response of sensor cavities due to vertical beam position, the electron beam was swept against sensor cavities by vertical movers. For this calibration run, the electronics of Low-Q IP-BPM was performed 40dB amplification case and the electronics of High-Q IP-BPMs were performed without amplification. Calibration run (See Figure 6) was operated three times for each IP-BPM, to estimate their respective calibration factor. The results of the calibration run of each IP-BPM due to vertical mover positions was shown by Table 2.

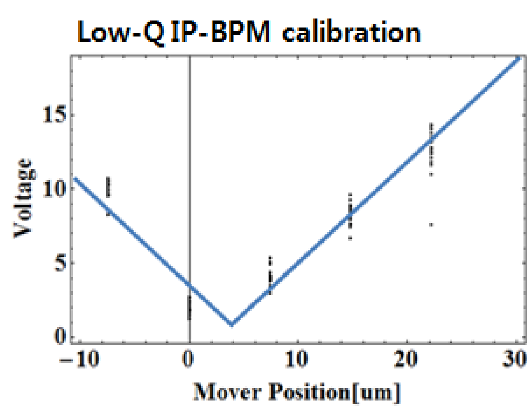


Figure 6: Low-Q IP-BPM calibration run under 40dB amplification condition.

Table 2: The Results of the Calibration Run of Each IP-BPM.

| | Calibration factor (mV/nm) | Stat. Error (mV/nm) |
|---|---|---|
| Low-Q IP-BPM (40dB Amp.) | 0.674 | 0.0264 |
| High-Q IP-BPM 1 | 0.922 | 0.0451 |
| High-Q IP-BPM 2 | 0.720 | 0.0260 |

### *Resolution Run*

Resolution run to measure beam position resolution of Low-Q IP-BPM was taken by 500 events for a fixed beam orbit nearby beam centre. Electronics set up was the same as calibration run. The resolution run was performed to measure "RMS of the residual between measured and predicted beam position at the Low-Q IP-BPM". The predicted beam position was obtained by using two High-Q IP-BPMs (See Figure 7).

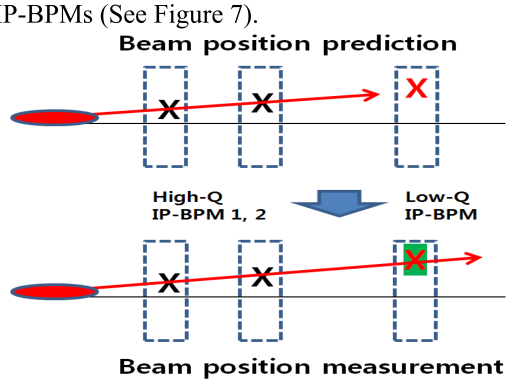


Figure 7: Beam position prediction and measurement.

The residual of Low-Q IP-BPM was calculated as

$$\text{Residual} = Y\_I_{measured} - Y\_I_{predicted} \quad (1)$$

Figure 8 and 9 show the results of the resolution run due to 500 events.

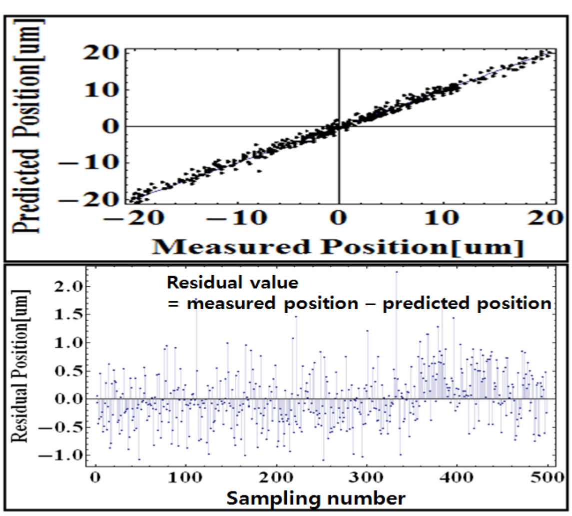


Figure 8: The measured position vs. predicted position (Top). Residual position due to 500 events (Bottom).

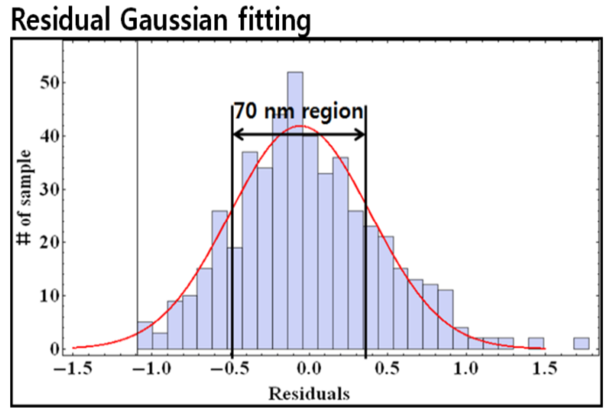


Figure 9: Gaussian fitting of residual position.

RMS of the residual was measured 440nm during 500 events resolution run, which value was divided by calibration factor, already. To obtain beam position resolution of a single cavity, we need to consider "Geometrical Factor". This coefficient determined by positional relation of three cavities. Geometrical Factor of these three BPMs was calculated approximately 0.8. Therefore beam position resolution was given by [3]

$$\text{Position resolution} = \text{G.F} \times \left(\frac{\text{RMS of residual}}{\text{Calibration factor}}\right) \quad (2)$$

The beam position resolution of Low-Q IP-BPM was measured 352nm. However, average beam charge during this resolution run was 0.2*1.6nC. This implies that under nominal condition of ATF2, which is 1.00*1.6nC. Therefore the beam position resolution of Low-Q IP-BPM was expected to be 70nm.

## CONCLUSION

We got the results of beam position resolution 70nm for the Low-Q IP-BPM in Jan. 2011. Three IP-BPMs will be designed and fabricate to install at the IP region. The electronics of Low-Q IP-BPM will be upgraded to get the high beam position resolution. The ultimate goal is to obtain a resolution of 2nm and orbit stabilization through beam feedback at the IP region.

## REFERENCES

[1] "ATF2 Proposal", KEK Report 2005-2.
[2] S. H. Shin, et al, "The Design Study For Low-Q IP-BPM", PAC'07, FRPMN054, New Mexico, USA.
[3] Y. Inoue, et al, "Development of a high-resolution cavity-beam position monitor", Phys. Rev. ST Accel. Beams 11, 062801 (2008).