DEVELOPMENT OF A CAVITY-TYPE BEAM POSITION MONITORS WITH HIGH RESOLUTION FOR ATF2

Siwon Jang, Eun-San Kim*, Kyungpook National University, Daegu, Republic of Korea
Yosuke Honda, Toshiaki Tauchi, Nobuhiro Terunuma, KEK, Tsukuba, Ibaraki, Japan

Abstract

We have developed a high resolution beam position monitors for ATF2 at KEK, which is an accelerator test facility for International Linear Collider (ILC). The main goals of ATF2 are achievement of 37nm beam size and 2nm beam position resolution for beam stabilization. For these goals, Low-Q IP-BPM (Interaction Point Beam Position Monitor) with latency of 20 ns is being developed. In this paper, we will describe about design of Low-Q IP-BPM, the basic test results as RF test and BPM sensitivity test. Electronics for Low-Q IP-BPM will be also described.

INTRODUCTION

The Accelerator Test Facility 2 (ATF2) at High Energy Accelerator Research Organization (KEK) is test beam line facility for achieving the high luminosity required at the International Linear Collider [1]. The beam energy is 1.3 GeV and nominal beam charge is 10^{10}electrons/bunch. The aim of beam size at the IP region is 37nm vertically, which is the first goal of ATF2. The second goal of ATF2 is the achieving beam position resolution of 2nm to maintain the beam collision with nano meter scale stability at IP-region. To achieve beam position resolution of 2nm, we developed proto type Low-Q IP-BPM and tested at ATF2 extraction beam line [2]. After the proto type test, we modified the design of Low-Q IP-BPM. Modified design of Low-Q IP-BPM was much smaller and lighter than prototype to install at IP region. The entire Low-Q IP-BPM system consists of three sensor cavities (See Fig. 1) and two reference cavities. Three sets of electronics are also developed and fabricated for the signal processing.

DEVELOPMENT OF LOW-Q IP-BPM

As we mentioned, we modified the design of Low-Q IP-BPM to install it at IP region. The main point of modified design is to reduce weight of Low-Q IP-BPM than the prototype BPM. Thus, the material was changed from copper to aluminium. Moreover, the total cavity size was also reduced from 14cm to 11cm [3]. The sensor cavity size was almost the same, but wave guide part was changed to reduce entire cavity size. The design study of aluminium Low-Q IP-BPM was performed by using of the electromagnetic simulation program HFSS. Low-Q IP-BPM used two dipole modes to avoid isolation issue between x and y ports. Therefore, the sensor cavity structure was determined to be rectangular shape to split the frequency of two dipole modes.

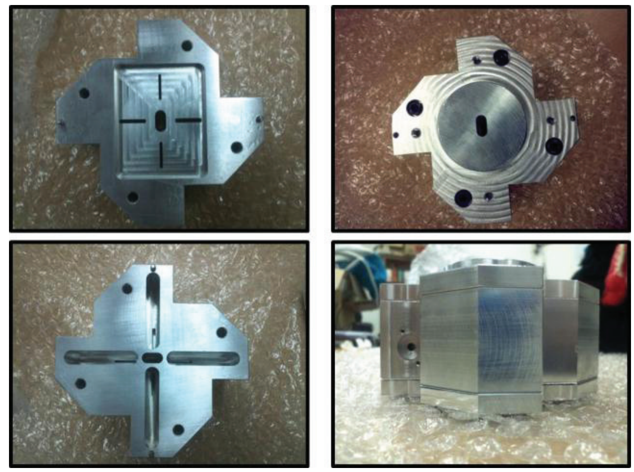

Figure 1: Fabricated one block Low-Q IP-BPM. Sensor cavity part (left up). Wave guide part (left down). Cavity covers with flange (right up). Side view (right down).

The frequency of two dipole modes are 5.712 GHz and 6.412GHz for x and y port, respectively. Figure 2 shows dipole mode fields for x and y ports, monopole mode field in sensor cavity.

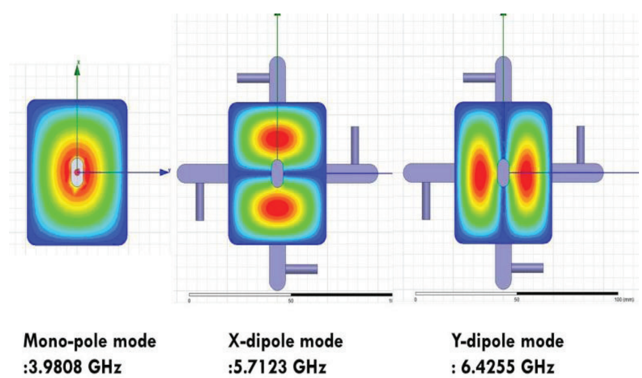

Figure 2: Electric field mapping of HFSS simulation.

The designed parameters are described as shown in Table 1. The decay times of two dipole modes are below 20ns. Therefore, it can be utilized by the multi-bunch trains with bunch train space of 150ns.

Table 1: Design parameters

Port	f(GHz)	β	Q0	QL	T(ns)
X-port	5.712	5.684	4959	742	18.72
Y-port	6.426	5.684	4670	699	17.23

* Corresponding author: eskim1@knu.ac.kr

Table 2: Results of RF measurement of Low-Q IP-BPM

	Port	f_0 (GHz)	β	Q_0	Q_{ext}	Q_L	τ(ns)	V_{out} [mV/nm]
Double_1	X-port	5.697	0.656	362.34	552.14	218.77	6.112	4.870
Double_1	Y-port	6.410	0.668	845.66	1266.7	507.11	12.59	3.005
Double_2	X-port	5.698	0.817	483.38	591.45	265.99	7.430	4.705
Double_2	Y-port	6.410	0.641	834.70	1302.5	508.70	12.63	2.964
Single_1	X-port	5.699	0.855	502.05	587.04	270.61	7.557	4.722
Single_1	Y-port	6.409	0.986	1238.0	1255.9	623.43	15.48	3.019

Figure 3 shows the cavity dimension of Low-Q IP-BPM by HFSS simulation. The size of cavity part was 60.88mm, 48.57mm and 5.8mm for horizontal, vertical and longitudinal directions, respectively.

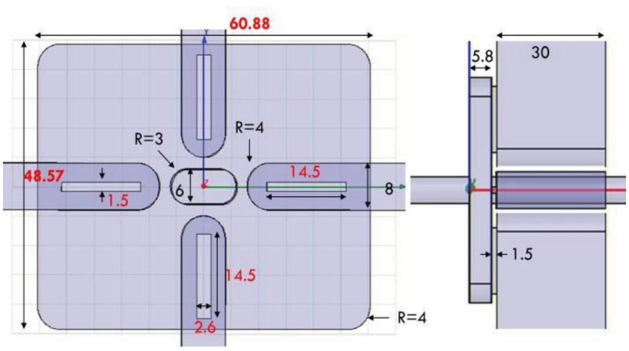

Figure 3: The sensor cavity dimension for HFSS simulation.

RF MEASUREMENT OF LOW-Q IP-BPM

The main properties of Low-Q IP-BPM were measured by using network analyser after the fabrication was completed. The results of RF measurement are described as shown in Table 2. The measured frequency of two dipole modes shows lower than design value. Even though the measured frequency of three cavities are different with designed value, if the reference cavity frequency can be set to same level, then we can get the clear I-Q signal by using electronics system. The measured quality factors were also different with designed value, but the output voltage per beam offset shows still proper values to measure high beam position resolution.

BEAM POSITION SENSITIVITY MEASUREMENT OF LOW-Q IP-BPM

As shown in Figure 4, double block of Low-Q IP-BPM was installed in the vacuum chamber at the end of Linac section. The test beam line consist of two horizontal steering magnets, two vertical steering magnets, two strip line BPM and two Low-Q IPBPMs. The beam orbit was controlled by using four steering magnets and the beam position at BPM2 was predicted by using two-strip line BPMs. The sensitivity of kicked beam offset by steering magnet was measured by changing the current of steering magnets.

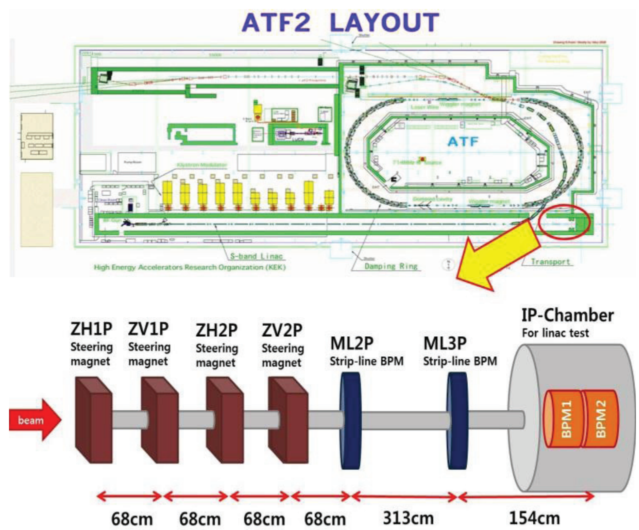

Figure 4: Test beam line scheme for beam position sensitivity measurement of Low-Q IP-BPM.

One of Y-port for each cavity BPM 1 & 2 was used for measurement of the beam position sensitivity and the other port was terminated. To check the beam position sensitivity, we measured peak point of output signal while sweeping the beam orbit by using steering magnets. In that time, ATF2 operation beam power was 0.37×10^{10} electrons/bunch so that the output signal voltage was normalized to 10^{10} electron/bunch (1.6nC), which is nominal beam condition of ATF2. The peak point of output signal shows V shape while sweeping the beam orbit. The electrical center of BPM was located at the minimum point of V shape. Eventually, the slope gradient of V shape was sensitivity of Low-Q IP-BPM and the expected slope gradient can be calculated by Eq. (1) [4],

$$V_{out} = \frac{\omega q}{2}\sqrt{\frac{Z}{Q_{ext}}}(R/Q)\exp\left(-\frac{\omega^2\sigma_z^2}{2c^2}\right). \quad (1)$$

Figure 5 shows the beam position sensitivity results of BPM 1. These results also include the beam power loss

ISBN 978-3-95450-122-9

due to long coaxial cables from inside tunnel to outside tunnel.

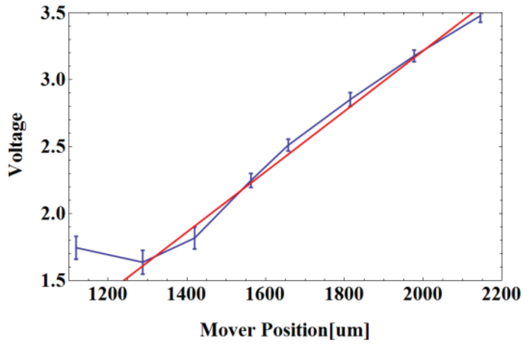

Figure 5: The beam position sensitivity measurement results of BPM1 Y-port.

Actually, the measurement of BPM sensitivity is performed by using two output ports of BPM but in our case, we used just one port of Y-port so that we should consider twice of output voltage to calculate real position sensitivity of Low-Q IP-BPM. The one port case results were shown in Table 3. The measured beam position sensitivity of cavity BPM shows a good agreement with expected sensitivity value.

Table 3: Sensitivity of 11cm Low-Q IP-BPM (BPM 1 & 2)

Y-Port	BPM 1	BPM2
Expected Sensitivity	3.005uV/nm	2.964uV/nm
Normalized Sensitivity (10^{10} electron/bunch)	2.256uV/nm	2.230uV/nm

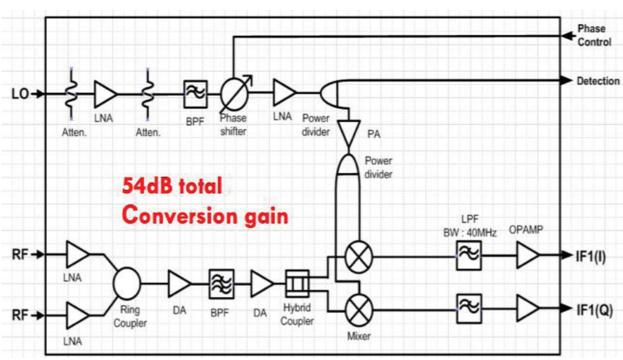

Figure 6: Schematic diagram of the y-port electronics.

ELECTRONICS OF LOW-Q IP-BPM

We developed the electronics for Low-Q IP-BPM for signal processing. The electronics were used to down convert from raw signal to I-Q signal. The input signals of electronics were used two raw signals from sensor cavity (RF) and reference cavity (LO). To acquire I-Q signal, the signal mixing and I-Q phase tuning, signal amplify processing are performed on the electronics system. A schematic diagram of the electronics is shown in Figure 6.

The developed electronics performance was tested with prototype Low-Q IP-BPM at the extraction beam line in ATF2. The Y-port electronics sensitivity test result was 450.9uV/nm, which value corresponds to 3.7count/nm for 14bit ADC. The results of electronics sensitivity are enough to measure 2nm resolution by using 14bit ADC. Table 4 shows the specification of Y-port electronics and Figure 7 shows the measurement result on Y-port electronics sensitivity value.

Table 4: The Y-port electronics design parameters

Port	f_0 (GHz)	Gain	N.F	Latency
Y-port	6.426	54 dB	1.88dB	25ns

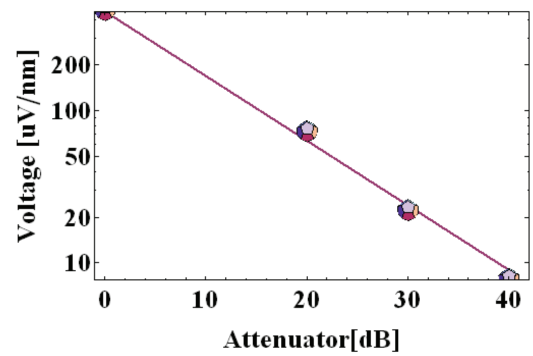

Figure 7: The electronics sensitivity measurement results.

SUMMARY

We have described about the design study, RF test and position sensitivity test of Low-Q IP-BPM. The results of RF measurement show unexpected quality factor values but expected output voltage shows good performance. The result of y-port sensitivity of Low-Q IP-BPM also shows a possibility to get the beam position resolution of 2 nm. Some additional parts of the electronics system and the reference cavity BPM will be fabricated until June 2013. After the fabrication, the entire Low-Q IP-BPM system will be installed at IP region with IP-Chamber to get the higher beam position resolution. The ultimate goal is to obtain a resolution of 2 nm 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. Honda, "Update on IP-BPM design", 23 November 2005
[4] Y. Inoue, et al, "Development of a high-resolution cavity-beam position monitor", Phys. Rev. ST Accel. Beams 11, 062801 (2008)