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DEVELOPMENT OF L-BAND CAVITY BPM FOR STF

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Abstract

We developed a L-band beam position monitor(BPM) with position resolution of few hundred nano meter for Superconducting Test Facility(STF) in High Energy Accelerator Research Organization (KEK). The L-band BPM was developed to install inside the superconducting cryomodule of STF in KEK and it's test was performed at Accelerator Test Facility(ATF) in KEK. The three L-band BPM are fabricated and installed at the end of Linac of ATF. The position resolution measurement was performed with new L-band BPM electronics.In this talk, we will describe about the development of L-band BPM and its beam test results of nano meter level beam position resolution with new electronics system.

INTRODUCTION

The STF is a research center for studies on issues 1.3GHz superconducting cavity with cryostat system for the ILC [1]. The main goal of STF is development and complete ILC RF unit which is compatible with ILC design and consisting of three cyromodules which contain 8 SC cavities and beam position monitor. The proto type of L-band cavity BPM for the ILC cyromodule was developed at 2011 [2]. For the resolution measurements, three L-band BPM are fabricated and 1st stage electronics is developed with new design scheme. A fabricated L-band BPM system are installed at the end of linac of ATF, which is a research facility for a studies on issues concerning the injector, damping ring, and beam delivery system for the ILC [3]. The beam energy of ATF is 1.3 GeV and nominal beam charge is 10^{10}electrons/bunch. Figure 1 shows the layout of ATF.

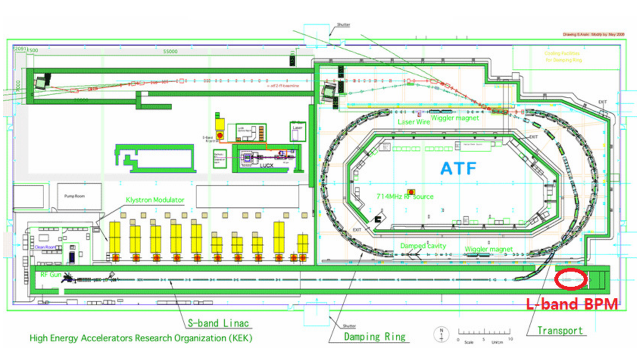

Figure 1: The layout of ATF. The red circle shows the installation location of three L-band BPM.

The entire L-band BPM system consists of three sensor cavities (See Fig. 2), reference cavity and its electronics for the signal processing. The L-band BPM resolution measurement was performed at the end of ATF linac during last spring beam operation.

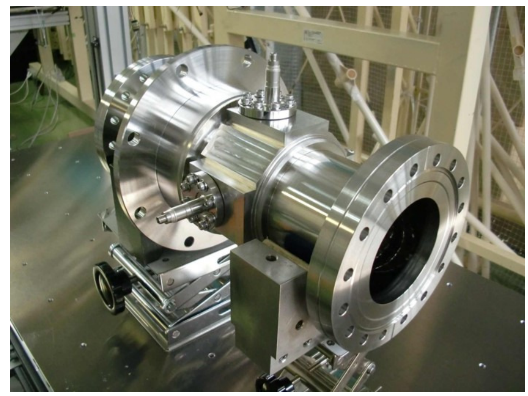

Figure 2: The fabricated L-band BPM.

L-BAND CAVITY BPM

The L-band re-entrant cavity BPM is developed to install inside cryostat for ILC and to monitor the beam orbit. The L-band BPM should be operate under 2K condition and measure the multi bunch beam position to stabilize the beam orbits along the ILC linac. The sensor cavity used a cylindrical shape and the beam pipe size was determined to 78mm. The resonant RF frequency was designed to be 2.04GHz to avoid interference with acceleration cavity HOM. Figure 3 shows the HFSS simulation results of L-band BPM [4].

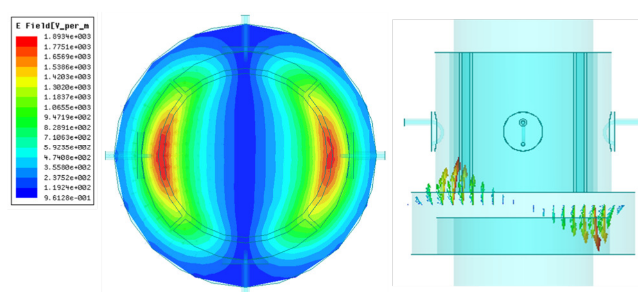

Figure 3: The HFSS RF simulation results of L-band BPM.

Table 1 shows the main parameters of L-band cavity BPM, a resonant frequency of the dipole modes f_0, the loaded quality factor Q_L, decay time τ. Unfortunately, the fabricated three L-band BPM have a different resonant frequencies with design frequency. However, the measured loaded Q values are below 300, which means that the fabricated three L-band BPM can be measure multi-bunch beam position under ILC beam operation condition. All of these RF parameters of L-band BPM are measured by using Network Analyzer.

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Table 1: The Measured RF Parameters of L-band BPM

Parameter	BPM-A	BPM-B	BPM-C
f_0 [GHz]	2.015	2.050	2.019
Δf [MHz]	13.12	9.62	10.95
Q_L	154	217	185
τ [ns]	12.18	16.83	14.54

1ST STAGE ELECTRONICS OF BPM

An electronics for the signal processing of L-band BPM is developed. The L-band BPM electronics is considered as two parts, a first stage electronics is called a down converter and a second stage electronics is called a phase detector. In this beam test, we only used to first stage electronics to check the characteristics of RF signal and to check the performance of down converter.

The first stage electronics consists of three parts. The purpose of RF filter part is signal amplification and signal filtering within 400 MHz range to eliminate higher order mode signals. After the RF filter, the RF signal will be mixed with LO signal then the RF signal frequency is down converted to 80 MHz. The down converted IF signal pass through IF filter part, which part consists of a series of amplifiers, BPF and LPF. Figure 4 shows the details of first stage electronics.

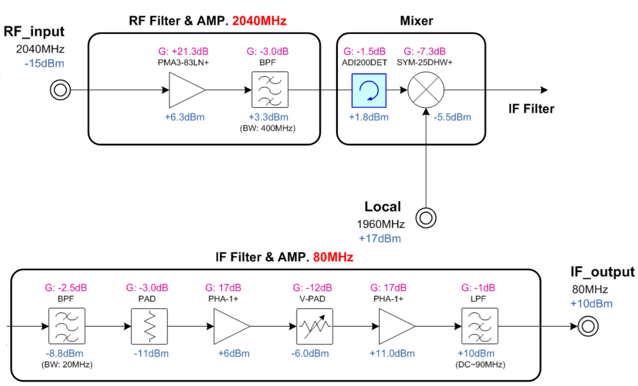

Figure 4: The first stage electronics scheme for L-band BPM signal processing.

BEAM TEST SCHEME OF L-BAND BPM

Three L-band cavity BPMs are installed inside tunnel near the end of linac of ATF. The sensor cavity BPM, reference cavity BPM, 1st stage electronics, LO signal splitter, hybrid and RF signal attenuators are installed. At the outside of tunnel, the LO signal generator(S/G) and Oscilloscope are installed. Two signal generators are used for the RF signal mixing cause three L-band BPM have a different resonant frequencies so that one of S/G is set to 1.940GHz for BPM A and C, the other S/G frequency is set to 1.970GHz for BPM-B. Then the expected IF frequencies are around 80MHz. More detailed scheme was shown in the Fig. 5.

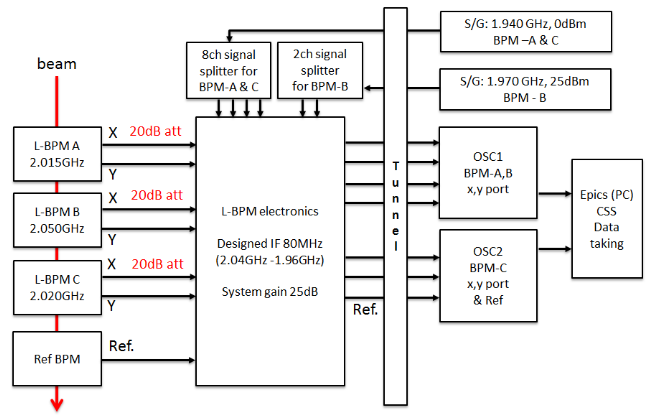

Figure 5: The beam test scheme of L-band BPM entire system.

CALIBRATION RUN OF L-BAND BPM

At the beginning of beam test, we performed the calibration run to calculate the calibration factors of three sensor cavities. Four steering magnets are used to sweep the beam position and the reference beam position of each L-band BPM was calculated using a stripline beam position monitor installed at the front and rear. The calibration run was taking 20 data at each mover position. To calculate the calibration factor, we first calculate FFT amplitude of IF signals as like Fig. 6.

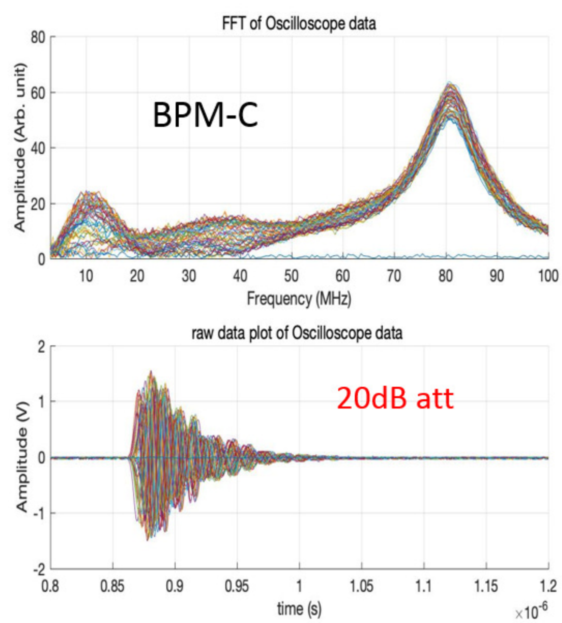

Figure 6: FFT of IF signal for L-band BPM-C.

The calibration factor was calculated by using integration method within 80MHz ± 2.5MHz. The Fig. 7 shows the results of calibration run for L-band BPM-C x-port case. Three of L-band BPM calibration factors under 0dB attenuation are listed in Table2.

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Table 2: The Calibration Factor of L-band BPM

BPM name	X-port cal. [/um]	Y-port cal. [/um]
BPM-A	0.728	1.363
BPM-B	1.836	2.140
BPM-C	0.682	2.003

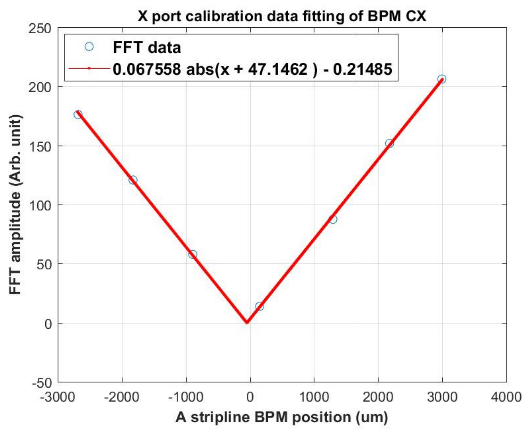

Figure 7: L-band BPM-C x-port calibration factor. The calibration run performed under 20dB attenuation case.

RESOLUTION RUN OF L-BAND BPM

The position resolution of the L-band cavity BPM was estimated with a fixed beam offset. The main purpose of resolution run was to measure the residual, which is the difference between the measured position at one of BPM and the predicted position by using the other two BPMs. The predicted beam position was calculated by using a singular value decomposition(SVD) method [5]. The linear regression formula by using SVD method with 6 parameters is shown in below, and determined the coefficient α of each parameter.

- BPM-CY = α0 + α1*BPM-AX + α2*BPM-AY + α3*BPM-BX + α4*BPM-BY + α5*BPM-CX

Figure 8 shows the result of the resolution run of BPM-C y-port. The results of beam position resolution measurement of L-band BPM are summarized in Table3. The measured best beam position resolution is 324nm but the other BPM port shows quite different, it comes from several reason but we found that the correlation between BPM-B and other two BPMs is poor. One of this reason is LO input power saturation problem for BPM-B so that the input power level will be adjust in the next beam test.

Table 3: The Measured Resolution of L-band BPM

	BPM-A	BPM-B	BPM-C
X-port	3.75μm	2.68μm	985nm
Y-port	698nm	2.26μm	324nm

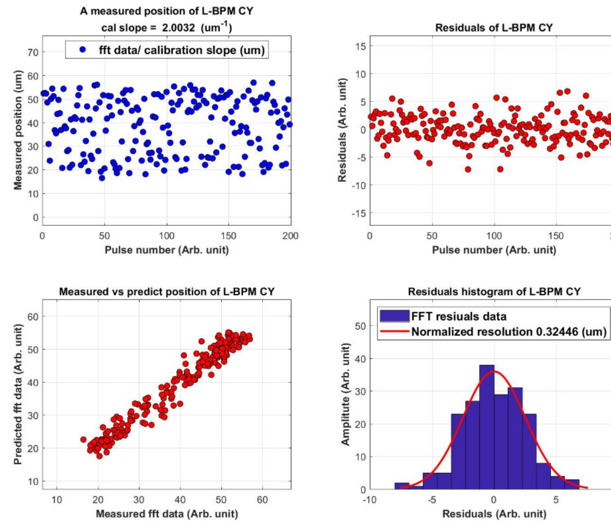

Figure 8: The measured position resolution of BPM-C y-port is 324nm with 1.6nC beam charge condition.

CONCLUSION

In this proceeding, we described the development and beam test results of a L-band BPM. The L-band BPM was developed to provide the beam position information and will be installed inside the cryostat of ILC to stabilize the beam orbits. A beam position resolution was measured with first stage electronics and the characteristics of RF signal from L-band BPM was also studied. The measured best beam position resolution is 324nm for BPM-C y-port but still we need to solve LO input power saturation problem of BPM-B to compensate correlation between the other two BPMs. In the next beam test, we will solve this kind of problem and will achieve below 300nm of beam position resolution. Additionally, we will fabricate the second stage electronics to adjust beam phase of L-band BPM.

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