NANOMETER RESOLUTION BEAM POSITION MONITOR FOR THE ATF2 INTERACTION POINT REGION

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Abstract

The ATF2 international collaboration is intending to demonstrate nanometre beam sizes required for the future Linear Colliders. The position of the electron beam focused down at the end of the ATF2 extraction line to a size as small as 35 nm has to be measured with nanometre resolution. For that purpose a special Interaction Point (IP) beam position monitor (BPM) was designed. In this paper we report on the features of the BPM and electronics design providing the required resolution. We also consider the results obtained with BPM triplet which was installed in the ATF beamline and the first data from ATF2 commissioning runs.

INTRODUCTION

The Accelerator Test Facility (ATF) at the High Energy Accelerator Research Organization (KEK) is constructing an extraction line as called the ATF2. It addresses two major goals; namely focusing the beam down to nanometer size and providing the beam position within nanometer stability [1]. Cavity type beam position monitor (BPM) is expected to require high resolution with a few nm. IP-BPM is required to provide a direct demonstration of beam position stability at the interaction point (IP) [2, 3].

In this paper we describe the design studies and the test results with beam for the Low-Q IP-BPM and its electronics module.

LOW-Q IP-BPM

ATF IP-BPM has characteristics; 1) Narrow gap to be insensitive to the beam angle, 2) Small aperture (beam tube) to keep the sensitivity, 3) Separation of x and y signal, 4) Signal decay times for x and y are ~ 110 and ~60 ns, respectively (3-bunch beam 150ns).

Low-Q IP-BPM was basically designed with same idea. Besides larger coupling slot dimension and stainless steel as cavity material were considered to decrease signal decay time for sensor cavity and for reference cavity, respectively. The changed signal decay times for sensor (x and y) and for reference signal are ~ 20ns and ~ 30 ns, respectively. The resolution can be expected less than 2nm by calculation of thermal noise power. Design parameters are described as shown in Table 1.

Table 1: Design Parameters

Port	f(GHz)	β	Q_0	Q_{ext}
X(sensor)	5.712	8	5900	730
Y(sensor)	6.426	9	6020	670
Reference	6.426	0.0117	1170	100250

The manufacture was done by a facility in KNU and each parts of BPM were brazed at 720°C temperature in PAL to avoid leakage into the cavity. The assembly is shown in Fig. 1 (a), and (b) shows the partial cross section. We will skip the detail for design study for this BPM since it has been described in [2].

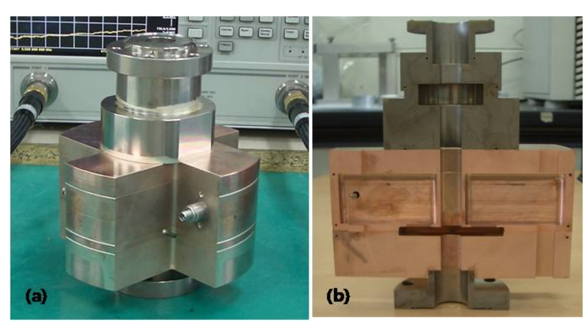

Figure 1: IP-BPM assembled (a), cut for inspection (b).

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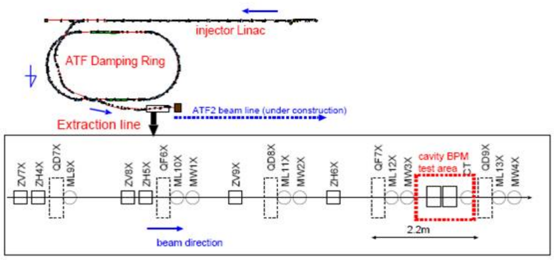

Figure 2: Layout of ATF and ATF2, and the installed position

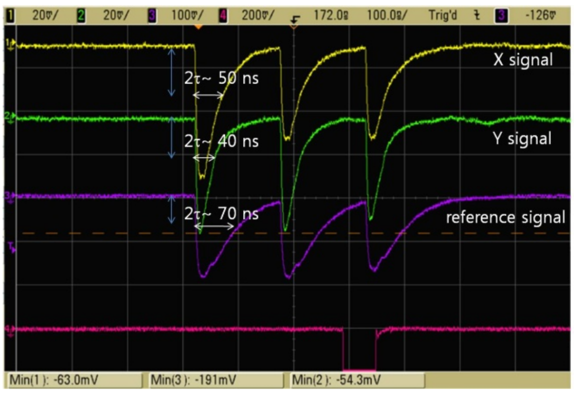

Figure 3: Measured decay time for X signal, Y signal and reference signal, respectively.

The IP-BPM was installed at the ATF2 beam line as shown in Fig. 2. The signal decay times for x signal, y signal and reference signal are 25ns, 20ns and 35ns, respectively as shown in Fig. 3.

PROTOTYPE ELECTRONICS MODULE

The design of electronics module was suggested by our KNU team, and then Microwave Communication Laboratory (MCL) in KNU took over and manufactured it. The frequency range determined by length of cavity is from 6.2GHz to 6.6GHz [4]. The Fig. 4 shows roughly the configuration of system. The detector with high sensitivity was designed to detect LO signal. Low Noise Amplifier (LNA) was designed and fabricated due to amplify RF signal and to reduce its noise. The system was configured to be readout In-phase (I) and Quadrature (Q) components to detect beam position by mixing RF signal and LO signal.

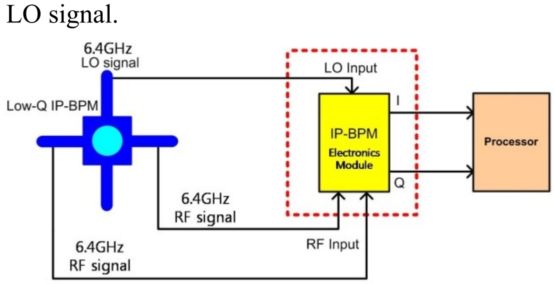

Figure 4: The configuration of the system.

Broadly speaking this system is separated LO signal circuit and RF signal circuit. Their simplified schematic of the circuits is shown in Fig. 5. LO signal circuit is composed of Band Pass fitter (BPF), power divider, detector, limiter, phase shifter and Drive Amplifier (DA), while RF signal circuit is made up of Low Noise Amplifier (LNA), Drive Amplifier (DA), ring coupler, Band Pass fitter (BPF), 90°–hybrid coupler, mixer and Low Pass Fitter (LPF). Two RF signals with 180° phase difference are converted into same phase passing through ring coupler. The signal of LO circuit is divided into two way and is mixed with RF signals. Finally they are output as In-phase (I) and Quadrature (Q) components.

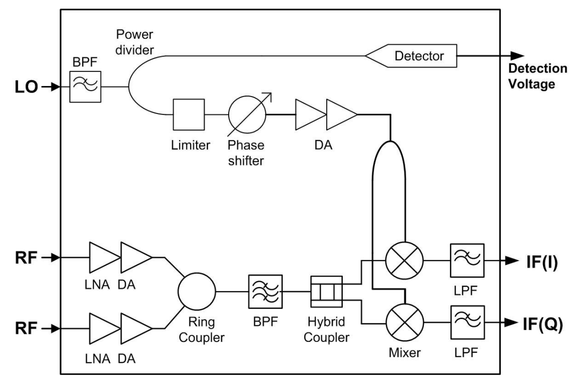

Figure 5: Simplified block diagram.

The power has constant value due to saturation of a limiter and drive amplifier if input power of LO has more than +9dBm. IF output power along RF input power is shown in Fig. 6 while LO signal is fixed with 6.4GHz frequency and +9dBm power. RF signal was arranged from 6.41GHz to 6.45GHz since the range of IF output frequency is DC ~50MHz. The conversion gain for this system has from 8.1dB to 8.8dB. Mixed RF signal and LO signal is passed through 90°–hybrid coupler and then I/Q signal with 90° phase difference is output as shown in Fig. 7.

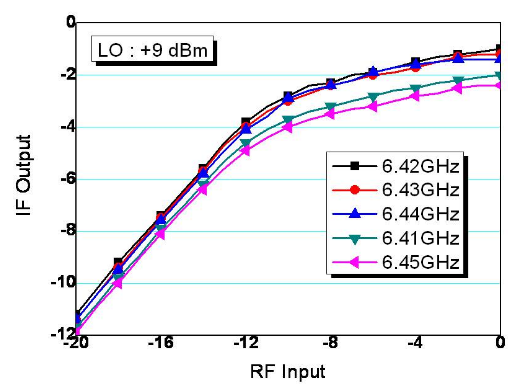

Figure 6: IF output power along RF input power (unit: dBm).

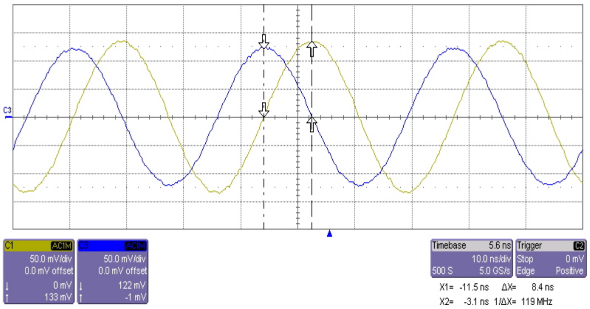

Figure 7: Waveform of output of I/Q measurement.

Beam signal source from MAD10X C-band QBPM was used to test the electronics module under beam operating of ATF2 while Low-Q IP-BPM was removed from the beam line since it has small aperture and was expected some problem at the first commissioning of ATF2. The electrical specifications were tested under beam operation at ATF2 as shown in Table 2.

Table 2: The electrical specifications of design and measurement.

Parameter	Design	Measurement
Conversion Gain	8.5dBm	8.69dBm
Input P_{1dBm}	-12dBm	-9dBm
Return loss (LO to IF Isolation)	-48dBm	-51.58dBm
Return loss (LO to RF Isolation)	-59dBm	-55.79dBm
Return loss (RF to IF Isolation)	-50dBm	-51.76dBm
I, Q measurement (Phase Difference)	90degree	86.25 degree

We checked the waveform shape visually as shown in Fig. 8. The decay time for C-band QBPM instead of IP-BPM were measured as 206ns which is designed 10 times longer than 20ns of IP-BPM.

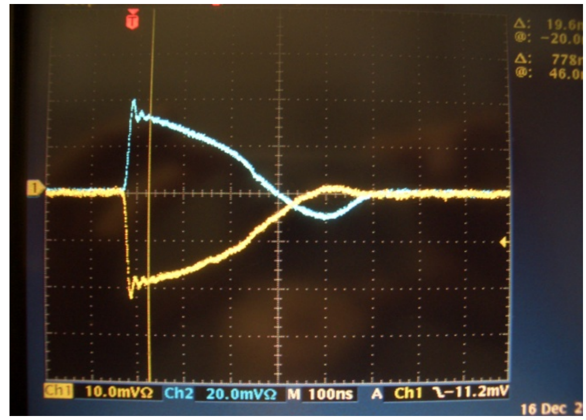

Figure 8: Beam generated signals seen from the system.

SUMMARY

Low-Q IP-BPM and its electronics module were designed and were performed the first beam test at the ATF2. This test could not show any issue. The BPM is removed now, but in the future that the BPM and electronics module will be reinstalled the characteristics of BPM and electronics module such as resolution and stability measurements will be required to test more.

REFERENCES

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