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 
is 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 150 ns).
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 ~ 20 ns and ~ 30 ns, 
respectively. The resolution can be expected less than 
2 nm by calculation of thermal noise power. Design 
parameters are described as shown in Table 1.

Table 1: Design Parameters

<table>
<thead>
<tr>
<th>Port</th>
<th>f(GHz)</th>
<th>β</th>
<th>Q₀</th>
<th>Q_ext</th>
</tr>
</thead>
<tbody>
<tr>
<td>X(sensor)</td>
<td>5.712</td>
<td>8</td>
<td>5900</td>
<td>730</td>
</tr>
<tr>
<td>Y(sensor)</td>
<td>6.426</td>
<td>9</td>
<td>6020</td>
<td>670</td>
</tr>
<tr>
<td>Reference</td>
<td>6.426</td>
<td>0.0117</td>
<td>1170</td>
<td>100250</td>
</tr>
</tbody>
</table>

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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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.

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.

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

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

Figure 4: The configuration of the system.

Figure 5: Simplified block diagram.

Figure 6: IF output power along RF input power (unit: dBm).
Beam signal source from MAD10X C-band QBPM was used to test the electronics module under beam operation 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.

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

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.

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