A BEAM TEST OF BUTTON-TYPE BEAM POSITION MONITOR FOR THE ATF DAMPING RING

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The Button-type Beam Position Monitors (BPMs) were fabricated for the ATF damping ring. The BPM was designed to achieve the position resolution less than 5 μm, and the fabrication of the first 40 BPMs was completed. For this BPM, a beam test was carried out at the 80 MeV injector part of the ATF LINAC. All of bunch signals in multi-bunch beam were clearly observed without any discharge. The calibration of BPMs was also performed to check their offset from the electrical center to the mechanical center and their position detection sensitivity. The result shows a good uniformity of position detection.

I. INTRODUCTION

The ATF [1] is under construction in KEK to study the feasibility for the linear-collider (JLC [2]). The ATF damping ring will be operated at 1.54 GeV with multi-bunch electron beam, which has the vertical emittance of 5 x 10^{-11} m•rad. To achieve such a low emittance beam, we must correct the dispersion of the orbit, which is small (η < 2 mm) in the long wiggler section of the damping ring. A precise measurement of the dispersion is indispensable. Usually the actual dispersion is obtained by comparing each closed-orbit distortion under the conditions of different RF frequency (Δf^{RF} ~10 kHz). For this reason, the requirement for the resolution of the BPM is less than 5 μm [3]. Furthermore, impedance of the components such as the vacuum chamber can be a source of the single-bunch instability which degrades the beam quality. To avoid such instability, the total longitudinal impedance must be less than about 0.2 Ω [1]. Results of wake field calculations indicate that the impedance is very small on the electrode of the button type compared with the directional-coupler type [4]. We therefore selected the button-type electrode for the BPM [5].

II. CONFIGURATION OF BEAM POSITION MONITOR

A. Pickup Electrode

The feedthrough consists of a central conductor with a button electrode, an outer conductor with an SMA connector and an insulator, as shown in Figure 1. The central conductor is made of Kovar and the button electrode is made of stainless steel. Taking into account the impedance, the button shape has a curvature with the same inner radius of the BPM block. The insulator is ceramics Al_2O_3. The outer conductor with the SMA connector is made of aluminum alloy with titanium joined by a HIP transition. Some electrodes have been tested for mechanical strength and vacuum leakage. The threshold level of the brazing strength of the central conductor is 60kg against the tensile forces. No vacuum leak occurs after heat-cycle tests from liquid-nitrogen temperature up to 200 °C. Furthermore, all of electrodes have been checked concerning to the dielectric strength (> 1000 Volts).

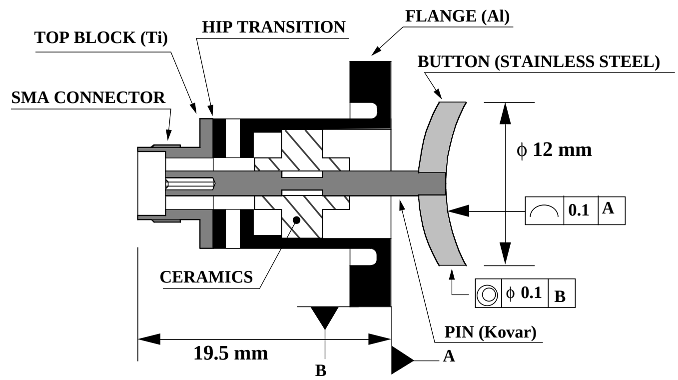

Figure 1: Pickup electrode for the BPM.

B. BPM Block

Each BPM is installed at a location near to every quadrupole magnet and sextupole magnet; there are 120 BPMs in the ring. We have already fabricated 40 BPMs in 1994.

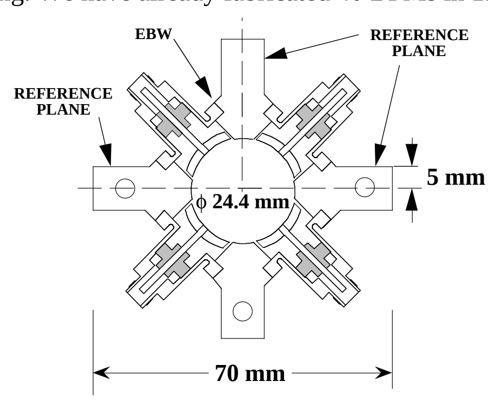

Figure 2: Cross-sectional view of the BPM.

The BPM block was machined from a mass of aluminum alloy, and four pickup electrodes were welded onto the block by the electron beam welding, as shown in Figure 2. It has both horizontal and vertical reference planes, which are used for the alignment of the BPM to the Q magnet. Both planes are also used as a reference for the calibration process to obtain an electrical center of the BPM block. After installation of the vacuum chamber with BPMs to the beam line, the offset of the BPM to the Q magnet will be measured with an accuracy within 50 μm by using the reference planes.

III. BEAM TEST

To study the low emittance beam in detail, each bunch signal in the multi-bunch beam should be clearly distinguished. Furthermore, BPMs must be operated stably against 3×10^{10} particles per bunch in maximum. Since the feedthrough of the BPM has a cavity structure, there is a possibility to occur a discharge by the multipactering effect due to resonance fields excited by the wake-field, which is induced by the beam. At the TRISTAN main ring, in fact, such discharge effect, caused by a TE_{11} coaxial mode, was observed on the button-type BPM placed at RF cavity section [6]. The result of a resonance measurement shows that the lowest resonance frequency is 11 GHz, which is consistent with the result calculated by a MAFIA code. According to the calculation of the multipactering zone [7], at such high frequency, the discharge due to the multipactering will not occur, however, it should be checked by the actual beam. To check the performance of the BPM, a beam test was carried out at the 80 MeV injector part of the ATF LINAC.

A. Setup of Beam Test

The setup of the beam test is shown in Figure 3. Electron beam generated at the thermionic gun are accelerated up to 80 MeV and then traverse the wall current monitor (WCM) and the BPM. The BPM is welded to beam ducts which have a length of 70 mm and an inner diameter of 24 mm, and placed at the upstream of the beam dump. The output signal from the BPM is transmitted by RG-213/u cable (~33m) and observed by a sampling oscilloscope (Tektronix 11802, sampling head SD-24). The output signal is attenuated before the oscilloscope due to the small dynamic range of the oscilloscope. The beam current is measured by the WCM. The beam size and the bunch length were measured by a wire-scanner and a streak camera using an optical transition radiation as ϕ 2.2 mm and 20 psec in FWHM, respectively.

B. Beam test by Single-bunch Beam

An observed signal at the single-bunch operation is shown in Figure 4. The peak pulse height is 5 V for 1.6×10^{10} particles. There is a ringing shape at the signal tail. This is caused by a multiple reflection of the wall current at the edge of BPM chamber due to the discontinuity. The difference of the inner diameter between the vacuum chamber of LINAC (ϕ58mm) and the BPM (ϕ24mm) is 34 mm. However the inner diameter is the same in the damping ring. Therefore it might not be a problem for the actual use. Furthermore, a pickup signal variation for the number of particles was also measured up to 2×10^{10} particles per bunch, and which shows a good linearity. Any discharge such as multipactering was not observed. A beam test with more high intensity beam will be done after the beam commissioning of the beam transport line in this fall.

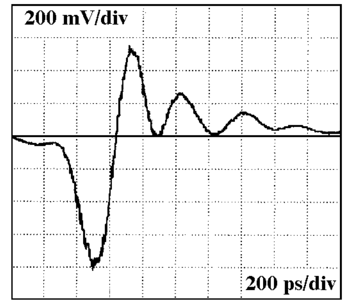

Figure 4: Observed signal of the single-bunch beam.

C. Beam test by Multi-bunch Beam

Figure 5 shows an observed signal for the multi-bunch beam. The bunch spacing is 2.8 nsec. All of bunch signals were clearly observed without any discharge. The signal is almost the same shape as the single-bunch beam. The signal

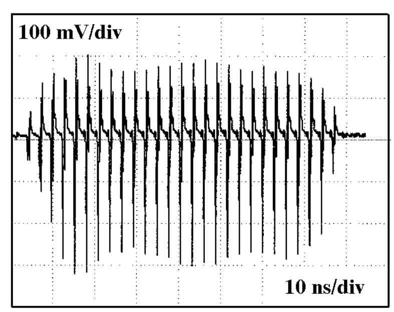

Figure 5: Observed signal of the multi-bunch beam.

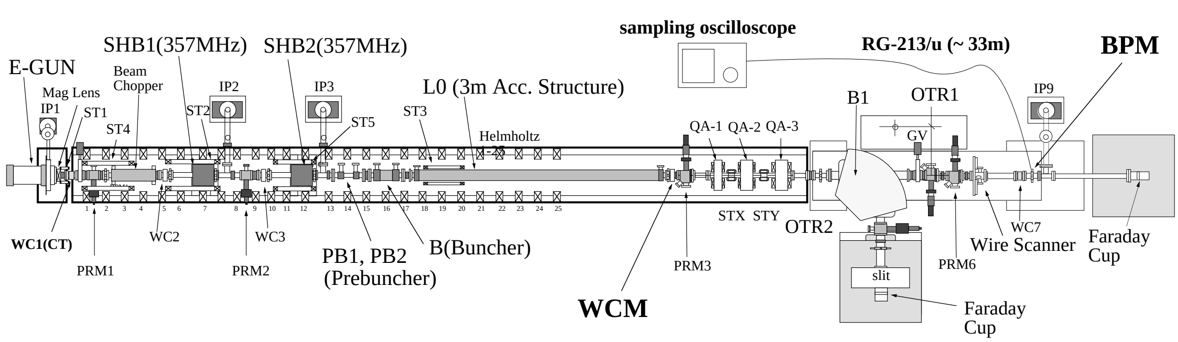

Figure 3: Setup of the beam test.

tail of each bunch is sufficiently small when the next bunch signal arrives.

IV. Electrical Characteristics

A. Capacitance of Electrode

Before and after electrodes were welded on blocks, the capacitance of each electrode was measured using a capacitance meter at a frequency of 800 Hz. The electrical-capacitance values are distributed in the 2.5 ~ 4.7 pF region. Thus, four pickup electrodes with similar capacitance values were grouped and welded on the monitor block to get uniform signals.

B. Mapping for the calibration

Every BPM block was calibrated so as to obtain the offset between the mechanical and the electrical center of the BPM block [1,5]. The mechanical center is defined by the horizontal and vertical reference planes within an accuracy of machining. The electrical center is measured by the following procedure.

The BPM block was mounted on a fixed stage, and a 50 µm diameter tungsten wire was strung coaxially in the BPM block. Both ends of the wire were placed in a V-shaped groove made of ceramics, which was installed on both of the x-y movable stages. The stage has a high positioning accuracy of 0.1 µm. One side of the wire was soldered to the SMA connector. The other end was terminated so as to match into a 50 Ω line; attached 100 *g* weights provide a constant proper tension. The wire was put in the base position of a gauge, which has the same reference planes of the BPM, and observed directly by a microscope. Thus, the wire was aligned precisely to the mechanical center of the BPM block with an accuracy of 40 µm. The calibration was performed by using a pulse signal with 5 ns rise time. Signal processing is based on the same principle as that for the SLAC/FFTB [8]. The readout electronics, which is a combination of a pulse stretcher amplifier, a Track&Hold ADC and a pulse generator, has a resolution of 5 µm. We measured the four output signals (V_1, V_2, V_3, V_4) induced electrostatically on each electrode due to pulse signals transmitted on the wire. In order to obtain the beam position, the following two calculation steps are performed. The first is a normalization procedure (x', y'), given by

$$x' = k\frac{V_2 - V_4}{V_2 + V_4},\ y' = k\frac{V_1 - V_3}{V_1 + V_3}\ ,$$

where k is a coefficient of the sensitivity on the position measurement, which depends on the geometry of the monitor chamber. It was obtained by a measurement for each BPM. Secondly, we converted the normalized results to the geometrical position (x,y) according to

$$x = \frac{\sqrt{2}}{2}(x' - y'),\ y = \frac{\sqrt{2}}{2}(x' + y').$$

In this way, we obtained a relation between the measured position (x, y) and the set position (X, Y) of the wire position for each monitor.

The calibration was performed at 169 points in the central area, which is a 3.6 mm square region with 0.3 mm step. As a result, there was no remarkable distortion in the mapping of all the BPMs. In the central region of ±0.5 mm, the distortion was less than 10 µm, while it was 100 µm at the point of 1.8 mm away from the center. This distortion is acceptable for our practical use. In the central region, however, it is only 2 % and quite well.

We obtained the distribution of the offsets of the electrical center to the mechanical one from the calibration data. The mean values of the offsets are X = -19 µm and Y = 58 µm, and the standard deviations are ~90 µm in both directions. The main source of this deviation came from the errors on the manufacture of the BPM block and pickup electrode.

The second fabrication of 40 BPMs and the calibration are now in progress.

V. SUMMARY

The Button-type Beam Position Monitors (BPMs) were fabricated for the ATF damping ring. A beam test of the BPM was carried out at the 80 MeV injector part of the ATF LINAC. All of bunch signals in multi-bunch beam were clearly observed without any discharge up to 2×10^{10} particles per bunch. The calibration of BPMs was also performed and the result shows a good uniformity of position detection.

VI. REFERENCES

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