DEVELOPMENT OF A BEAM-POSITION MONITOR FOR THE KEK ELECTRON/POSITRON LINAC (II)

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Abstract

A stripline-type beam-position monitor (BPM) is under development at the KEK electron/positron linac. This monitor will be installed in order to easily handle the orbit of a high-current electron beam (~10 nC) generating a positron beam in the B-factory. The prototype BPM was tested by using a single-bunch electron beam. In this report the experimental results of the BPM are presented.

1. Introduction

The KEK electron/positron linac is being upgraded for the B-factory project[1]. In the B-factory linac, a high-current primary electron beam will be necessary for generating a high-current positron beam. It is especially important to easily handle orbits of the high-current electron beam so as to suppress any beam blowup generated by a large transverse wake field[2]. A prototype BPM using stripline pickups has been under development since last year. In this report, the experimental results of some basic characteristics of the BPM are presented based on the use of a single-bunch electron beam (E=35MeV, I=0.27 nC/bunch) at the NERL linac of the University of Tokyo[3].

2. Beam-Position Monitor

The prototype BPM is shown in Fig. 1. It is a conventional stripline-type monitor made from stainless steel (SUS 304). The total length (250 mm), stripline length (130 mm) and stripline inner radius (20 mm) were chosen so as to be able to be installed into the present beam line of the KEK linac. The four pickups are connected with 50Ω SMA vacuum feedthroughs. The opening angle of the electrode viewed from the center position of the BPM was chosen to be 60 degrees. The beam position in the BPM can be calculated by the ratio Δ/Σ (Difference/Sum) of the signals coming from two pairs of the electrodes facing each other[4] (Fig.2):

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

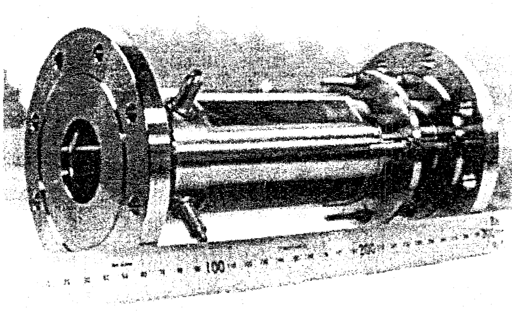

Fig.1 Picture of the stripline-type BPM

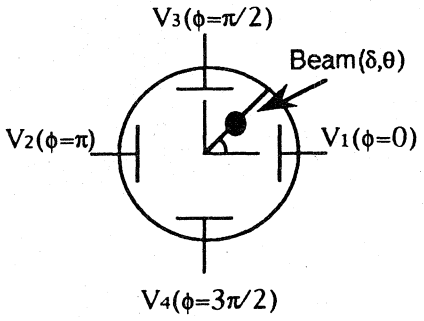

Fig.2 Cross section of stripline BPM

where S_b is a conversion factor which is calculated based on the geometrical configurations between the beam and electrodes. If the BPM has a π/2 rotational symmetry, the conversion factor is the same in the x and y directions. The induced charge distribution on the inside of the BPM from a line charge displaced at polar coordinates (δ,θ) from the center is

$$q = \frac{a}{2\pi R} F(\delta,\theta,\phi)\lambda,$$

where

$$F(\delta,\theta,\phi) = \frac{R^2 - \delta^2}{R^2 + \delta^2 - 2R\delta\cos(\phi - \theta)}.$$

Here, λ is the charge density of the beam, R the inner radius of the BPM, a the electrode area and ϕ the angular coordinates of the electrode at the BPM wall. $F(\delta,\theta,\phi)$ contains the beam displacement dependent terms (see Fig.2). If the BPM has a $\pi/2$ rotational symmetry and the electrode width is very narrow, the beam displacement can be calculated by using the above formula in the following form:

$$x = \delta\cos\theta = S_b \frac{F(\delta,\theta,0)-F(\delta,\theta,\pi)}{F(\delta,\theta,0)+F(\delta,\theta,\pi)},$$

$$y = \delta\sin\theta = S_b \frac{F(\delta,\theta,\pi/2)-F(\delta,\theta,3\pi/2)}{F(\delta,\theta,\pi/2)+F(\delta,\theta,3\pi/2)}.$$

When the BPM has broad electrodes, the conversion factor can be calculated by integrating the induced charge over the surface of the electrode in order to calculate the pickup voltage [4]:

$$S_b = \delta\cos\theta \times \left[\frac{\int_{-\Delta\phi}^{\Delta\phi} F(\delta,\theta,\phi)d\phi - \int_{-\Delta\phi}^{\Delta\phi} F(\delta,\theta,\phi+\pi)d\phi}{\int_{-\Delta\phi}^{\Delta\phi} F(\delta,\theta,\phi)d\phi + \int_{-\Delta\phi}^{\Delta\phi} F(\delta,\theta,\phi+\pi)d\phi}\right]^{-1}.$$

If the beam displacement goes to zero ($\delta \to 0$), S_b obeys the following formula [4]:

$$\lim_{\delta \to 0} S_b = \frac{R}{2}\frac{\Delta\phi}{\sin\Delta\phi}.$$

3. Experimental Set-up and Procedure

The beam experiment of the BPM was carried out by using a single-bunch electron beam (E=35 MeV, I=0.27 nC/bunch, FWHM~10 ps). The experimental set-up is shown in Fig.3. At the exit of the linac a slit (3 mmϕ) was inserted to ensure small beam size. After the slit a lead block with a hole (9 mmϕ) was placed to reduce background showers from the slit. After the lead block, two waveguide-type BPMs and the stripline-type BPM have been installed on a precision micro-adjustable stage in order to change the position of the BPMs relative to the beam in the horizontal and vertical directions manually. After the BPMs, several lead blocks have been inserted so as to reduce back scattering of the beam from carbon blocks used as a current monitor. A screen monitor was inserted after the lead blocks in order to monitor the beam profile. The profile was about 6 mm in diameter measured by a radiation color film at this point. The pickup signals were sent to the measurement room using 15 m coaxial cables (RG 223/U) and the pulse height was measured by an analog Tektronix oscilloscope (model 7104, BW=1GHz) and a digital sampling scope (HP 54120B, BW=50 GHz). The frequency spectrum was also measured by using a spectrum analyzer (ADVANTEST R4131D).

4. Experimental Results

The pulse height from each pickup was measured by changing the position of the BPM in the vertical and horizontal directions by using the micro-adjustable stage manually. A typical wave form measured by the digital sampling oscilloscope is shown in Fig.4. The sensitivity curves of the pickups are shown in Fig.5. Here, the output pulse height is defined as being the height of the first negative peak measured by the oscilloscope. The upper and lower data points show the measurement at beam currents of 0.27 and 0.12 nC, respectively. The solid and dashed lines are the theoretical curves discussed in section 2. The measurement includes about a 10% error due to the oscilloscope amplifier gain difference and the absolute position error relative to the beams. Fig.6 shows Δ/Σ curves measured by moving the BPM in the horizontal direction. The conversion factor (S_b) is 13.9 mm at the center position, which can be calculated by

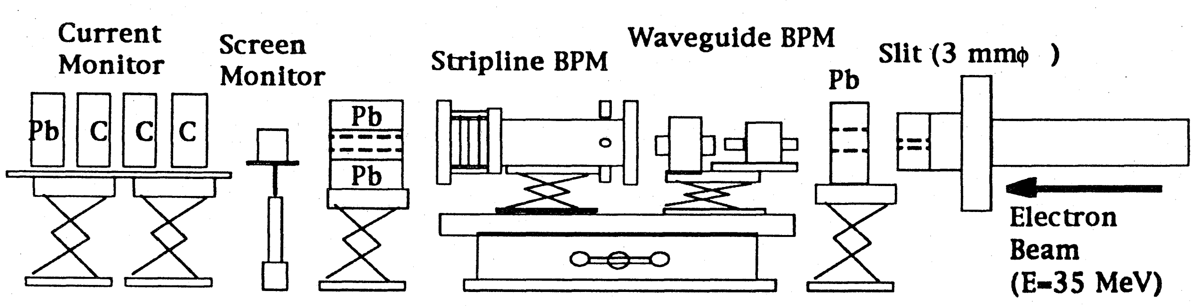

Fig.3 Experimental Set-up

using the slope of the Δ/Σ curve. The agreement between the theory and the experiment is good within the errors. Fig.7 shows the frequency spectrum of the pickup pulse measured by the spectrum analyzer. The spectrum shows half-sine forms with some dips which depend on the length of the stripline. The first dip is at 1.17 GHz and the second one at 2.35 GHz. These frequencies agree well with the theoretical values.

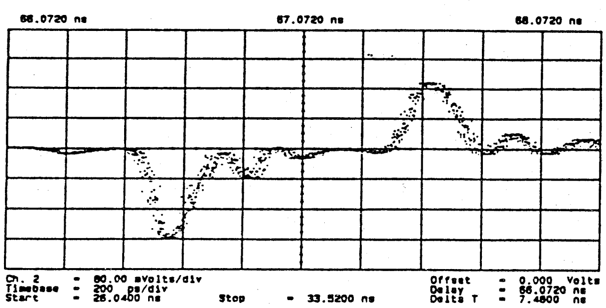

Fig.4 Pickup pulse measured by the digital sampling oscilloscope

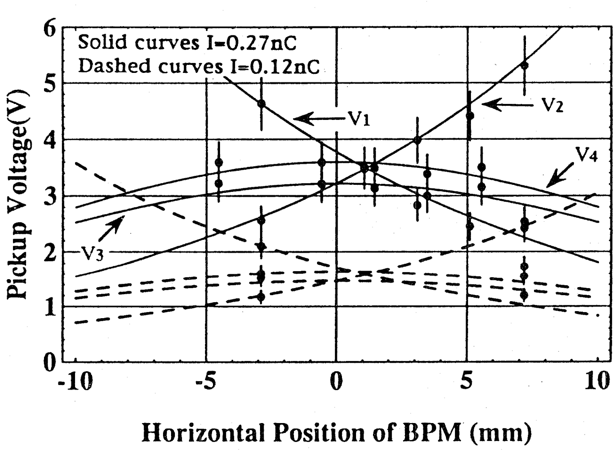

Fig.5 Sensitivity curves of the pickups

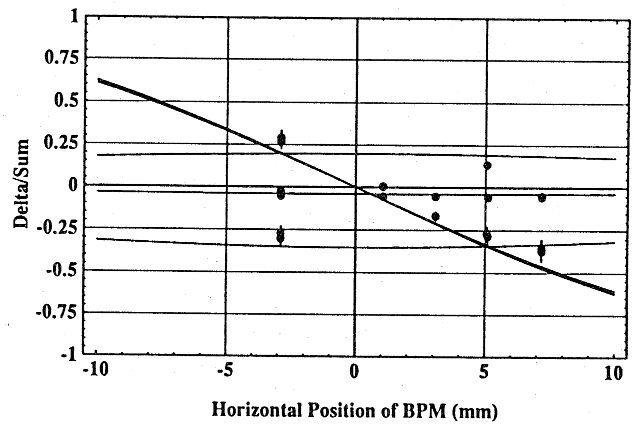

Fig.6 Delta/Sum curves measured by moving in the horizontal direction

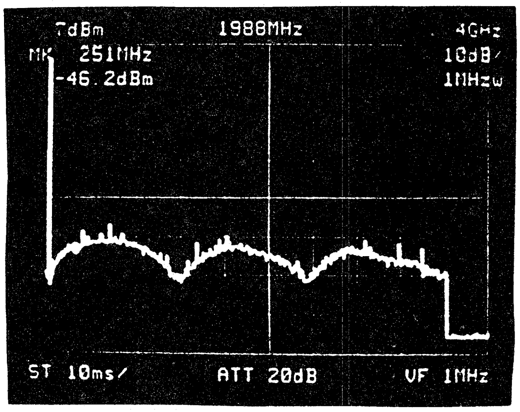

Fig.7 Frequency spectrum of the pickup pulse

5. Summary

The prototype BPM using striplines was tested by a single-bunch electron beam. The frequency spectrum response as well as other basic characteristics are in good agreement with the theory.

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References

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