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Beam Position Monitor for an Orbit Feedback System

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Abstract

We have developed a stripline type beam position monitor system. This system was intended to be used in the beam study on the orbit feedback system which will be used in the KEKB. Characteristics of the monitor system were investigated in both bench tests and beam tests. We succeeded to detect these positions with enough accuracy of a few micron using the system.

1. Introduction

An orbit feedback system is vital for maintaining an optimum collision condition at a B factory where two beams circulate in separate rings. For this purpose the beam-beam deflection technique, pioneered at the SLC, may be utilized to detect an offset of the two beams. Methods of applying this technique to a ring collider are described in a previous paper[1]. Feasibility study of the technique has already conducted successfully by using beams of the TRISTAN Main Ring. Details of this beam test were shown in another paper[2].

In this paper we focus on characteristics of the beam position monitors developed for the beam test. Results of bench tests and beam tests on the characteristics of the monitors are described in detail.

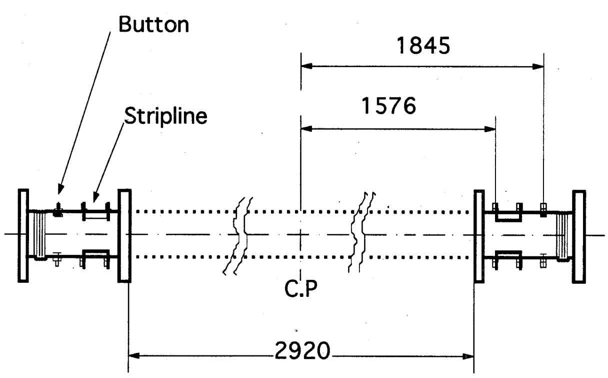

Fig.1 Beam position monitor locations.

2. Stripline Monitor

Stripline electrodes, which are also called directional coupler pickup electrodes, are essentially transmission lines with a well-defined characteristic impedance. Since we want to pickup the signal of two beams separately, we chose this stripline monitor with four electrodes. In addition, the stripline has the advantage of the higher signal level in comparison with button type electrode.

The design value of the characteristic impedance is 50 Ω. The length of the stripline electrodes was chosen as 148 mm to maximize signal amplitude at the detection frequency of 508MHz. Directivity of stripline electrode can help us to distinguish a signal of one beam from that of the other. To avoid degradation of accuracy due to insufficient directivity of stripline electrodes, we have worked out two countermeasures. First, the locations of the monitors were carefully selected as shown in Fig.1 so that Fourier components of this signal are not disturbed very much by the counter-rotating beam at the detection frequency. Second, we designed the structure of the monitors so that the characteristic impedance of the dipole mode matches to 50 Ω taking account of the electromagnetic coupling with the other electrodes. Details of the two countermeasures are described in a previous paper[3].

The schematic view of the stripline monitor we finally adopted is shown in Fig.2.

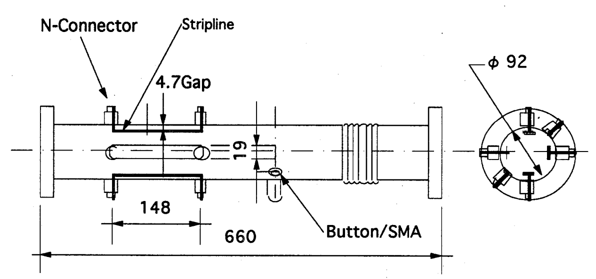

Fig.2 Stripline monitor

Matching of the characteristic impedance of electrodes was measured by using a time domain reflectrometer (TDR), as shown in Fig.3. A mismatch of the stripline electrode itself seems small. A large mismatch exists at the part of line to connect the stripline and the center conductor pin of the feedthrough. Although this mismatch can not be avoided, the directivity is hardly influenced by this at the detection frequency. To obtain the beam position, we convert the electrical position(H,V) to the geometrical position(X,Y) following the first order approximation as;

$$X=kx\cdot H,\ Y=ky\cdot V$$

where kx and ky are coefficients of conversion which are determined from the geometry of the monitor chamber. And the electrical positions are given by the normalization procedure as follow;

$$H=(A-B-C+D)/(A+B+C+D),\ V=(A+B-C-D)/(A+B+C+D)$$

where A,B,C and D are the induced voltages of the four electrodes.

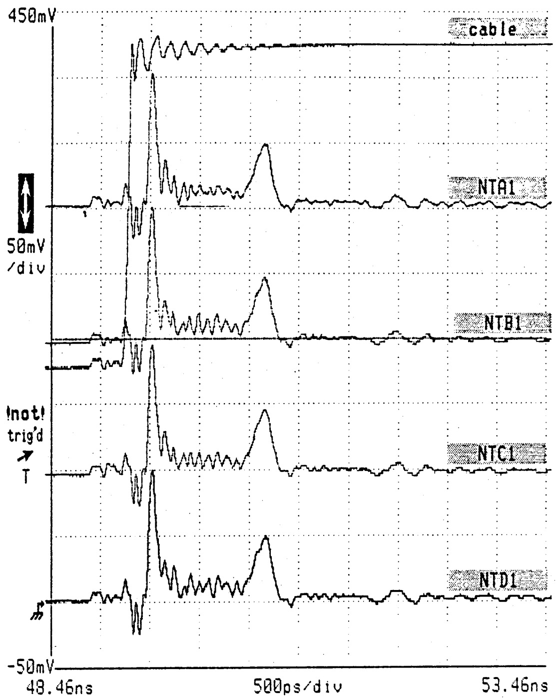

Fig.3 TDR response of four stripline electrodes. The waveforms are outputs of each electrodes 50mV/div., 500psec/div.

The kx and ky were determined by using actual beams as is shown below. Two button electrodes are housed in the monitor chamber at both upstream and downstream sides of the stripline electrodes. We measured beam positions at seven different beam orbits by using both the stripline and the button electrodes. The beam orbit was changed by making orbit bump around the monitors. According to the beam positions obtained from the button monitors, the calibration constants of the stripline monitors, kx,y were determined. This is because we have mapping data for the button monitor from the bench test and we do not have those for the striplines. Fig.4 shows plots for the calibration. We obtained the values of kx,y=33.1.

3. Electronics

We developed new electronics for the beam position monitor. We adopted basically the same signal processing method as that for the BPMs of the TRISTAN Main Ring.

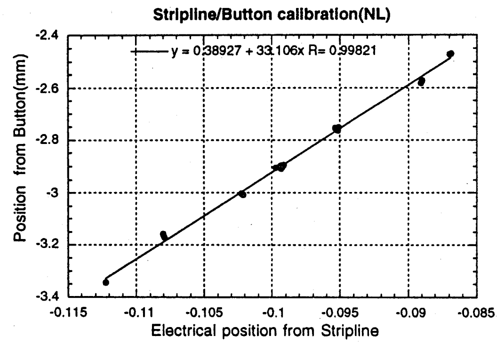

Fig.4 Calibration of Stripline monitor

We aimed at obtaining much better resolution than that in the TRISTAN. The configuration of position monitor electronics is shown in Fig.5. Eight output signals from a monitor chamber are sent to the local control room(D10) through their own coaxial cables. The signals are selected by RF switches and processed by a common front-end circuit. A programmable attenuator adjusts the signal level to match to the circuit. The front-end circuit consists of a triple stage super -heterodyne circuit, a synchronous detector and a 20 bits ADC.

These circuit components were made as CAMAC modules such as an RF switching module and a programmable attenuator module. We are able to control these modules from the central control room. A pick up frequency was chosen as 521MHz which is the 5267th harmonics of the revolution frequency (99.9KHz). This frequency was determined experimentally so that we can mitigate the effect of insufficient directivity. We mention this frequency choice in more detail in the next section.

The position resolution of this system is designed to be a few micron and this value was actually achieved in the beam test. The time which is needed to get beam positions of the two beams at one position monitor is about 3 sec. The time is mainly determined by A/D conversion, the typical value of which is around 120msec per conversion.

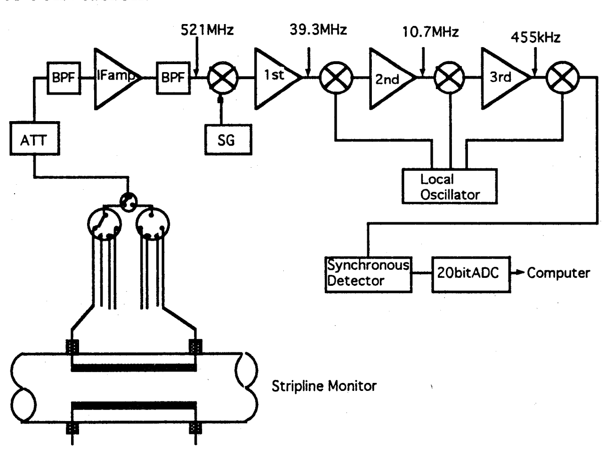

Fig.5 Configuration of position monitor electronics.

4. Measurement

We measured beam positions repeatedly by using the monitor system to check performance of the electronics and to observe an orbit change. Fig.6 shows a history of the beam positions at 8GeV for about three hours. We confirmed that the monitor system has a high position resolution of a few micron. We also measured repeatedly beam positions of the two beams at 29GeV as shown in Fig.7. We observed some fluctuation of the beam positions. Those were changing with a period of about 150 sec and about 50 min. The FFT analysis of those data reconfirms those periods as shown in Fig.8.

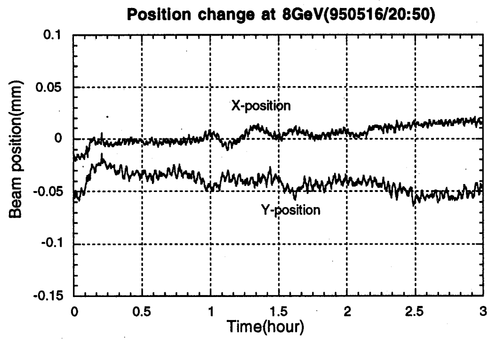

Fig.6 History of beam position at 8 GeV.

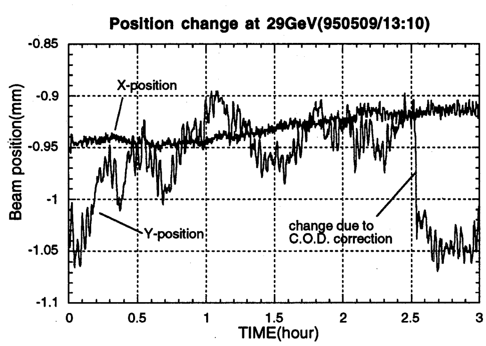

Fig.7 History of beam position at 29 GeV.

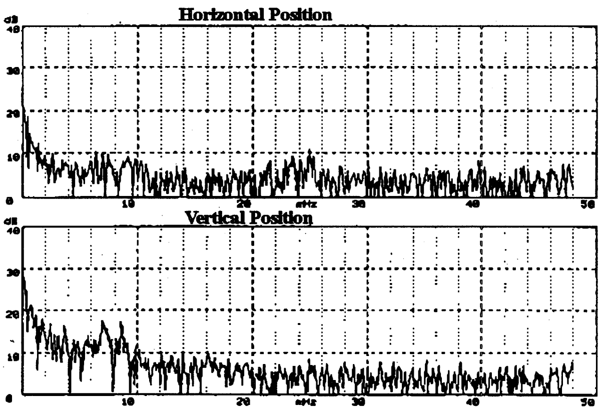

Fig.8 FFT analysis of the position history.

To see an influence of the counter-rotating beam on the beam position measurement, we made measurements in the following two conditions. First, with the positron beam we observed the signals coming from the upstream port of each electrode .Secondly, with the two beams we observed the signals from the same port. In the measurements the beam current was 1.2mA for the positron beam and 0.8mA for the electron. Fig.9 shows results of the measurements. The vertical axis is the difference of the signal levels in the two conditions. If the directivity of the stripline is perfect, the voltage shift should be zero. In reality, however, the signal levels do change due to the influence of the counter-rotating beam as seen in Fig. 9. The horizontal axis is the relative bucket difference of the two beams. The zero bucket shift corresponds to the situation where the two beams collide at the nominal collision point. We intended that the voltage shift should be zero with the zero bucket shift at the design detection frequency of 500MHz by choosing the locations of the monitors correctly. However, in the experiment the shift of 15 RF buckets were needed to minimize the voltage shift. We have not yet understood the reason for this. In the experiment on the beam-beam deflection[2], the detection frequency was changed temporarily to 521MHz to minimize the voltage shift.

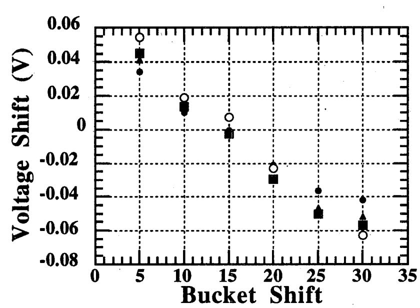

Fig.9 Influence of the counter-rotating beam observed at four stripline electrodes

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