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Beam Position Monitor System for TERAS

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Abstract

A beam position monitor system for an electron storage ring TERAS has been constructed. The system is consisted of four-button type electrodes, a signal processing electronics, and a micro-computer. The spatial resolution of less than 0.05 mm has been obtained with the stored current of 40 mA.

Introduction

SR from an electron storage ring TERAS has been used as the primary spectro-radiometric standards in VUV and soft X-ray region and as a light source for studies on atomic, molecular, solid physics, and ULSI lithography. The stored electron beam is also used to generate a quasi-monochromatic photon beam by Compton backscattering on laser light and to investigation of a Free Electron Laser. It is important to stabilize the stored electron beam for many investigations using the storage ring. Moreover, TERAS is a variable energy ring of 200-800 MeV. We have to offer the same orbit in different energies. To stabilize the beam position, variety of methods has been investigated.[1] The electrostatic pickup has widely been used in many facilities and good performance has been achieved to stabilize the beam with a feedback technique.[2] In this paper, we describe a beam position monitor system installed in TERAS.

Electronics and Calibration

Four four-button type electrodes have been installed in the quadrupole triplet section of the TERAS for the beam position monitor. Figure 1 displays the four-button type electrode included the vacuum chamber. The size of electrode is small enough to observe the waveform of the bunched beam. However, a fast signal processing system was not adopted in the present stage, because the long term displacement of the stored beam is the primary problem. The signal induced on a pickup electrode feeds into a coaxial switch, Dynatech N10-413G28, through a double shield cable of 7.5 m long. The signal processing system is shown in figure 2. To simplify the signal processing system, we used the Double Balanced Mixer just as the diode detection. This means that the same signals are fed into the DBM RF and local input. Of course, the nonlinearity remains for a variation of local input. The DBM response is generally written as,

$$C = AB\sin(\omega t+\phi)+\ldots \qquad (1),$$

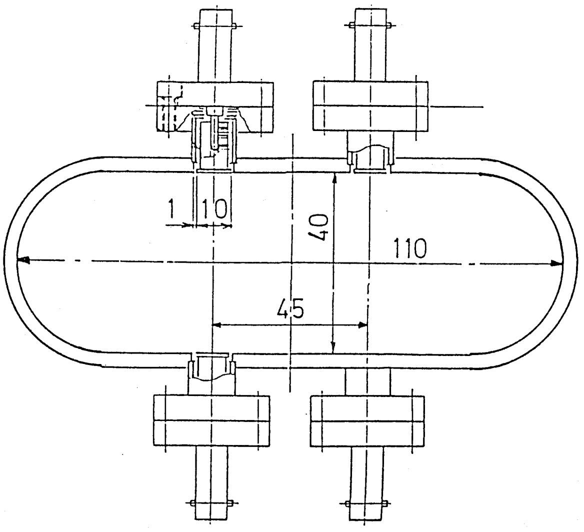

Fig.1 Cross section of the four-button type electrode.

here, an RF input signal is $A\sin(\omega t+\phi)$ and a local input signal is $B\cos(\omega t)$. In our case, the local input signal is $A\sin(\omega t+\phi)$. Then mixed output signal is written as,

$$C = AA+\ldots \qquad (2).$$

Thus we correct this nonlinearity with the software. The detected signal is digitized and sent to the micro-computer through the optical fiber transmission line of 100 m long. Fourth order least square fit is carried out, then we get the true signal amplitude of the pickup.

Position calculation is carried out a hybrid method. This method consists of the skew differential method[3] in horizontal axis X and the differential method[1] in the vertical axis Y. We write:

$$x_0 = k_x(x_0,y_0)U - x_{os} \qquad (3a),$$

$$y_0 = k_y(x_0,y_0)V - y_{os} \qquad (3b),$$

where x_{os} ,y_{os} are position offset and U, V are written as,

$$U = (v_1v_3 - v_2v_4)/(v_1+v_4)(v_2+v_3) \qquad (4a),$$

$$V = (v_1+v_2-v_3-v_4)/(v_1+v_2+v_3+v_4) \qquad (4b),$$

where $v_n(n=1,4)$ is the induced signal at the n-th electrode.

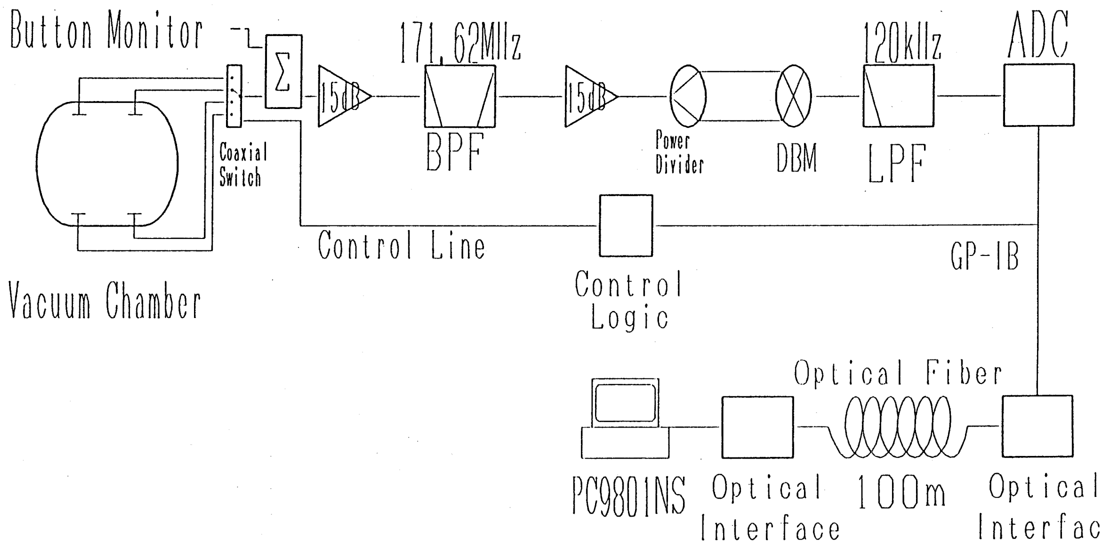

Fig.2 Block diagram of the beam position monitor system.

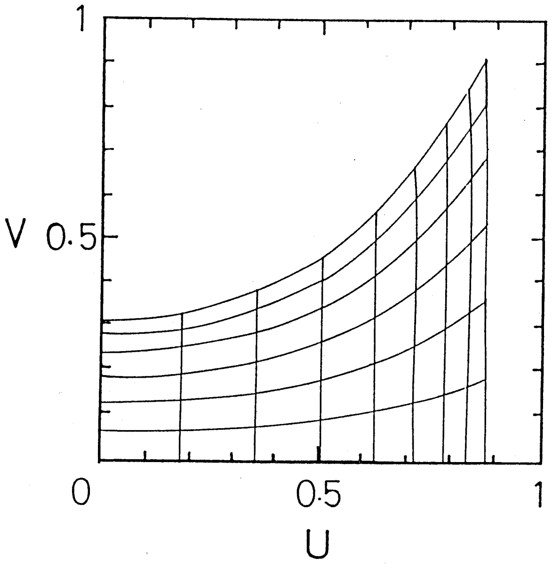

Fig.3(a) Nomograph of calculated U, V with the hybrid method.

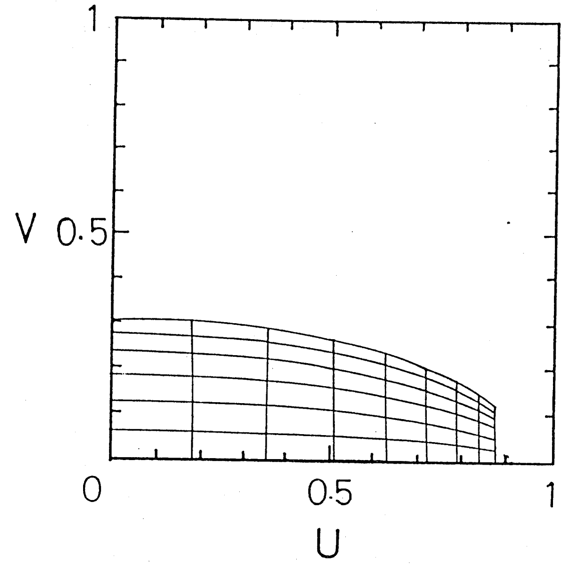

Fig.3(b) Nomograph of calculated U, V with the skew differential method.

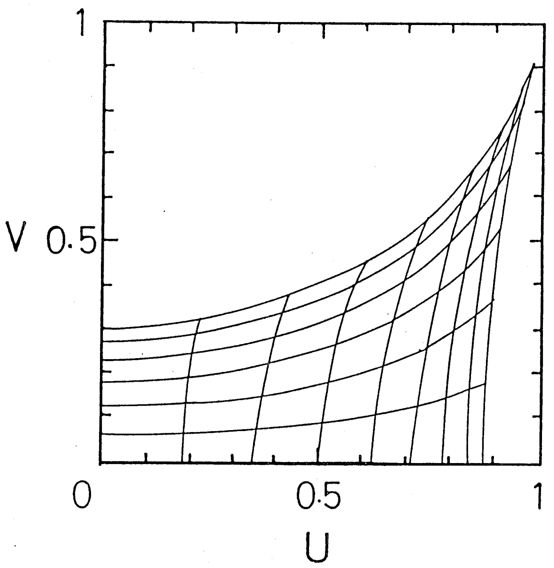

Fig.3(c) Nomograph of calculated U, V with the differential method.

Figure 3a displays a result of a simulation[3] of the beam position. Lines in the figure indicate the constant x_0 and y_0. The distances between lines are 2.5 mm. We also show the results with the skew differential method, $V = (v_1 v_2 - v_3 v_4)/(v_1 + v_4)(v_2 + v_3)$, in figure 3b and with differential method, $U = (v_1 - v_2 + v_3 - v_4)/(v_1 + v_2 + v_3 + v_4)$, in figure 3c. It is noticed that the hybrid method is small distortion and relatively large area in the (U,V) mesh. Moreover, the horizontal position is scarcely affected by the vertical one. Consequently, we adopt this method for the present system.

The system calibration was done by use of a semi-rigid coaxial antenna with a precision X-Y stage. The signal generator (SG) of 171.62 MHz, the same as the RF frequency of TERAS, was fed into the antenna. The calibration area was 20 × 10 mm. We fit the k_x and k_y to the calibration by a 4-th polynomial in x_0 and y_0.

The spatial resolution of the system was also measured at the same time. Figure 4 displays the spatial resolution of the whole system. We fed the antenna with the SG output current of 100 mA. Two peaks shows a distance of 0.5 mm in the horizontal axis (a) and in the vertical axis (b). As shown in figures, the spatial resolution in full-width at half maximum (FWHM) of 18 μ m in the horizontal axis and of 29 μ m in the vertical axis is obtained. When we decrease the SG output current to 2.5 mA, the spatial resolution in FWHM becomes worse to be 31 μ m (H) and 50 μ m (V). The position resolution with actual beam is 26 μ m (H) and 34 μ m (V) in the stored current of 40 mA. It can be explained that the beam width causes the growth of resolution. However, the system resolution satisfies our goal. The repetition rate of the position measurement is about 2 Hz. The repetition is determined by the AD conversion time and the GP-IB communication time.

Conclusions

A beam position monitor system has been installed in an electron storage ring TERAS recently. The system is consisted of 4 four-button type electrodes, a signal processing electronics, and a micro-computer. We use the DBM as a diode and a nonlinear effect is corrected by numerical calculation with calibration data. The position calculation is carried out with hybrid method. We get a small distortion and large area. The horizontal position is scarcely affected by the vertical one. The position resolution of less than 0.05 mm has been obtained with the stored current of 40 mA. The feedback system to stabilize the beam position is now in construction.

References

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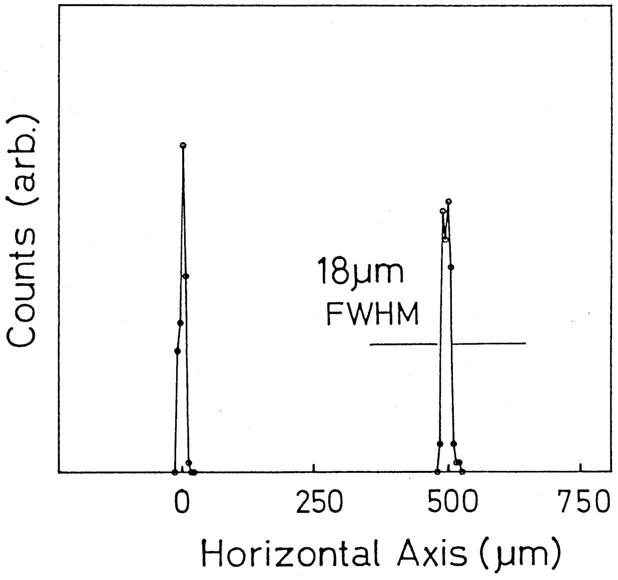

Fig.4(a) Histogram of the position spectrum in the horizontal axis. The distance between two peaks is 0.5 mm.

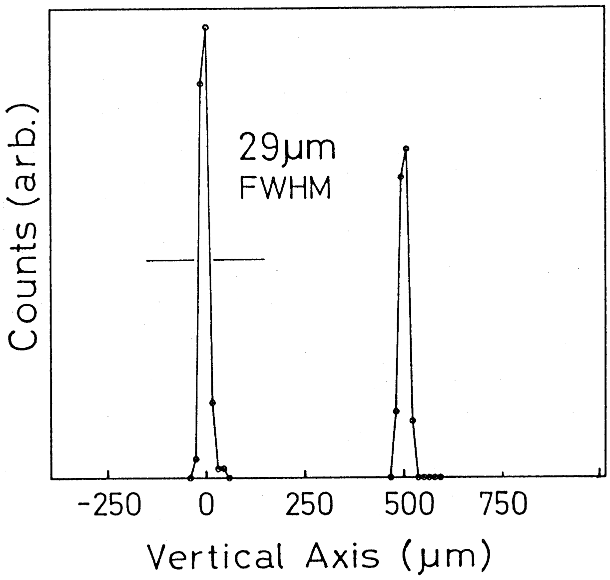

Fig.4(b) Histogram of the position spectrum in the vertical axis. The distance between two peaks is 0.5 mm.