Recent Development of a Closed Orbit Monitor System in the KEK Booster Synchrotron

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Abstract

The KEK 500MeV booster synchrotron is now under operating to provide a high intensity proton beam to a medium energy nuclear/neutron physics experiments, and also used as an injector into the 12GeV main accelerator. The KEK accelerator complex is scheduled to serve an intense beam for a neutrino experiment and booster utility also foreseeing more intense protons to produce a high intensity neurons. The accelerator machine studies are going on in order to improve the current beam intensity as high as possible.

A new closed orbit distortion monitor system has been developed in the booster synchrotron to make more clear the beam orbit behavior during the acceleration period, during which the beam caused from some emittance blow up and preventing the intensity. The system consists of newly designed electrostatic beam position monitor(ESBPM), analogue to digital convertor(ADC) and a graphic display. The detail of this system is described in this paper.

1. Introduction

The KEK 500MeV booster is a combined function synchrotron having eight cells in a 12m diameter circumference and is operated with a rapid cycling of 50ms period (Fig. 1).

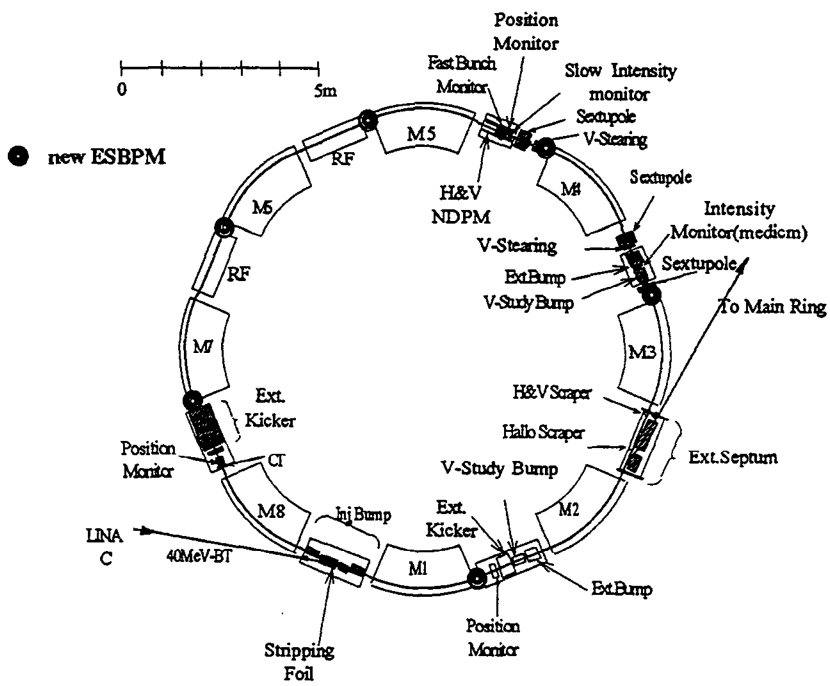

Figure 1. KEK 500MeV Booster Synchrotron and an installation of the new ESBPM.

Most of all the straight sections are already occupied by many equipments such as collection magnets, beam monitors *etc.* And the main bending magnets have a curved shape to provide a combined focusing function. So that there are no room for systematic beam orbit monitor installation. The beam orbit has been observed by only two monitors in the ring. However, recent accelerator machine study shows some transverse emittance blow up and a dynamic variation of the beam orbit in the booster ring during the acceleration period. A systematic beam orbit observation is strongly required.

A strictly small area are found to install the new beam position monitors between a bellow vacuum chamber in the main bending magnet and the short straight section, only 3cm in length is available.

2. Structure of the pick-up

By the strict installation condition, the beam position pick-up should have the length less than 3cm. The pick-up is the electrostatic pick-up, on which some electric charge are induced according to the beam bunch passed.

The outer case of the pick-up is just fit to the vacuum bellow cross section which is race track shape with the width of 150mm and height of 90mm. On the inner surface of the outer case, four thin stain-less steel electrodes are attached by using a ceramics pipe. The electrode and ceramics pipe are finely designed to fit the outer case shape in order to maximize the electric capacitance between the electrode and the outer case (Fig. 2). So as to make the gap between those small as possible, the ceramics pipe is a small tube designed to have the diameter of 1.2mm, and small stain-less steel tip is welded on the outer case. The gap is only 0.2mm and the electrode capacitance is typically 30pF. Each electrode is connected to a LEMO type vacuum feed through. The overview of the pick-up is shown in Fig. 3.

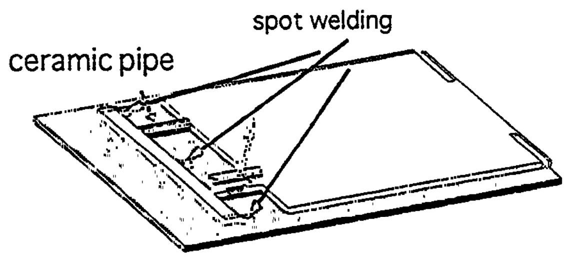

Figure 2. The electrode and support.

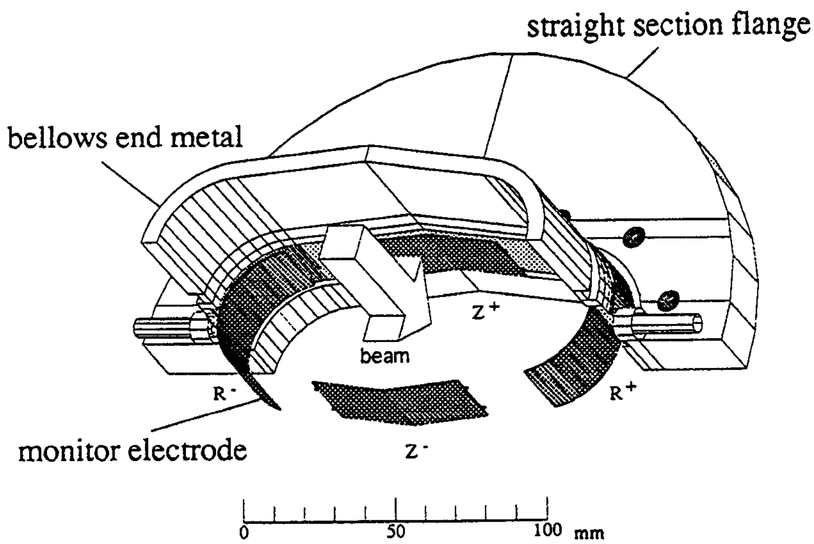

Figure 3. An overview of the position pick-up.

3. Calibration

The electrostatic pick-up is described equivalently as the circuit shown in Fig.4., and has a frequency characteristics like a high pass filter (equation 1).

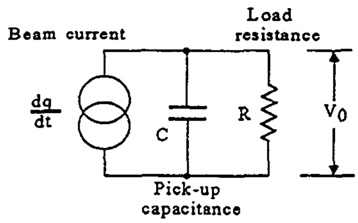

Figure 4. An equivalent circuit of the pick-up.

The transfer function from the beam current to the pick-up voltage is described as follow;

$$V_0 = \frac{S}{S + S_0} \frac{q}{C} \qquad (1)$$

Where S is the Laplace variable and S_0=1/CR.

The high cut off frequency is described as 1/CR, where C and R are the electrode capacitance and the load resistance, respectively. The high cut off frequency of our pick-up, about 660MHz, however, is too higher than the booster ring acceleration rf frequency which ranges from 4MHz to 6MHz. This wide band sweep causes some problems to detect the beam bunch signal, *i.e.*, the detected signal amplitude varies because of the variation of the frequency spectrum of the beam bunch. To avoid this difficulty, we put an additional capacitance of 2200pF on to the feed through, and it makes the high frequency cut off low enough to cover the lowest acceleration frequency.

A test pick-up was installed in the booster ring and carried out some examinations. An observation showed that there was a resonant characteristics around the frequency of 160MHz. So that the some spectrum of the beam revolution frequency disturb the pick-up signal when its frequency is just on the resonance of the pick-up. This resonance comes from the stray inductance of the feed through and is dumped by putting a small resistor in the connector. The dumping resistor is estimated by using a circuit simulation program "SPice" and the final results are shown in Fig. 5 and 6.

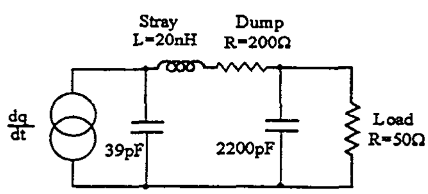

Figure 5. A dumped pick-up.

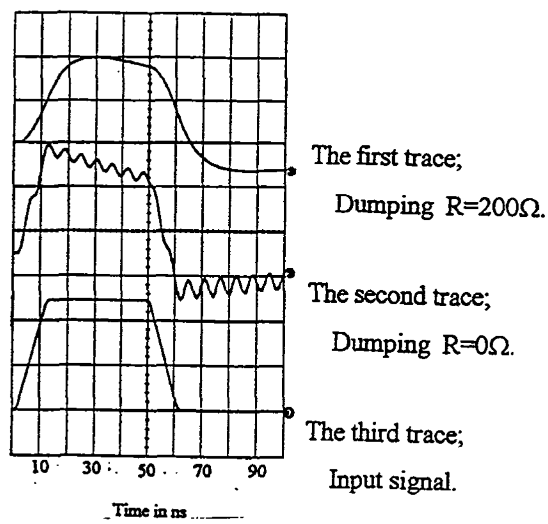

Figure 6. A simulation result of the dumping.

The electric field distribution in the pick-up is estimated to know the sensitivity of the pick-up to the beam orbit deviation. The field calculation is performed by a finite element method using a "Excel" program on an IBM PC compatible personal computer. Figure 7 shows an example of the calculation.

The cross section of the pick-up is a race track with low aspect ratio. It causes a large non-linearlity in the beam position sensitivity. So we developed a bench stand to measure the position dependence of the sensitivity. Each pick-up are calibrated by this bench stand measurement and typical result is shown in Fig. 8.

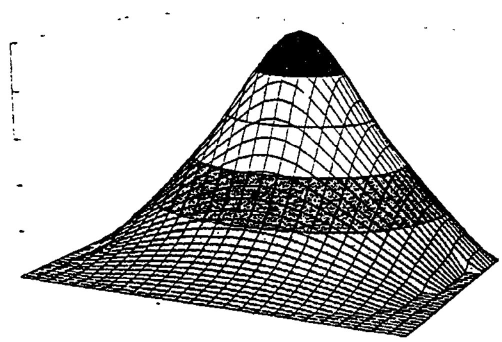

Figure 7. A calculated field distribution in the pick-up.

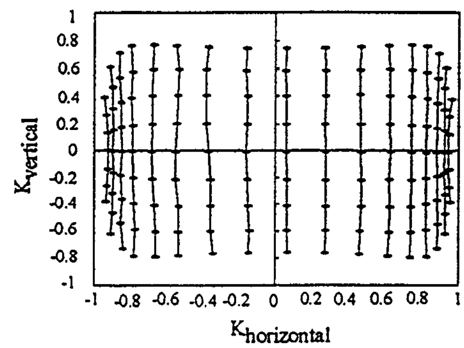

Figure 8. Mapping data of the pick-up. The point separation is 5mm.

4. Signal processing

Six pick-ups have been installed in the booster ring. The induced signal on each electrode is amplified immediately in the ring and diode detector is used in the amplifier to obtain a signal envelope. This process makes easy the signal transmission through a long distance, in which the signal disturbance coming from a high frequency noise can be avoidable. In the first stage of the test installation, the signal is directly transmitted to the control room. However, the position signals are disturbed by a stray acceleration rf power or the pulse noise caused from the kicker magnet *etc.* So that the bunch by bunch fast position monitor was difficult, then we put the diode detector in the ring and obtain only the low frequency envelope component, which makes easy to get the position accuracy of less than 0.5mm. The diagram of the signal processing is shown in Fig.9.

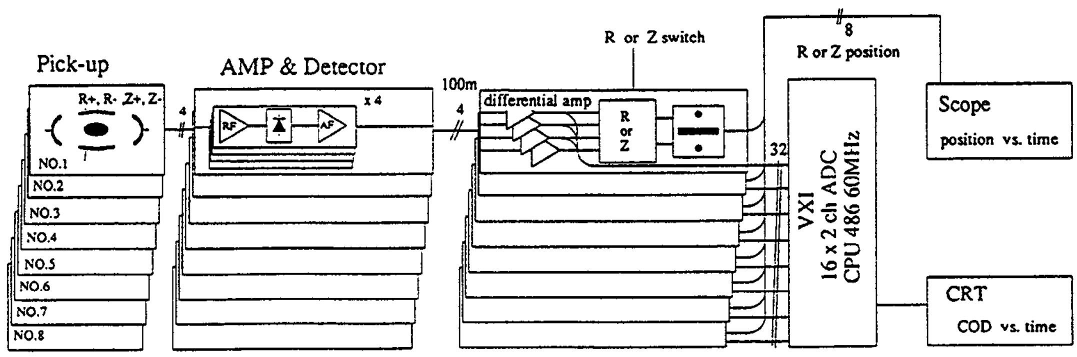

Figure 9. Circuit diagram of the system.

The beam position is displayed in two ways. The signal is divided into an analogue switch and to an analogue digital convertor (ADC). The switched signal is electrically normalized to obtain the beam position following the arithmetics as:

$$X = K \frac{V_{X+} - V_{X-}}{V_{X+} + V_{X-}}$$

where X and K are the beam position in the unit of mm and the calibration constant, respectively. This normalized signal shows the time variation of the beam position at the pick-up and displayed on a CRT scope (Fig. 10).

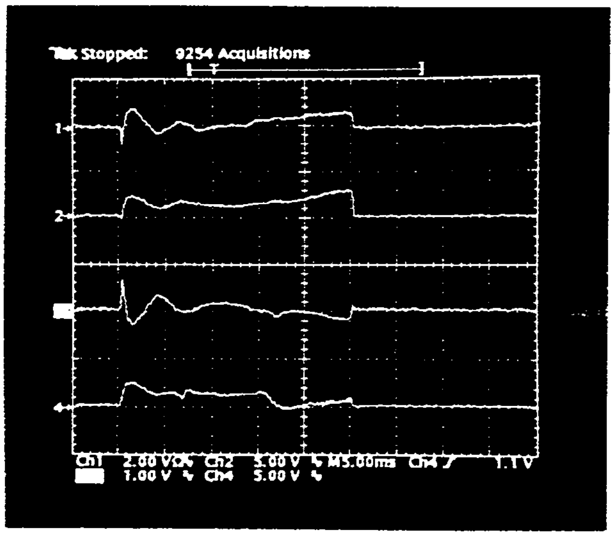

Figure 10. Analogue display of the COD.

However, the strong non-linearlity mentioned in the section 3 is too difficult to compensate in this electrical process.

While, the digitized signal is easy to proceed both the normalization and non-linearily compensation by using a computer. Two 16 channel ADC and a IBM PC compatible computer are installed in a VXI crate, and the digitized signal is transmitted via the VXI bus. The software programming is now going on.

Conclusion

A new closed orbit monitor system is developing for the KEK 500MeV Booster Synchrotron. The new electrostatic pick-up electrode and its support are designed. And the data acquisition system by using the VXI and computer is now developing to display the real time display of the detected beam orbit.