Beam Diagnostics

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1. Introduction

The works related to the beam diagnostics are categorized in the following three items; rf beam position monitors, monitors (current monitors, tune monitor and so on) to be installed in a straight section of No.5 cell of the Spring-8 storage ring, and diagnostic system using synchrotron radiation.

For the Beam Position Monitors (BPM's) the calibration was done, and the prototype of the signal processing circuit was evaluated. About the monitors to be installed in a straight section, the conceptual deign was completed and detailed design is in progress. For the diagnostic system using synchrotron radiation, the status is conceptual design phase.

2. Calibration of the BPM

The calibration of the BPM is necessary to compensate the effect of mechanical imperfection of the BPM section of the chamber, because BPM section of the vacuum chamber was not machined precisely. To the contrary, the button pickups of the BPM were welded directly on the vacuum chamber made of extruded aluminum-alloy. As the details of the method and procedure of the calibration are described to some extent in a individual report on this issue of the Spring-8 Annual Report, the summary is reported here.

The calibration was done for obtaining the offset of "the electrical center" from the mechanical "reference point" of the BPM. To define the mechanical reference point, a block of aluminum was attached to each BPM section of the chamber and two square area on the top and side surface of the block were machined as reference planes. These two planes are perpendicular each other. The definition of the reference point is that the cross point of a line parallel to the top reference plane with the distance from the plane of 95 mm and a line parallel to the side reference plane with the distance from the plane of 107 mm. These two lines define not only the reference point but also the coordinate axes: x and y axes.

Obtaining the mapping function which connects the signal strength unbalance to the position is the other purpose of doing the calibration. The mapping function are written as $x = fx(u,v)$ and $y = fy(u,v)$, where u and v are defined by the signal amplitude of the four electrodes as $u = ((A1-A2)/(A1+A2) + (A4-A3)/(A4+A3)) / 2$, and $v = ((A1-A4)/(A1+A4) + (A2-A3)/(A2+A3)) / 2$, where A1, A2, A3, and A4 are signal amplitudes from the four electrodes. The electrical center is also defined using the quantities u and v as $u=v=0$.

To calibrate the BPM, a single end supported antenna was used as radiator of the signal that simulated the signal made by beam passages. Since the signal detection system uses the accelerating RF frequency (508.58 MHz), feeding only the 508 MHz component is sufficient to simulate the signal source made by the beam. In order to obtain the electrical center and the mapping functions, the antenna position relative to the reference point and the signal strength on each electrode were recorded for each position of the antenna. The scanning area of the antenna was 10 mm by 10 mm square area with 1 mm step size surrounding the electrical center as central point. Figure 1 shows the typical example of of a mapping data.

Taking data for the calibration was finished for 80% of all the BPM, and the data analysis is in progress.

3. Signal Processing Circuit

The signal processing circuit has two modes: COD mode and SP mode as explained below. Each mode is realized with separate module. The COD mode is for measuring the close orbit (distortion) of the stable stored beam in the storage ring. The SP mode stands for the Single Pass mode; the mode for measuring turn by turn beam position when

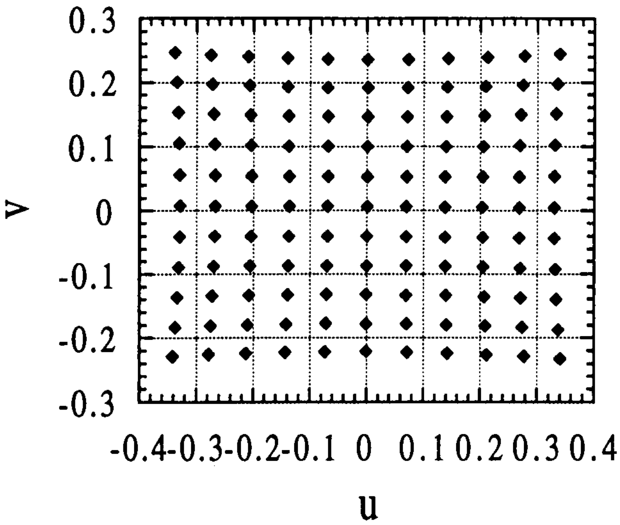

Fig. 1. An example of a mapping data.

the beam conducts a coherent (betatron) oscillation in the case such as just after the injection, or the oscillation is excited intentionally by feeding power to the beam shake, etc..

The front end part of the circuit is the switching module for selecting one of the two modes. Before the signals are fed into the switches, the signals pass lowpass and band pass filters to limit the input power to the switches, which are made of GaAs FET. The signal processing circuit is composed of an ordinary heterodyne type amplitude modulation detector for both the modes. The prototype was made and evaluated as reported in the the Spring-8 Annual Report of 1994 [1].

The composition for the COD mode was changed. In the new version the frequency was down converted to 10.7 MHz by only single step, while in the old version the frequency was down converted to 455 kHz by two steps. The demodulation method is RMS-DC conversion for both versions, but the detection frequencies are different. A detection unit prototype of new version was tested and almost the same performance as the old version was found to be expected.

For the SP mode, the down conversion of the frequency is single step to 55 MHz or 50 MHz, which is selectable. The demodulation method is the synchronous detection at 55 or 50 MHz.

One set of circuit consists of 12 front end modules, one COD mode module, 4 SP mode modules, and one power supply module. With this set, 12 BPM's are covered by switch selection. Twelve BPM's correspond to the BPM's installed 2 cells out of 48 cells of the whole the storage ring. Since one set of the circuit covers 2 cells out of 48 cells, the 24 sets of circuits are necessary. The circuits to be actually used are under production in a manufacturer.

3. Monitors to be Installed in a Straight Section

The following monitors are concentrated to one of the straight sections: beam current monitors and tune monitor. The conceptual designs of the monitors and their related components of the straight section were made. In addition to the monitoring devices, absorbers to avoid unnecessary irradiation of the synchrotron radiation, vacuum pumping system are installed in the same straight section. The overall arrangement of the components in the straight section decided and the detailed design of each component are in progress.

3.1. Current Monitors

Two types of current monitors will be installed. One is to monitor the DC component of the stored beam current, and the other is to measure the charge of one of the bunches in the storage ring. The DC component can be measured regardless of the operation mode of the storage ring, i.e. filling pattern of the bucket, while for measuring bunch charge the bunch separation must be larger than about 100 ns.

A DCCT (Direct Current Current Transformer) of parametric current transformer type will be installed for monitoring the stored beam current with the resolution is 5 μA. The output of the signal processing circuit for the current monitor is scaled as 10 V which corresponds to 300 mA. The output voltage will be read by digital multi-meter (DMM) and transformed to the beam current value by multiplying the 300 mA / 10 V factor.

The bunch charge monitor consists of pulse current transformer and the signal processing circuit that generate subtracting and integrating time window from an external trigger signal. The trigger signal must synchronize to the passage of the beam bunch of which the charge is desired to be measured. The circuit outputs the voltage signal proportional to integration of the signal during the integration time window after subtraction of the signal integrated during the subtraction time window. This monitor will be used for the single bunch operation mode, and "multi-single bunch" operation mode. The multi-single bunch means the equally spaced buckets are filled with electrons up to about 10 to 20 bunches. In the case that equally spaced 21 buckets are filled with electron bunches, the separation of the bunch is 230 ns. The bunch charge monitor can select one of the 21 bunches and measure the charge of the bunch continuously.

The DCCT and the pulse current transformer will be installed on the same vacuum chamber assembly which contains one ceramics gap for guiding the magnetic field associated with the beam passage to the transformer troidal core. The detailed design of the assembly is in progress.

3.2. Tune Monitor

The tune monitor consists of a beam shaker, signal source for power feeding to a beam shaker, amplifier, pickup electrodes, signal processing circuits, and a measuring device such as spectrum analyzer.

By feeding power to the shaker, the beam feels the driving force from the shaker. When the frequency of the driving force coincide to the characteristic frequency of the betatron oscillation, the amplitude of the coherent betatron oscillation becomes large. The oscillation will be observed with signals induced on the pickup elèctrodes. In actual use, the tracking generator output of the specturm analyzer will be amplified and fed to the shaker electrode, and the pickup electrodes will be connected to the spectrum analyzer input through signal processing circuit. The peak in the spectrum analyzer gives the betatron tune value.

The shape of the shaker electrodes was designed. The guideline of the design is (1) to minimize the beam impedance of the shaker structure as far as possible, (2) to compose 50Ω strip line system for shaker electrode and the chamber wall, and (3) for field made by the electrodes to be the same for both horizontal and vertical shaking modes. A two dimensional field calculation was done to optimize the cross sectional shape of the shaker electrode-vacuum chamber system. And, the principal dimensions of the structure was decided. Detailed design is undergoing including the design of the end point supporting structure of the electrodes.

Reference

[1] S. Sasaki; Spring-8 Annual Report 1994, p.32.