# BEAM MONITOR SYSTEM FOR CENTRAL JAPAN SYNCHROTRON RADIATION RESEARCH FACILITY

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*Abstract*

We have designed beam monitor system for light source accelerator complex of Central Japan Synchrotron Radiation Research Facility. A simple turn-by-turn beam position monitoring system based on a fast digital oscilloscope was developed. Performance of the system was evaluated at the UVSOR-II storage ring. We also designed RF knockout system for measuring betatron tune of electron beam in the booster synchrotron and in the storage ring, based on studies at UVSOR-II.

## INTRODUCTION

Central Japan Synchrotron Radiation Research Facility which provides synchrotron radiation for a large community of users is under construction in the Aichi prefecture, Japan. The facility is conducted by the local government, universities and industries in Aichi prefecture. The accelerator complex was designed based on the requirement that stable synchrotron radiation up to hard X-ray region is available and that it is operated and maintained by only several persons. It is also important to reduce the cost to construct the accelerator complex and to maintain it. The final solution is 1.2 GeV energy and 72 m circumference storage ring with 4 superconducting bending magnets. A full energy booster synchrotron which enables a top up operation is also adopted to provide stable synchrotron radiation. Detail of the accelerator complex is given elsewhere in these proceedings [1].

Because of limited persons working for the accelerator, we employ ripe technologies and existing equipments rather than novel or newest ones requiring specialist knowledge. The beam monitoring systems are designed under the same concept. However, some developments for the monitors were needed taking into account simplicity of operation and the cost. In this report, we describe a turn by turn beam position monitor (BPM) system and an RF knockout system to measure the betatron tunes, which are designed under the restriction that newest technologies are not introduced and general-purpose equipments are used as far as possible.

## OVERVIEW OF BEAM MONITORING SYSTEM

The accelerator complex consists of a 50 MeV linac , a 1.2 GeV booster synchrotron and 1.2 GeV storage ring. 8 and 32 BPMs will be installed in the booster synchrotron and in the storage, respectively. The BPMs are standard ones consisting of 4 button pick-up electrodes mounted to a beam vacuum chamber. For the processor of the BPM signals, commercial electronics modules using heterodyne detection will be installed. To measure beam position in the linac and transport lines, screen monitors will be prepared. As for beam current monitor, commercial in-flange-type devices (DCCT for the storage ring and ACCT for the booster synchrotron and the linac) will be installed.

## TURN BY TURN BPM SYSTEM

A turn by turn BPM system is expected to play an important role in commissioning stage of accelerators, but will not be used so frequently in daily operation. So we decide not to install the commercial ones based on digital circuit because they are still high in cost and require detailed expert knowledge about the system. Instead, we introduced a simple system based on a high sampling rate digital oscilloscope (5 GS/sec).

We examined the turn by turn BPM system at the UVSOR-II electron storage ring [2]. A beam induced signals from existing BPM electrodes was detected by the oscilloscope. The direct signal (~200 psec FWHM, bipolar) from the electrode was found to be too fast to measure the signal peak voltage precisely with limited sampling rate of the oscilloscope. Therefore we fabricated a simple waveform processing circuit to expand the pulse

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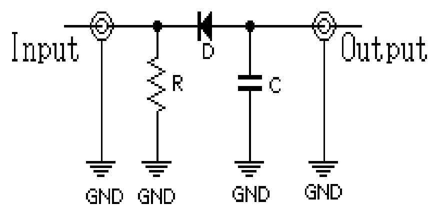


Figure 1: Diagram of wave processing circuit for turn by turn BPM.

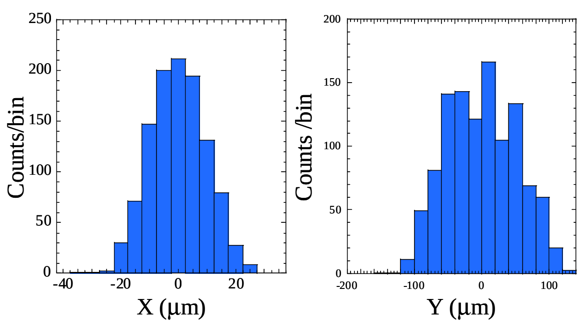


Figure 2: Accuracy of turn by turn BPM system (left shows horizontal right shows vertical).

duration and broaden the signal peak. The diagram of the circuit is illustrated in Fig.1. In the circuit, NEC 1SS99 diode which displays good response at a high frequency region was used to rectify the bipolar signal from the electrode. Since the diode has threshold voltage, a high frequency amplifier is used when the pulse height of the signal is not sufficient for the diode. We estimated the relative accuracy of the system via a repetitive measurement of a stable stored beam orbit. Figure 2 shows histograms of distribution of measured deviation from the averaged beam position. Standard deviations of 10 μm in horizontal and 50 μm in vertical have been obtained.

To demonstrate the performance of the turn by turn BPM system, the injection bump orbit of the UVSOR-II storage ring was measured. Temporal variation of beam position near the injection point was recorded. Analog low pass filter of 200 MHz attached to the oscilloscope was used reduce the high frequency noise. Figure 3 shows the horizontal bump orbit measured using the system as a function of number of turns around the ring. Simulation calculation on the bump orbit was also performed using the code ELLEGANT [3]. As shown in the figure, measured orbit agreed very well with the numerical result.

## RF KNOCKOUT SYSTEM

We are going to install RF knockout system to measure betatron tune in the booster synchrotron and in the storage ring. Two different experiments on betatron tune measurement were carried out at the UVSOR-II in order to design RF knockout system of Central Japan

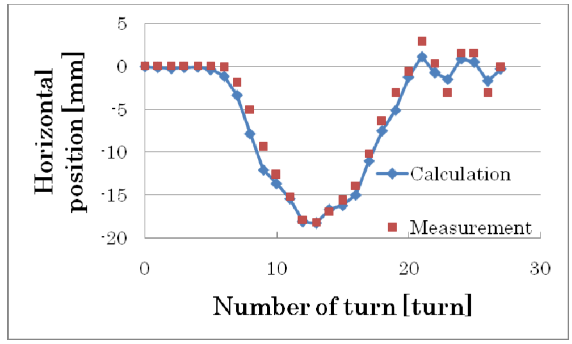


Figure 3: Measured bump orbit compared with numerical calculation.

Synchrotron Radiation Research Facility. One experiment is evaluation of betatron oscillation amplitude excited by an RF knockout and the other is on the method of observation of fast variation (~ msec) of the betatron tune of electron beam in the booster synchrotron during ramping-up.

The experiment on the betatron amplitude was carried out using the turn by turn BPM system which we describe above and an existing RF knockout system of the UVSOR-II storage ring. We also simulated the betatron oscillation by a transfer matrix calculation and compared with the experimental result. The simulation includes the radiation damping, the kicks by the RF knockout, and the non-linear effect of sextupole magnets. The kick angle of the RF knockout is estimated using electromagnetic field analysis software, POISSON [4]. We included the effect of sextupole magnets given as the following:

$$x'_{n+1} = x'_n + kx_n^2$$

where $x_n$ is beam position at n turn, $x'_n$ is beam angle at n turn, and k is a constant proportional to the sextupole field strengths which were determined to make the chromaticity zero. Figure 4 shows the measured and

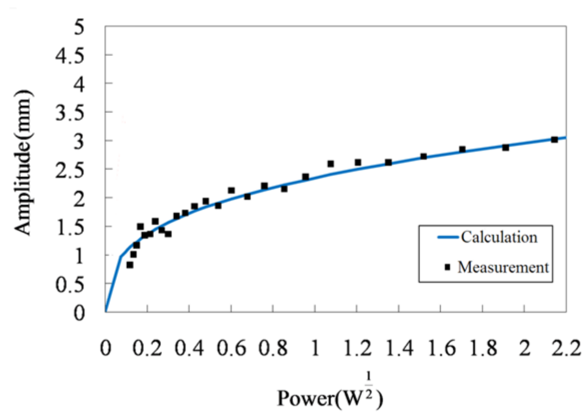


Figure 4: Measured and calculated horizontal betatron oscillation amplitude as a function of applied power.

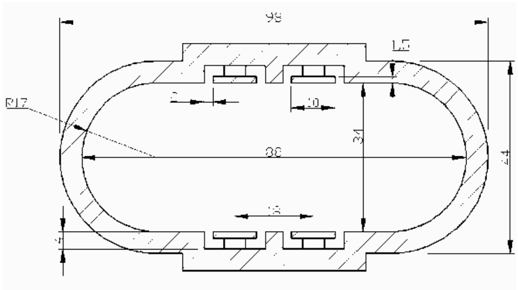

Figure 5: Cross section of RF knockout chamber designed for tune measurement.

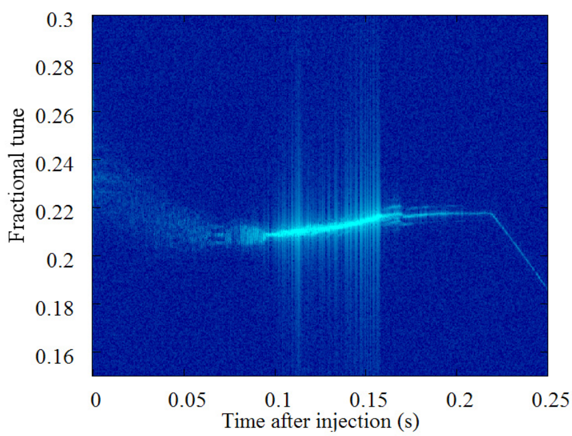


Figure 6: Measured betatron tune of the UVSOR-II booster synchrotron as a function of time after injection. In a usual operation, electron beam is extracted from the booster synchrotron before the changing point of 0.22 sec.

calculated horizontal betatron oscillation amplitude versus electric power fed to the RF knockout. As the electric power increases, the amplitude increases, but tends to saturate due to the non-linear effect of the sextupole magnetic fields. The measurement agrees well with the simulation result including the sextupole effect. This result indicates that it is essential to consider the non-linear effects of the sextupole magnets in design of an RF knockout system.

Based on the experience at the UVSOR-II, we designed an RF knockout chamber for the storage ring and the cross section is shown in Fig. 5. As shown in the figure, smooth groove structure around the striplines is adopted to avoid unwanted interaction with the electron beam, which sometimes leads beam instabilities. Electromagnetic calculations were performed using the code POISSON. We adjusted distance between striplines so as to produce a kick of the same strength in the vertical and horizontal directions. The characteristic impedance between the stripline and the chamber wall was adjusted to 50 ohm. Using the same simulation, we estimated the betatron oscillation amplitude excited by the RF knockout system. In the calculation, lattice parameters of the storage ring of the Central Japan Synchrotron Radiation Research Facility [1] was used. The calculation result indicates that 2 mm oscillation at the position of the RF knockout chamber can be excited with applied power of about 25 W for one stripline.

To investigate the optimal methods for measuring betatron tune in the booster synchrotron, we carried out test experiments at the UVSOR-II booster synchrotron. There we applied an amplified RF signal into shaker electrodes mounted to the synchrotron and measured beam signal from pickup electrodes. For the detection of fast variation of the tune, we employed a real-time spectrum analyzer, 3026 Tektoronics. In the initial stage of the acceleration, the electron beam energy is low and was easily lost by excitation of the betatron oscillation, while high power was required to measure the oscillation in the final stage of the acceleration. Therefore we modulated amplitude of the RF source with the ramping pattern of the synchrotron magnets using a double balanced mixture, ZAD1 Mini-Circuits. For the RF signal source which needs appropriate frequency band width, we applied an arbitrary wave generator, AFG3102 Tektoronics with "random FM modulation" mode for the signal source. Figure 6 shows an example of betatron tune measurement using the above method. Variation of the betatron tune as the ramping was clearly observed. The method will be applied to Central Japan Synchrotron Radiation Research Facility.

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