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PERTURBATION TO STORED BEAM BY PULSE SEXTUPOLE MAGNET AND DISTURBANCE OF THE SEXTUPOLE MAGNETIC FIELD IN AICHI SYNCHROTRON RADIATION CENTER

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Abstract

In the Aichi synchrotron radiation center (Aichi-SR) [1], a pulse sextupole magnet (PSM) has been installed as a pulse magnet for beam injection. This leads to the injection scheme without using a bump orbit and stable supply of the synchrotron radiation. In Aichi-SR we have performed usual injection scheme with 4 kicker magnets and making the injection bump. Because the circumference of the Aichi-SR [2–4] is only 72 m, 4 beam lines are inside the bump. The Aichi-SR has performed top-up operation since its public open, so it is a crucial subject to eliminate the disturbance of the synchrotron radiation during the injection. We have installed the PSM in 2015 and developed the beam study continuously. At present, however, a perturbation to the stored beam by the PSM still has been observed and is not acceptable for the synchrotron radiation experimental users. We have performed beam diagnostic experiment and concluded that an additional dipole kick affects the beam.

INTRODUCTION

The Aichi synchrotron radiation center (Aichi-SR) is a synchrotron radiation facility which is mainly operated for delivery of hard X-ray to users. The accelerator system in the Aichi-SR is composed of 50-MeV linac, a 1.2-GeV booster synchrotron as injector and 1.2-GeV electron storage ring. In the Aichi-SR we have operated four 5-T superconducting bending magnets (super-bends) as hard X-ray light source. Due to the super-bends we can deliver the hard X-ray up to 20 keV to the beamline despite its lower beam energy without any serious troubles up to now. The other point of the Aichi-SR is the size of the accelerator; the circumference of the storage ring is 72 m and now 11 beamlines (8 for hard X-ray and 3 for soft X-ray) are in operation. From the public open, we have performed successfully a top-up operation and now we can keep the stored beam current of 300 mA during the users operation.

At present we have performed an usual beam injection scheme which uses 4 pulse kicker magnets and makes a bump orbit at the beam injection. In the usual top-up operation, we frequently (typically once per 2–3 minutes) make the bump orbit, and not only the beamlines (4 beamlines) inside the bump but also the outside affect the bump; they observe a fluctuation of the position of the synchrotron radiation. Because such influence cannot be avoided in principle inside the bump, we have considered another injection scheme [5] not to make the bump orbit. To solve the problem we have installed a pulse sextupole magnet system (PSM) [6, 7] and performed the study for this scheme. The injection has done with enough injection rate, but simultaneously we have observed additional fluctuation on the stored beam.

To make clear the source of the perturbation, we have performed a turn-by-turn beam diagnostic measurement both with an optical and with an electric method. From the analysis we have performed a macro-particle tracking for the stored beam under the perturbation and discussed the simulation and experimental results.

BEAM DIAGNOSTICS

To make clear the influence of the PSM on the stored beam, we have performed beam diagnostic experiment by using a fast gate camera. We have stored electron bunches to the storage ring and turned the PSM on without additional beam injection. Figure 1 shows transverse beam profiles observed by a fast gate camera in the visible light beam diagnostics beamline for 10 successive beam revolutions just after the PSM is on. The gated camera can be operated with synchronized to the beam revolution and the PSM operation trigger, and by adjusting the gate time width we can observe the beam profile in single turn beam passing. By changing the timing delay we can observe the beam profile at any timing after PSM is on. As seen in the figure, it is clearly seen that the beam profile changes due to the PSM.

The change in the horizontal beamsize after the PSM is on is summarized on Fig. 2. In the figure, the PSM is on at the horizontal position of 100 turns. As seen in the figure, the beamsize quickly increases just after the PSM is on and tends to saturate after 300 turns.

We have also performed another beam diagnostics measurement by using a turn-by-turn horizontal beam position measurement with LIBERA system by using the PSM trig-

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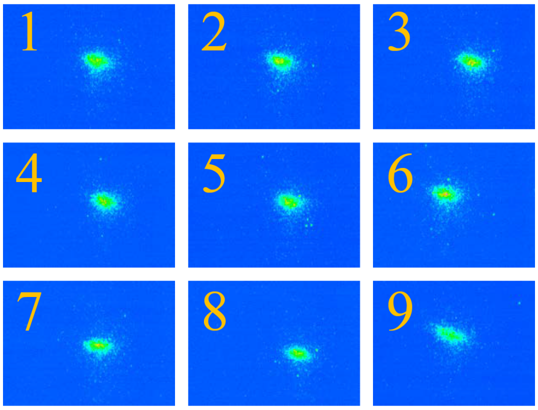

Figure 1: Beam profile after the PSM is on. Numbers in the figures correspond to the turn number after the PSM is on.

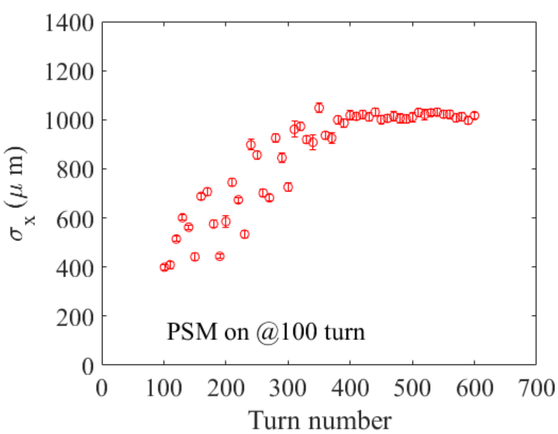

Figure 2: Change in the horizontal beamsize after the PSM is on. In this figure, the PSM is on at 100 turns.

ger signal as a start trigger for the LIBERA. The result is shown in Fig. 3. The result on the figure shows an averaged data for several times PSM excitation. As seen in the figure, the oscillation amplitude of the beam quickly increases and converges after 600 turns.

TRACKING SIMULATION

We have performed a tracking simulation considering the effect of the PSM to the stored beam. From the measurement of the magnetic field [8] inside the PSM, we can calculate the motion of the beam under the perturbation by the PSM. We have also considered 2 families of the sextupole magnets and the synchrotron oscillation in the simulation. Because the saturation of the horizontal beam size due to the perturbation is supposed to occur in ~1000 turns, we have ignored the radiation damping/excitation effect because the radiation damping time of the Aichi-SR is about 2.8×10^4 revolution period. Figure 4 shows the particle distribution on the horizontal phase space before and after the PSM perturbation. The particle distribution gradually spread out on the phase space and the oscillation of the center of mass is suppressed due to the smear out.

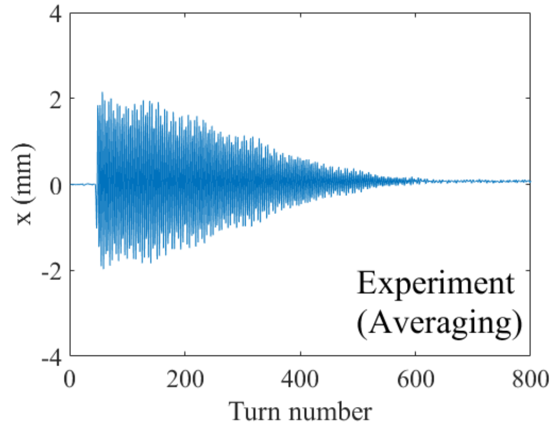

Figure 3: Change in the horizontal beam position after the PSM is on.

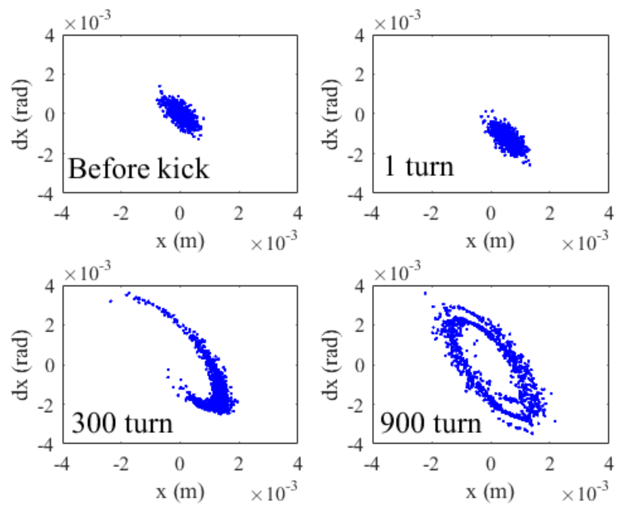

Figure 4: Change in the phase space distribution due to the PSM perturbation.

Figure 5 shows a comparison of the change in the horizontal beam size after the PSM perturbation between the experimental result and the simulation. As seen in the figure, it is clearly seen that the beamsize tends to increase quickly just after the PSM kick and saturate at around 300 turns with the beam size of ~1 mm (rms) in both the experiment and the simulation.

Figure 6 shows a simulation result of the change in the horizontal position of the beam center on time after the PSM perturbation. As seen in the figure, the oscillation of the beam center in the simulation tend to suppress at ~600 turns after the PSM perturbation, that agrees with the experimental result in Fig. 3. On the other hand, the oscillation amplitude in the experiment has smaller value that that in the simulation; it is supposed that because we have had the data with averaging over several individual measurement the peak amplitude tends to decrease due to some timing jitter between the individual measurement. We need additional measurements by improving the timing jitter for this turn-by-turn measurement.

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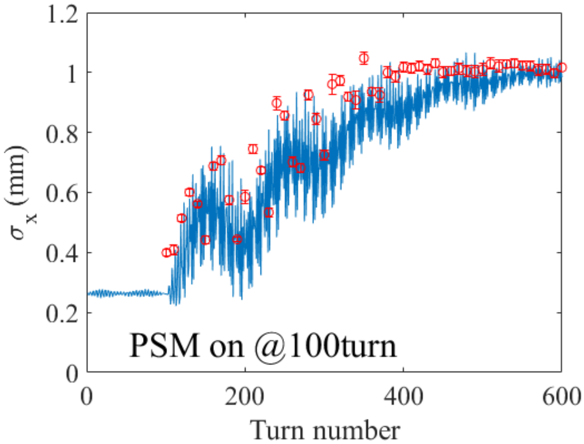

Figure 5: Change in horizontal beam size after the PSM is on. Red circles and a blue curve correspond to the experimental result and the simulation result.

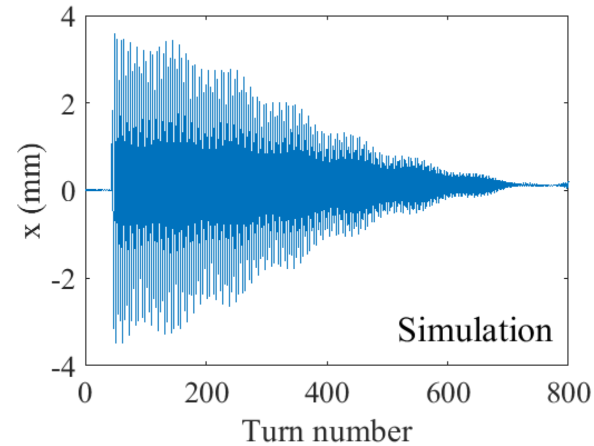

Figure 6: Simulation result of the change in the horizontal position of the beam center after the PSM is on.

SUMMARY

To investigate the perturbation to the stored beam by the PSM, we have performed beam diagnostic experiment in which we have observed the change in the horizontal beamsize and the oscillation of the beam center. From the measurement data of the magnetic field inside the PSM we have also performed tracking simulation for the perturbation by the PSM. The results between the experiments and the simulation for both the beamsize and the oscillation of the beam center agree very well.

Now we supposes that the additional magnetic field may come from some eddy current phenomenon inside the PSM. Investigating thoroughly the source of such phenomenon is one of the next purpose of the development of this injection scheme. Also we are considering possibility to apply a counter kick to the beam to suppress the perturbation due to the PSM. The simulation is underway and now we are trying to find an optimum condition for such a counter kick.

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