RECENT PROGRESS OF DITHERING SYSTEM AT SUPERKEKB

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Abstract

Recent progress of the dithering system at SuperKEKB is described. Some details of the system layout are shown. Beam orbit and optics related issues are discussed. Preliminary tests of the some components in the Phase 1 beam commissioning or in the bench are described.

INTRODUCTION

The design of the orbit feedback system at the IP for SuperKEKB was described elsewhere [1]. As for the vertical offset at the IP, the orbit feedback will use the beam-beam deflection method like the case of KEKB. As for the horizontal offset, however, we can not rely on the beam-beam deflection method unlike the case of KEKB, since the horizontal beam-beam parameters are much smaller than those at KEKB with the "nano-beam scheme (large Piwinski angle scheme)" [1]. Instead, we will adopt the dithering system for the horizontal orbit feedback which was used at PEP-II [2]. In this paper, recent progress and preparation status of the dithering system are described. The Phase 1 beam commissioning of SuperKEKB was performed in 2016. In this period, no beam collision was performed and we did not need the orbit feedback system for beam collision. However, some components for the dithering system, the fast luminosity monitors and the dithering coils, were installed and tested with the beams. The results of those beam tests and a bench test are described below.

SYSTEM LAYOUT AND FUTURE PLANS

Figure 1 shows a block diagram of the dithering system for SuperKEKB. The components of the system are distributed in three locations; *i.e.* Belle II Electronics Hut, the Tsukuba B4 control room or the SuperKEKB tunnel. Some components are connected via an EPICS control network. Almost all components have been already prepared. Eight dithering coils were fabricated and measured at SLAC and were already installed in the SuperKEKB tunnel in 2015. The programmable amplifier was also fabricated at SLAC and already delivered to KEK in 2016. We bought a Lock-In amplifier newly from AMETEK ADVANCED MEASUREMENT TECHNOLOGY which is different from the type used at SLAC. We will shortly prepare some ADC modules and PLC (Programmable Logic Control) which includes an EPICS IOC module. Cable connections among the components will be completed before July 2017 when a comprehensive system test is scheduled. A control software which was developed at SLAC and written in Maple language has been transferred to KEK and will be converted to C language so as to run on the IOC module by July. The Phase 2 beam commissioning will start in February 2018 and the commissioning of the dithering system will be in the fast beam collision tuning to be done in March or April.

BEAM ORBIT ISSUES AROUND THE IP

The locations of the 8 dithering coils in the ring and their strength were designed so that an orbit bump with an enough height can be created at the IP. Each dithering coil can provide both horizontal and vertical kicks. The beam orbits and related parameters are depicted in Fig. 2. The rows in the graph show the horizontal orbit, the horizontal dispersion, the vertical orbit, the vertical dispersion, the horizontal kick angles of the dithering coils and the strength (K_2 value) of the sextupole magnets from the top to the bottom, respectively. The horizontal axis is the distance (m) measured along the ring from the middle point opposite to the IP and the center of the graph is the IP. In this case, the horizontal offset at the IP created by the orbit bump is 50μm which corresponds to $\sim 5\sigma_x^*$. The maximum kick angle of the dithering coils required for making this orbit bump is $\sim 40\mu$rad. The design values of the maximum horizontal and vertical kick angles of the dithering coils are $\sim 39\mu$rad and $\sim 51\mu$rad, respectively. Then, the maximum horizontal bump height at the IP is slightly smaller than 50μm. A beam-beam simulation shows that a luminosity degradation of 3.5% is caused by an horizontal offset of 2.5μm at the IP in the design optics or 20μm in the optics to be used in the Phase 2 commissioning where the vertical beta function at the IP is 8 times larger than the design value [3]. This luminosity degradation associated with the horizontal offset is caused by the shift of the collision point from the vertical waist point. Therefore, the maximum bump height of 50μm in the horizontal direction is sufficient for the purpose of beam dithering. The horizontal orbit bump in the graph is created by the horizontal kicks of the 4 coils near the IP. Due to x-y coupling near the IP, some vertical orbit and vertical dispersion are created by the horizontal bump. However, the vertical orbit and the dispersion can be localized near the IP by using vertical kicks of 2 dithering coils. The emittance growth due to the bump orbit is negligibly small both in horizontal and vertical directions. Here, the Phase 2 optics was used for drawing the graph. However, the result is not very different with the design optics.

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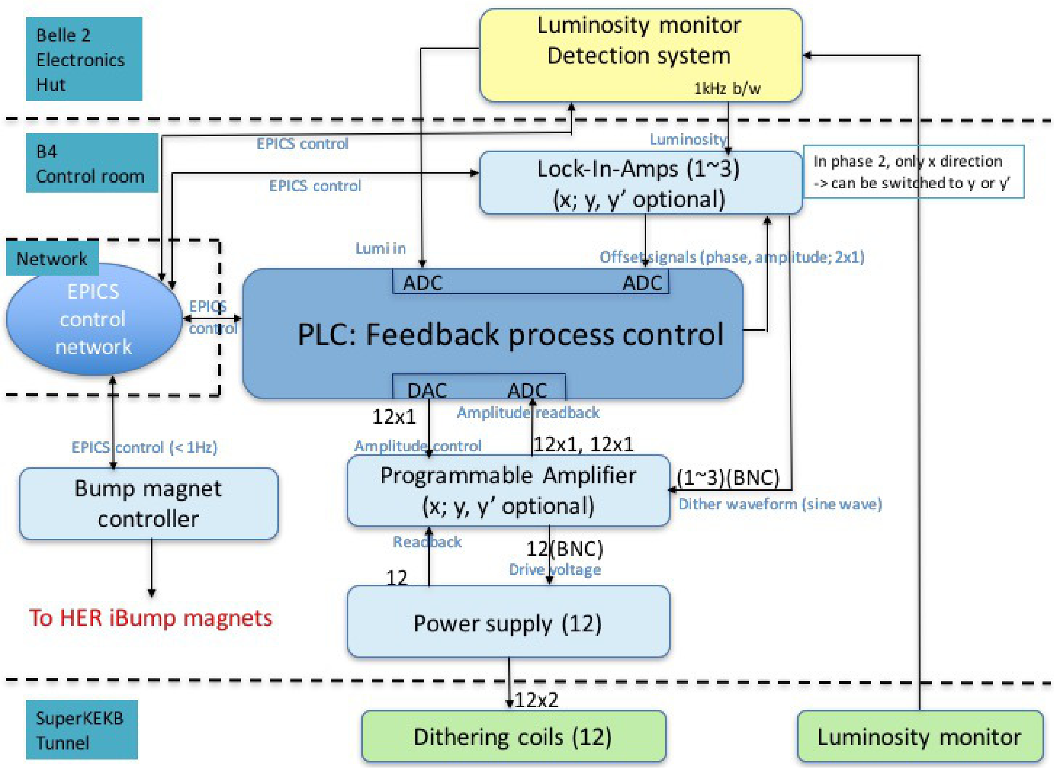

Figure 1: Bock Diagram of Dithering System at SuperKEKB.

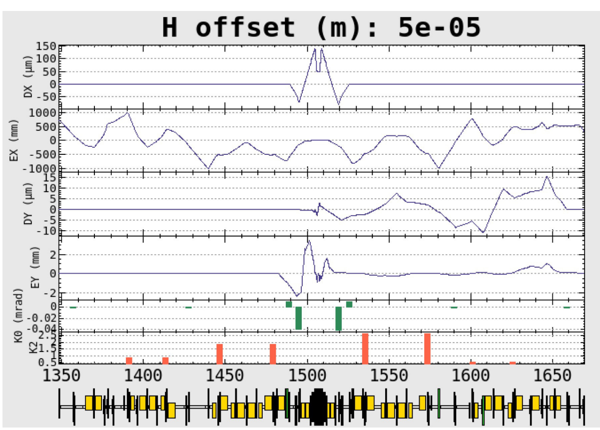

Figure 2: Horizontal bump orbit around the IP for dithering.

DAMPING AND PHASE DELAY OF MAGNETIC FIELD DUE TO BEAM PIPE

An amplitude and a phase of an alternating magnetic field inside a cylindrical beam pipe are damped and delayed respectively due to an eddy current induced on a surface of the beam pipe. The magnetic field inside the beam pipe is expressed by Eq. 1 [4], where $B_{out} = B_0 \sin(\omega\tau)$, b, t and ρ are the magnetic field outside the beam pipe, an outer radius (m), a thickness (m) and a resistivity (Ωm) of the beam pipe, respectively. Here, a ramping time for a step response $\tau = (\mu_0 bt)/(2\rho)$ characterizes the damping effect, where μ_0 is the magnetic permeability in vacuum.

$$B_{in} = \frac{1}{\sqrt{1+(\omega\tau)^2}} B_0 \sin[\omega t - \arctan(\omega\tau)]. \quad (1)$$

Therefore, the damping ratio and the phase delay are expressed as $1/\sqrt{1+(\omega\tau)^2}$ and $\arctan(\omega\tau)$, respectively. In the case of the beam pipe with an antechamber [5] which is not cylindrical cross section, the antechamber can lead to disturb the eddy current. Figure 3 shows the cross section of a beam pipe, which is installed for the SuperKEKB iBump system and is made of SS316L.

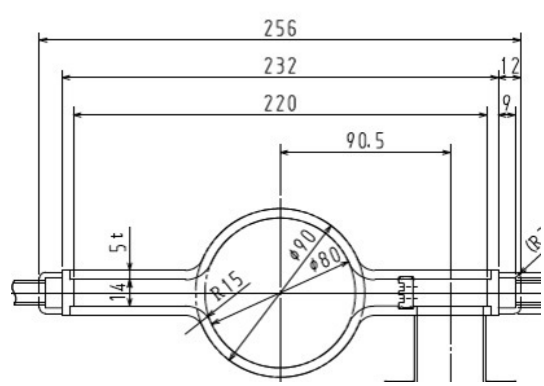

Figure 3: Cross section of a beam pipe with antechamber.

For a horizontal magnetic field, the eddy current is not so affected by the antechamber, so that a simulation by the Opera code shows that τ is ~0.21 ms, which is consistent with the result of Eq. 1. For a vertical magnetic field, however, the eddy current is disturbed and the simulation shows that τ is ~1.5 ms. The damping ratio and phase delay are also measured experimentally. The setup is shown in Fig. 4. The results of the measurement show good agreements with calculations as shown in Fig. 5.

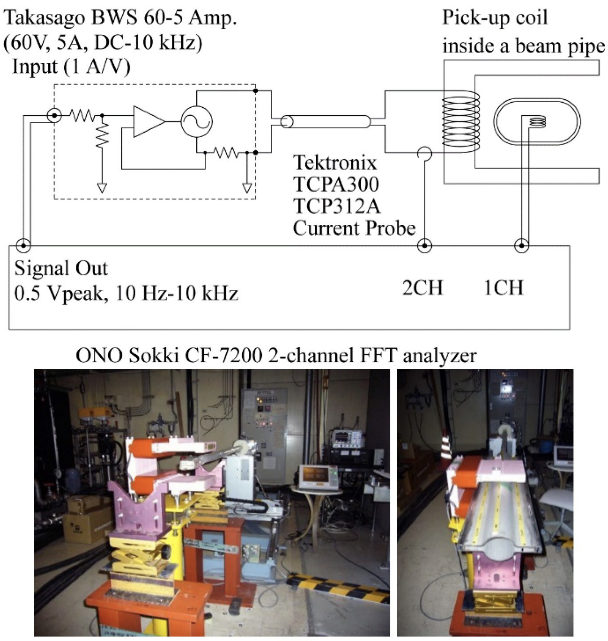

Figure 4: Setup of measurement.

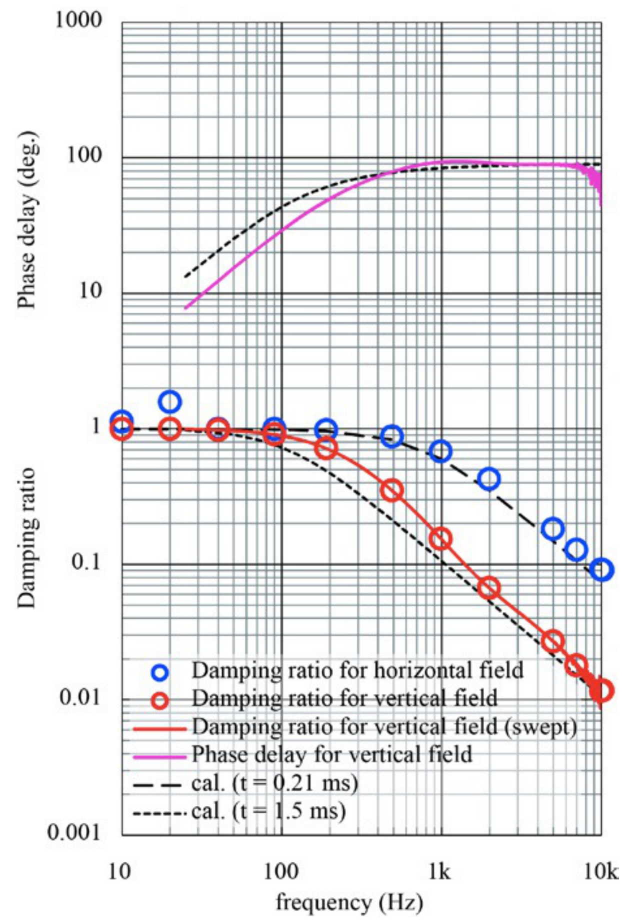

Figure 5: Results of measurement.

PROGRESS OF FAST LUMINOSITY MONITOR

The fast luminosity-monitor teams of LAL and KEK have performed background measurements in the Phase 1 of the SuperKEKB commissioning. During all the commissioning period (from February to June 2016) measurements of single beam backgrounds have been realized with both diamond sensors and Cerenkov + scintillator detectors placed downstream the IP both on LER and HER.

A part of data acquisition electronics has been tested as well as preliminary reconstruction algorithms to be used for luminosity survey. The electronics for the luminosity monitors is placed in the Belle II Electronics Hut and is connected to the detectors with long (~100m) coaxial cables, with which we can investigate raw signal pulses. Basic response of the detectors has been observed and analyzed with oscilloscopes.

The background behaviors of each contribution according to beam intensity, beam size or vacuum pressure of the machine have been well understood, and the simulation tools which had been specially improved for the luminosity monitoring case have been benchmarked [6]. This gives a good confidence in the predictions of signals and backgrounds we will have to deal with for the future luminosity monitoring in Phases 2 and 3.

Bunch time structure of the backgrounds has been well detected both with Cerenkov+scintillator and diamond sensors. We confirmed the time resolution, 0.7ns, of the Cherenkov counter from the bunch-by-bunch measurement, which is consistent with that expected from test-bench measurement. The analog gate and amplifier circuits to integrate luminosity-signal pulses for the dithering system are also successfully tested.

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