PRESENT STATUS OF THE KEKB BUNCH FEEDBACK SYSTEMS

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Abstract

KEKB is a double-ring energy-asymmetric electron-positron collider, now operating at KEK. In order to achieve a luminosity on the order of $10^{33}/cm^2/s$ or more, a very large number of bunches are stored. At present, the number of bunches is about 1,200 and the bunch spacing is 8 ns, in the usual physics operation. Consequently, strong coupled-bunch instabilities have been observed. In order to suppress the instabilities, we use bunch-by-bunch feedback systems. In this paper, we present the recent status of the feedback systems and their related systems.

1 INTRODUCTION

At KEK, we are operating an electron-positron collider (KEKB) consisting of an 8-GeV electron storage ring (the high energy ring: HER) and a 3.5-GeV positron storage ring (the low energy ring: LER), as well as the injector linac. Since the start of the commissioning of the collider, its luminosity has been continuously increasing, reaching $7.3 \times 10^{33}/cm^2/s$ in May 2002.

The beams stored in these rings are distributed among about 1200 rf-buckets and strong coupled-bunch instabilities are observed. Transverse bunch-by-bunch feedback systems are working to suppress these instabilities. In this paper, we report the present status of the feedback systems.

2 OUTLINE OF THE FEEDBACK SYSTEMS

2.1 The feedback systems

According to the KEKB Design Report[1], the target luminosity of KEKB is $1 \times 10^{34}/cm^2/s$ with 2.6 A of positrons and 1.1 A of electrons. The bunches would be stored in every rf-bucket. Considering these machine parameters, we expected strong coupled-bunch instabilities in the transverse planes in both rings. In addition, in the LER, an instability in the longitudinal plane was also expected. We developed wide-band (250 MHz) bunch-by-bunch feedback systems for transverse and longitudinal damping.

Figure 1 shows a block diagram of the transverse feedback system now we are operating. Two sets of beam position monitors (BPMs) are installed in separated positions in the rings to detect beam positions. The beam positions are obtained with a very wide-band detector with a detection frequency of 2 GHz (four times the rf frequency). The two signals from these detectors are vectorially combined to make the effective betatron phase-rotation from the BPM to the kicker to be $\pi/2 \pmod{2\pi}$ The combined position signal is sent to the digital signal processing system[2]. It performs 2-tap digital FIR filtering[3] and digital delay to adjust the signal timing of the bunches. The front-end of this signal processing system is a 500 MS/s analog-to-digital converter with a resolution of 8 bits. The output of the signal processing system is sent to the kicker system, which consists of power amplifiers and transverse kickers. The kicker is made up with four strip-lines with a length of 40 cm. Each of the four striplines is fed by an amplifier, then the four amplifiers are used for one kicker. Each amplifier can produce a power up to 250 W with a bandwidth of 10 kHz – 250 MHz.

We prepared a longitudinal kicker of the DAFNE type[4] with wide-band amplifies of 1150 MHz of the center frequency. Even though the longitudinal system was installed in the LER, as we explain later, we have not used this system.

2.2 Feedback related systems

We have several feedback-related systems. One is the tune-measurement system. The feedback loop has a port which accepts an external kick signal. By inputting signal from a tracking analyzer, we measure the betatron tune. As we describe later, this system is very important for maintaining high luminosity.

The wide band position-detector system can be modified into a bunch-current detection system by slightly changing the structure of the circuit. By recording the output of this detector we run a real-time bunch current monitor system.

The high-speed digital signal processing system can be used as a powerful beam-diagnostic tool, after replacing the output part with memory chips. This system enables us to analyze the oscillations of all the bunches over 4096 turns. We can choose various signals, such as a beam-loss signal or an operator-oriented signal, for initiating data taking with this system.

3 PRESENT STATUS

3.1 Ring status

In ordinary physics running of KEKB, the bunch spacing is 4 rf buckets, namely ~ 8 ns, and the total number of bunches is about 1200. We have a gap in the fill pattern which occupies 5% of the 5120 rf-buckets. It is necessary to make such a gap for the abort kicker. In January 2002, the gap length was changed from 10% to 5%. Basically the 4-bucket-spacing fill-pattern has not been changed for about 2 years, but the total beam currents have been increased step by step. At present time, the beam currents are 940 mA and 1450 mA, for the HER and the LER, respectively.

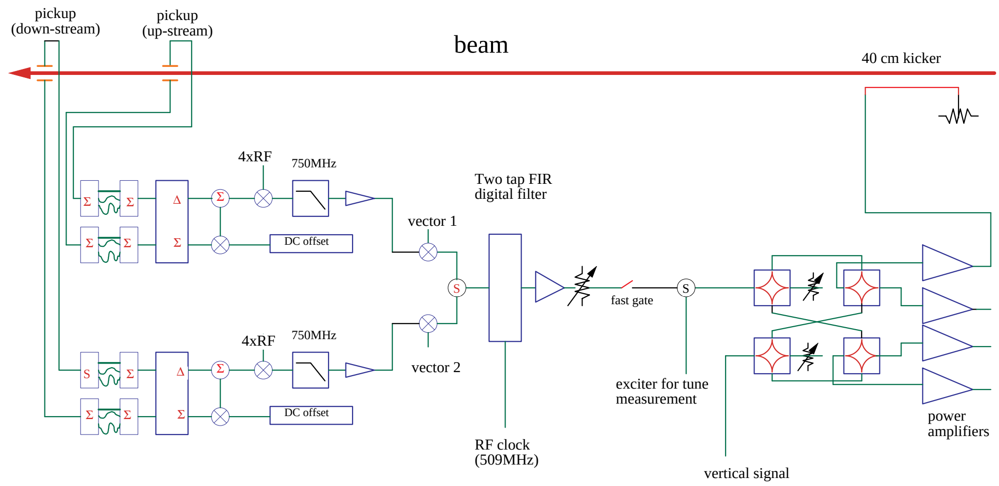

Figure 1: A block diagram of the transverse feedback system. The system consists of three parts: the BPMs, signal processing and kicker. The BPM signal is proportional to the bunch position multiplied by the bunch-current. The signal processing part is a high-speed digital system performing hardware digital filtering. The feedback loop is switched by a high-speed rf switch (fast gate), which enables us to disable feedback for the tune measurement (see text). The horizontal and vertical feedback signals are recombined to send the signal to the kicker electrodes which are rotated by 45 degrees.

Since the start of the commissioning at the end of 1998, we have observed strong coupled-bunch instabilities in the transverse planes both in the HER and in the LER. The instabilities are stronger than we expected at the design stage, particularly in the horizontal plane. On the other hand, no serious instability has been observed in the longitudinal plane. Therefore, we have not operated the longitudinal system yet.

3.2 Daily tuning/monitoring

Position offset adjustment It has been observed that the closed orbits of the KEKB rings drift. It was a serious problem in the operation of the rings in the early stages of commissioning. For the transverse feedback system it was a serious problem, because this DC-change of the beam-position consumed the dynamic range of the ADC in the signal processing system.

In order to overcome this problem, a continuous closed-orbit correction[5] system was developed by the optics group and the drift of the orbit was suppressed to within a tolerable amplitude. In Fig. 2, we show the beam position observed at the feedback BPM, as a function of time. As shown in this figure, the change of the position is within 50 micro-meters. The dynamic range of the ADC can cover this range and we do not need very frequent adjustments of the offset.

We perform regular accelerator maintenance every two weeks. After the maintenance, the beam optic are carefully checked and corrected. After a series of such optics corrections, the closed orbit can change more than 100 micrometers. In this case, we must adjust the offset of the position by compensating the position signal.

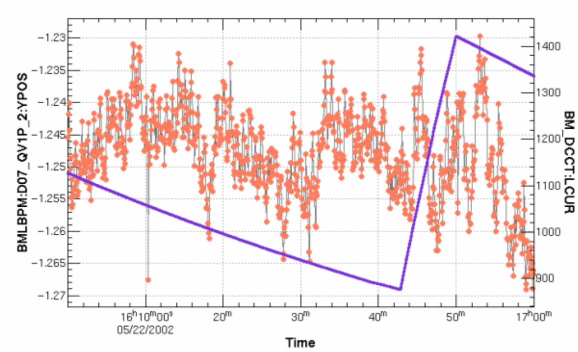

Figure 2: Observed position (red) of the LER beam at the BPM of the feedback system during one fill, as well as the total beam current (purple).

Beam phase monitoring In the feedback BPMs, we employ a detection circuit which uses the sinusoidal signal of 4 times the rf-frequency. This signal is made by multiplying the rf-signal actually used in the acceleration. This sinusoidal signal is also used for detecting the current in each rf-bucket (bunch current). Thus, if the timing of the beam relative to the rf-signal is displaced, the detected output of the BPM and that of the bunch-current monitor would be degraded.

In Fig. 3, the detected phase-pattern of the bunches observed in the LER is shown, where one group of the envelop corresponds to one turn. The upper envelop of this trace corresponds to the phases, and the slope of the envelop indicates a gradual shift of the synchronous phase of the bunches. When the stored current in the LER is

1200 mA, the shift of the synchronous phase is » 2 degrees at 509 MHz, from the head of the train to the tail. This is value of the phase shift, 2 degrees, corresponding to 8 degrees at 2 GHz (the detection frequency of the feedback BPM) is acceptable for the feedback systems.

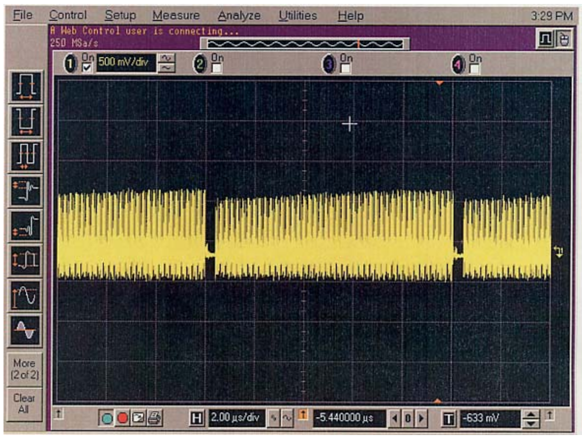

Figure 3: An oscilloscope photo of the real-time beam phase monitoring. Upper envelop of the trace corresponds to the phase (timing) of the stored bunch.

3.3 *Recent change – Feedback gating*

In the operation of KEKB, the most important of the parameter (from a practical point of view) is the luminosity. We have learned from experience that the luminosity is very sensitive to the betatron tunes (sometimes, a change less than 0.001 can be a problem). Thus, during the collision experiment, we continuously measure the tunes and correct them if they stray from the ideal regions. For this purpose, we store a special bunch in each ring, a non-colliding pilot bunch, which has no counter-part bunch in the other ring. Feedback damping would make the resonance peak of the tune-measurement less sharp, so we use a very fast gating switch, in order for the pilot bunch to be free from feedback damping.

Figures 4 and 5 show the observed resonance peaks with feedback off and on. By this system we can measure the tune with a higher resolution and the fine adjustment of tune became possible.

4 SUMMARY

Since the start of the commissioning, the transverse feedback systems have been working very well and they have been contributing to increase of the luminosity. For the precise adjustment of the tune, the fast gating of feedback signal is very useful and contributes to maintaining the high luminosity.

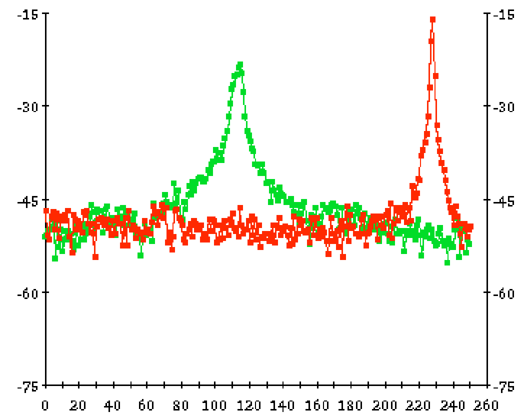

Figure 4: Observed tune spectra with the feedback off. The plots in red is the resonance peak to the horizontal tune and the green ones to the vertical.

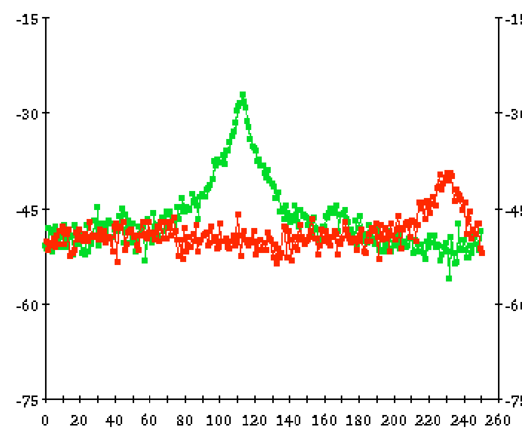

Figure 5: Observed tune spectra with the feedback on.

5 ACKNOWLEDGEMENTS

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