FAST ORBIT STABILIZATION SYSTEM FOR TANDEM APPLE-II UNDULATORS AT THE KEK-PF

Takashi Obina#, Kentaro Harada and Ryota Takai,
KEK Accelerator Laboratory, 1-1 Oho, Tsukuba 305-0801, Japan

Abstract

A rapid polarization switching source has been developed in the KEK Photon Factory 2.5-GeV electron storage ring. The source consists of two APPLE-II type undulators and five fast kicker magnets. This paper reports on the progress of fast orbit stabilization system which consists of digital signal processing box and corrector magnets.

INTRODUCTION

APPLE-II type elliptically polarizing undulator (EPU) is a very popular source of polarized synchrotron radiation [1]. Fast helicity switching together with lock-in technique is a promising method to measure weak signals like linear or circular dichroism of the materials [2]. In the KEK-PF, we have developed a fast polarization switching system which consists of two EPUs and five kicker magnets. The first APPLE-II type undulator was installed at the long-straight section in March 2008, and the second one was installed in the summer of 2010. Figure 1 shows the photo of the tandem undulators and kicker magnets.

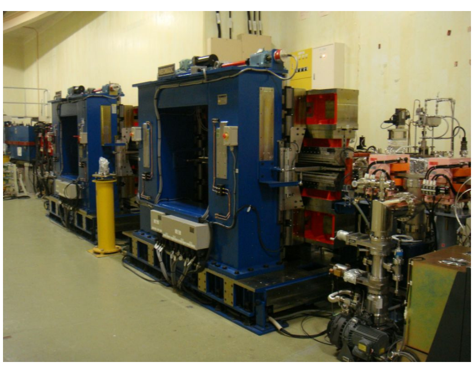

Figure 1: Tandem APPLE-II type undulators installed in the long straight section. Two pink-color magnets at the right side are the kicker magnets.

The kicker magnet creates triangle-shape bump as shown in Fig. 2. With the bump shape of (D), only the downstream undulator (ID2) is used for users. In case of (U), light from upstream undulator (ID1) is used, and two light is mixed in case of (M). Polarization switching is realized by selecting the SR polarization of ID1 and ID2 to left-handed and right-handed, respectively. In our case, angular bump of 0.3 mrad is demanded to separate the SR from two undulators.

Figure 3 shows the time-variation in kick angle of each magnet. The kick angle of K1 and K2 changes in time with sinusoidal shape with the maximum value of

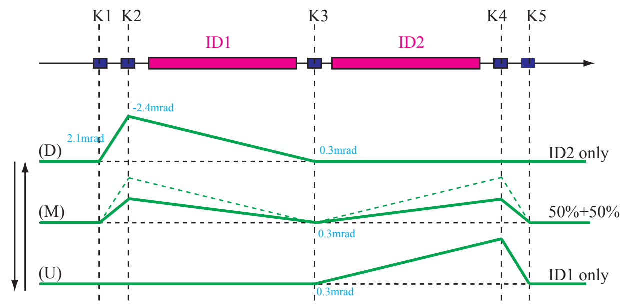

Figure 2: Shape of angler bump.

2.1mrad and 2.4 mrad, respectively. K4 and K5 are operated with similar manner except for the phase of the kick signal. Note that a fixed kick angle of 0.3 mrad is required for K3 which locates between two undulators. Typical operating frequency is selected to 10 Hz.

It is important to adjust the angle and position of SR axis of two EPUs. For the other beam lines, it is strictly required to minimize the leakage of bump orbit to the outside of the bump. The initial target of the leakage is 1/10 of the beam size, namely 30 μm in horizontal and 3 μm in vertical in typical beam lines.

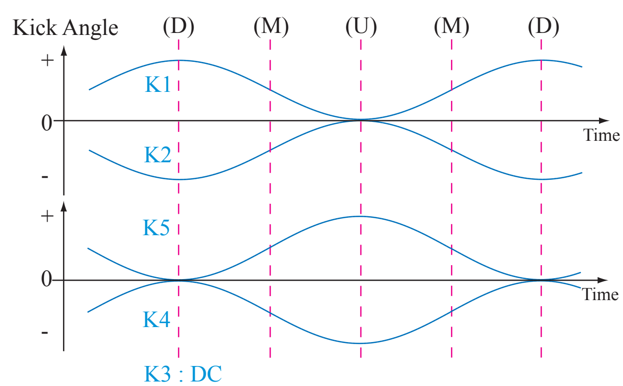

Figure 3: Time variation of kick angle. K3 produces constant kick angle of 0.3 mrad.

BEAM POSITION MONITORS

There are 80 beam position monitor heads in the PF. 65 BPMs are connected to the narrow-band switching detection circuit [3], and 10 BPMs are measured with Libera Brilliance [4]. The other BPMs are used for beam diagnostics such as tune measurement, bunch-by-bunch feedback, etc. Most BPM can only be used for very slow switching of the bump orbit because the typical COD reading speed is about 2 Hz. We installed fifteen 4-channel coaxial switches in front of the narrow-band

#takashi.obina@kek.jp

circuitry. The switched signal is concentrated to one location at middle of the storage ring utility space, and fed to a Libera.

KICKER CONTROL SYSTEM

Five kicker magnets with separate power supplies are appropriate to adjust amplitude and phase independently. As a signal source of the power supplies, we have evaluated several products, such as DAC based signal generators [5], FPGA-based digital synthesis modules and function generators from several companies. Finally, we selected the arbitrary function generator of Tektronix AFG3022 because of its high phase resolution of 0.01 degree and the excellent phase continuity when we change the frequency or phase. This feature is quite important for the tuning process. Sudden jump in phase is not avoidable in other products.

The lower part of Fig. 4 shows a signal generation part. Every AFG is synchronized with 10 MHz reference clock and external start trigger. We introduced a six channel voltage-controlled attenuator which can control the six output voltage with one DC control voltage. The attenuator is used to start and stop of the kicker excitation.

We have developed a new method to determine the kicker parameters. The detail is reported in Ref [6]. The orbit distortion can be resolved to amplitude and phase errors which correspond to sine and cosine component of the bump excitation signal. Before the correction, the maximum horizontal orbit distortion was about 150 µm, which was successfully reduced below 10 µm with the adjustment of amplitude and phase of four kicker magnets.

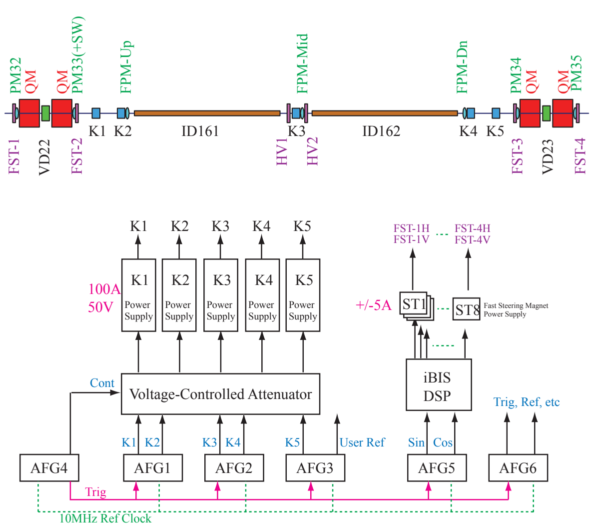

Figure 4: Block diagram of kicker magnet control system. The upper figure shows components in the storage ring. QM is quadrupole magnet, K1-K4 is kicker magnet to produce bump orbit, ID161 and ID162 are undulators, PM is narrow-band position monitor, FPM is fast position monitor, HV1,2 and DV22, 23 are corrector magnets used for DC orbit correction. The lower part is the control signal part. AFG is the arbitrary function generator, iBIS is digital signal processing box.

FEEDFORWARD CORRECTION

The skew quadrupole field of the EPU produces the orbit distortion in vertical direction which cannot be suppressed by the tuning of kicker magnets. To suppress these errors, eight fast corrector magnets (4 for horizontal, 4 for vertical direction) are installed. They are labelled as "FST" in Fig. 4.

A commercial all-in-one digital signal processing box, named 'iBIS' from MTT Corporation [7], is adopted as a feedforward controller. It equips sufficient number of input/output channels and a real-time controller SH-4A. Main features are listed in Table. 1.

Table 1: Specification of Digital Signal Processing Box

Item	Specification
Communication Controller	Intel® ATOM™ N270 1.6GHz (Linux Kernel 2.6)
Realtime Controller	SH-4A 600MHz
Analog Input	16 channel, 16bit, 10V, 2us conversion
Analog Output	8 channel, 16bit, 10V
Misc In/Out	TTL DI/DO 16 channel, Counter, etc
Size	350(W)x250(D)x49(H) mm

Figure 5 shows the block diagram of the iBIS box. In most applications, user's program does not need to access FPGA block. The company supplied I/O development library of SH-4A to use A/D, D/A, DI, DO, Counter, etc. Software development of the real-time part is realized by KPIT GNUSH tools which are freely available from website [8]. Linux and Windows are supported for the development plathome. The MTT Corporation supplied a host library to access SH-4A memory space from remote host through Intel® ATOM™ processor. We only need to write the program of host and realtime application, so the rapid application development is possible for A/D and D/A application.

Two input signal which corresponds to sine and cosine part of kicker bump signal are generated by AFG and

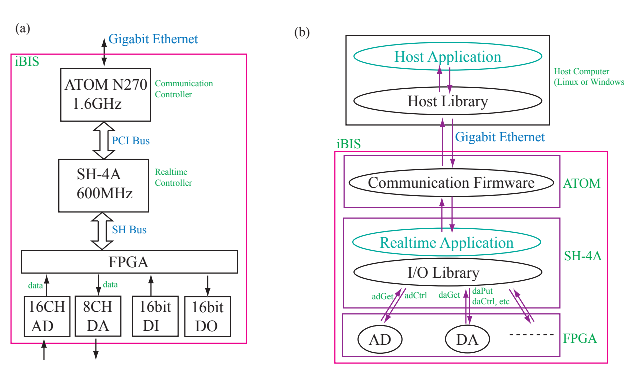

Figure 5: Block diagram of iBIS digital signal prosessor box. (a) shows the hardware block diagram and (b) is the software functional block.

digitized by ADC as shown in Fig. 4. The eight steering magnets are controlled depending on the user-supplied coefficients. We can adjust these coefficients from host computer while the program is running. The signal processing clock is selected to be 20 kHz for now. The speed is fast enough to control 10Hz orbit motion.

Figure 6 shows results of feedforward compensation while the kicker is excited in 10 Hz. Fig. 6 (a) shows an example of time-domain signal. This BPM#143 is located at 84.4 m in orbit path length. The amplitude of 10 Hz component is successfully suppressed from 8.9 µm to 0.47 µm. Some noise is apparent in Fig. 6(a), and the frequency of this orbit fluctuation was same as mains frequency of 50 Hz. We investigated the source of the mains noise, and determined it is excited from the AFG. The noise level of the function generator is very low, however the kicker magnet is strong to introduce the residual orbit motion. The isolation amplifiers and notch-filters are ready to install and we expect to reduce the residual noise in the next experiment. Fig. 6(b) and (c) shows the amplitude of 10 Hz component of the orbit distortion with and without feedforward compensation. Total 21 BPMs are plotted in this figure. As mentioned in the previous section, horizontal orbit is already well suppressed by the tuning of kicker magnets. The effect of

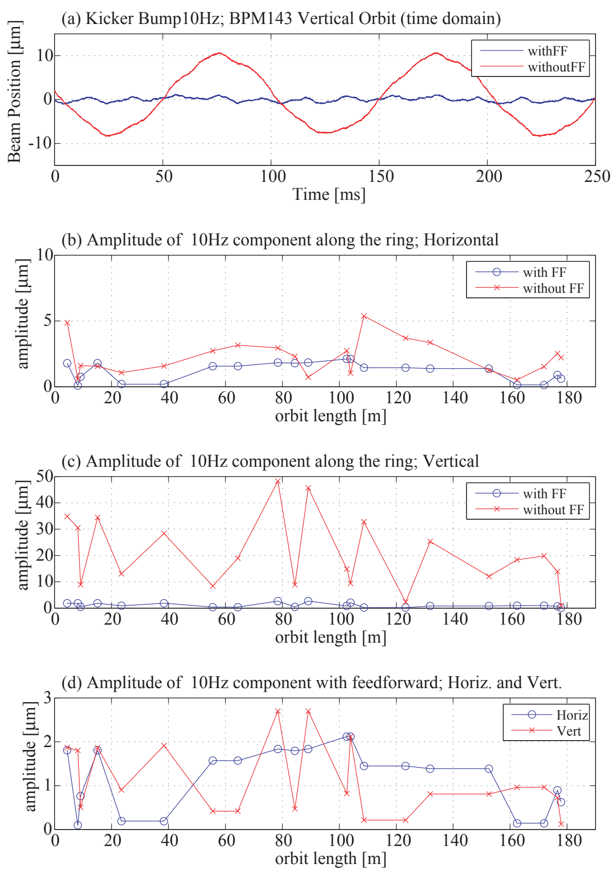

Figure 6: Results of feedforward compensation using digital signal processing box. Starting point of orbit path length is selected to the symmetry point of lattice. The circumference of PF-Ring is about 187 m.

feedforward is obvious in the vertical direction. The amplitude of residual 10 Hz motion achieves below 3 µm in both directions as shown in Fig. 6(d).

HIGH FREQUENCY TEST

The switching speed for SR user is 10 Hz, while the higher switching speed is desirable for better S/N ratio in user's experiments. We increased the switching frequency up to 115 Hz. Figure 7 shows the amplitude of 115 Hz component with and without the feedforward correction measured at the BPM outside the bump. Only six BPM are used in the measurement, and the feedforward parameter is not optimized yet. The amplitude of vertical residual motion is about 9 µm. We think the motion will be improved with the optimization of parameters.

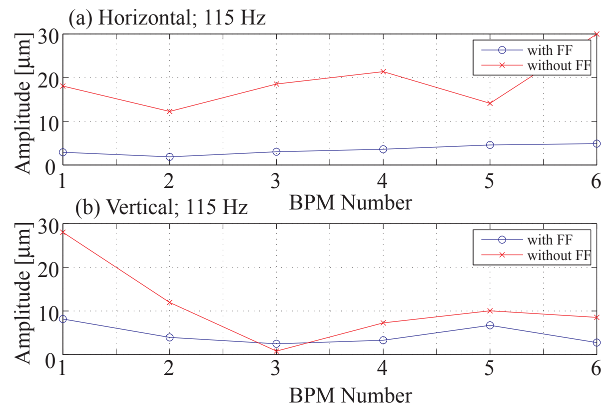

Figure 7: Amplitude of 115 Hz component of the BPM located at the outside of kicker bump.

SUMMARY AND FUTURE PLAN

The feedforward orbit stabilization system suppressed the unwanted orbit motion below 1/10 of beam size. The tuning method to stabilize the orbit is developed to determine the optimum kicker and steering magnet parameters. We are developing hardware and software to automate the parameter tuning procedure. Fast photon monitors at the outside of the kicker bump will be used to measure the orbit stability more than 100 Hz range.

For digital signal processing part, we plan to install EPICS inside the box. It can be a kind of turn-key I/O box.

After the final tuning of the kicker bump and feed-forward magnets, we plan to provide the switching system during the normal user run from autumn run in 2011.

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