PERFORMANCE OF THE TIMING SYSTEM FOR KEKB

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Abstract

This paper describes details of the software trigger signal distribution and the reference clock signal distribution for KEKB accelerator. The KEKB accelerator control system employs distributed CPUs along the accelerator and EPICS(Experimental Physics and Industrial Control System). The synchronization between IOCs is an important issue for precise control and measurement. The software trigger system provides synchronization pulses to each local control room and interrupt signals to the IOCs located in each local control room. The precise triggers and reference clock are distributed by using phase stabilized optical fibers and optical links. The stability under temperature change and the PLL feedback test are mentioned.

1 INTRODUCTION

The KEKB accelerator commissioning started in December 1998. The accelerator is composed of a 600m linac, beam transport lines, two 3km circumference storage rings of 8GeV(HER) and 3.5GeV(LER). The timing system provides various timing signals from the central control room(CCR) to 26 local control rooms(LCRs) and an experimental hall. The hardware is classified into three categories[1]. 1)An Software trigger system for synchronizing software on different IOCs(Input/Output Controllers). The KEKB accelerator control system employs distributed hardware computers(IOCs) and EPICS(Experimental Physics and Industrial Control System). The IOCs and control modules installed in the LCRs are located around the linac, the beam transport, and the 3km circumference rings. The synchronization between IOCs is a significant issue for precise control and measurement. The software trigger system provides the synchronization pulse and/or the interrupt signal to IOCs or devices. 2)Hard wired triggers use twisted pair cables and RS422 level signals. These signals are used mainly for beam abort and machine status. 3)Precise triggers and a reference clock for providing the beam timing are sent by using phase stabilized optical fiber. This paper describes the details of the software trigger and the reference clock signal distribution.

2 EVENT SIGNAL

The software trigger system provides the synchronization pulse and/or the interrupt signal. The system consists of the following VME modules, an event transmitter module(EVT), event distribution modules using multi-mode optical links(EVDs) and event receiver modules(EVRs). The connection scheme of these modules are shown in Fig.1. In order to minimize the cost of the transfer lines, the event signal is produced and submitted as a 16 bits code at the EVT. It is decoded at the EVR and produces the event pulse, or interrupts the IOC. The event codes of 65536 can be sent by using this system. The transfer lines between the EVT and the EVR are connected in a star form, with the exception of some LCRs which are located at more than over 2km from the CCR. Data transfers of less than 2km distance are guaranteed by the multi-mode optical fiber. The EVR has a repeater function of the multi-mode optical link. The data are transferred to the some LCRs in the daisy-chain.

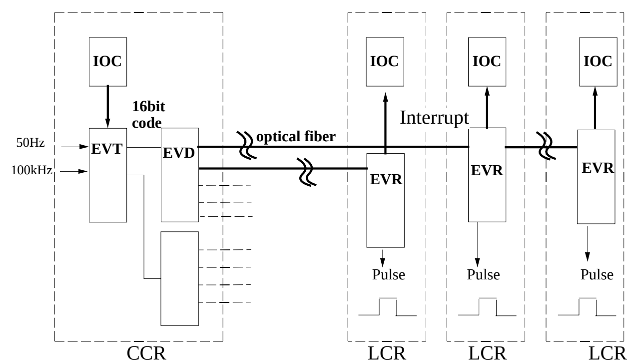

Fig.1 Layout of the Software trigger system - an EVT(event transmitter module) produces 16 bit codes, EVDs(event distribution modules) distribute the codes using the multi-mode optical link, and EVRs(event receiver modules) decode the code. If the sent data matches with the preset data then it generates a synchronized pulse or interrupt to each IOC.

2.1 Event modules

EVT - The EVT generates 16 bits event code signals. TAXIchips(Transparent Asynchronous Xmitter receiver Interface), Am7968(transmitter), are used for the parallel to serial conversion. The generated timing is synchronized with the beam injection(50Hz) or with the revolution frequency(100kHz). The transmission rate is 50Mbit/sec. The asynchronous jitter between the transmitter and the receiver is ~200ns which corresponds to 2% of the revolution period(10 μsec.). The EVT has two independent FIFO data buffers of 64 words in order to avoid data collision. One is for synchronized data of 50Hz and the other is for synchronized data of 100kHz. The EVT has four NIM level outputs.

EVD - The EVD converts the EVT output from the one NIM level signal to eight 820nm digital optical signals. The EVD has eight optical outputs. Eight HFBR-1424(HP) are used for the optical outputs. The maximum distribution from one EVT is 32, by using four EVDs and more EVR can be connected in a daisy-chain.

EVR - The EVR receives the event signal as an optical signal. HFBR-2426(HP) are used for the optical input and HFBR-1424(HP) are used for the optical output to the next EVR as the repeater function. TAXIchips, Am7969(receiver), are used for the serial to parallel conversion. The EVR has four preset registers and four output channels. If the event signal matches with the value of one of the preset registers, then it outputs the synchronized pulse to the corresponding output channel or produces the interrupt to the IOC. The EVR has a 20μsec(2μsec step) programmable delay for each pulse output. In order to provide the beam timing at the LCR of the collider ring, the cable delay at each location must be adjusted.

2.2 Applications

Steering magnets control - For changing the beam orbit while keeping the beam in the storage ring, the currents of the steering magnets must be adjusted with synchronized operatation in 400ms. The power supply interface controller module(PSICM)[2] is used for the interface to the power supply, which can change the power supply current with an arbitrary tracking curve. The tracking starts when the event signal is received. The module sets the output value of the power supply at pre-determined intervals until the target value is reached. The power supplies with PSICMs are located at eight stations, and the EVR gives the start timing within a 2μsec time difference at the stations.

BPM data acquisition - 451 BPMs for LER and 442 BPMs for HER are used for the orbit measurement[3]. 20 IOCs located at 20 LCRs are used for data taking. The minimum data acquisition time of the BPM system is 7ms. The event signal is used for synchronizing the data acquisition timing. The configuration of the BPM synchronization is shown in Fig.2. The data acquisition sequence is as follows, 1)the host work station requests that the event signal is sent to the timing IOC, 2)the timing IOC sends the event code to the EVT, 3)the EVR at each BPM IOC receives the event code and produces the interrupt to the IOC, 4)the BPM IOC starts the data acquisition. The EVR gives the interrupt within a 2μsec time difference at each LCR, however, the response time to the interrupt in the IOC is several μsec[4]. The accuracy of the synchronization is limited by the response time of the interrupt of the IOC.

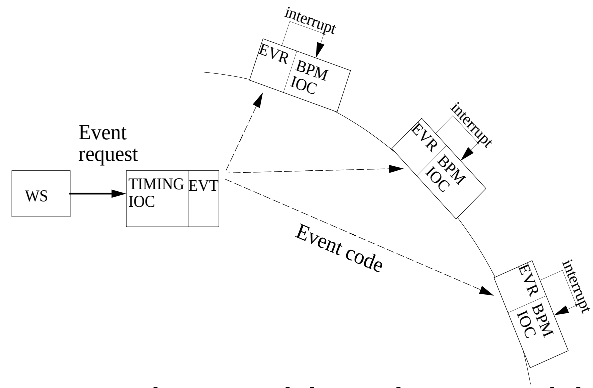

Fig.2 Configuration of the synchronization of the BPM data acquisition.

3 REFERENCE SIGNAL DISTRIBUTION

3.1 Optical fiber system

The following four signals are distributed to each LCR for the controlling and measuring devices, as the reference signal to the beam timing.

- RF frequency(508MHz)
- Revolution frequency(100kHz)
- Electron injection trigger(50Hz)
- Positron injection trigger(50Hz)

Temperature stability is essential for these signals. Phase stabilized optical fibers(PSOFs: made by Furukawa electric Co.) and optical links, are used for the signal distribution. The PSOF has a very low temperature coefficient(0.04ppm/°C), however, it is difficult to keep the phase stability without a feedback system at all LCRs. The CCR and eight acceleration stations have phase-locked-loop(PLL) feedback system with coaxial cables for the RF klystrons, and the phase stability is ~5ps. We used this signal for the 508MHz distribution at each acceleration station. The PSOFs are used for the 508MHz distribution from the LCRs to the other LCRs. Fig.3 shows the temperature and the phase variation

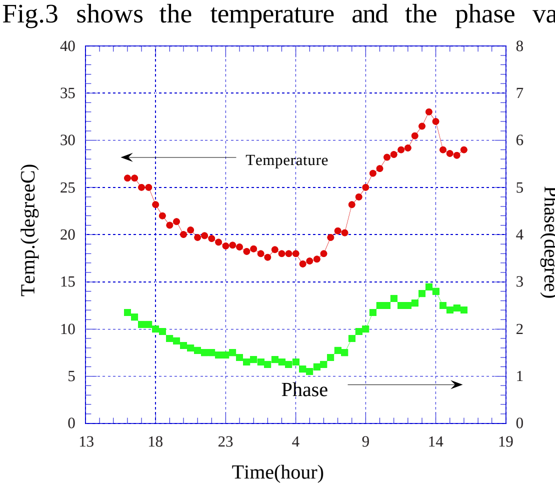

Fig. 3 Phase stability of the reference signal(508MHz) distribution system - Two LCRs have a 500m long cable distance, the phase change is less than 2°(10ps) with 15°C temperature change .

within a day between two LCRs(called D11 and D12) 500m apart. The phase variation is less than 2°(10ps) with a 15°C temperature change. The other signals, the revolution and injection triggers, are distributed using the PSOF to all LCRs. The stability is kept to within that of the 508MHz signal by using the synchronous delay counter module(TD4V) at each LCR. In order to adjust the cable delay, a delay module is required. The TD4V is a VME module which delays its input signal, revolution and injection triggers, by counting a clock signal. By using the 508MHz signal as the clock, the output is synchronized to the clock.

2.6 Phase compensation test of the optical link

It is required to have a better stability of the reference signal than that of the optical link using the PSOF. The optical link using the PSOF has many advantages compared to a coaxial cable transmission line, such as the temperature stability, low transmission loss, etc.. If we can use the PLL feedback, as in the case of coaxial cable, we can get a better stability of the reference signal. A preliminary test was made. The difficulty is how to isolate the transmitted and the received signals. The laser diode of the transmitter is very sensitive to reflection. We used wave-length division multiplexing devices(WDMs) to divide the transmitted and the received signals. The WDM has a high isolation ratio for the wave length(~60dB). We used 1.5µm and 1.3µm optical link pairs for the WDM. Fig. 4 shows the test circuit. We measured the phase after the optical link(called received phase) and the phase of one of the phase shifters(called feedback phase). To make a large phase variation, we pat a 100m long normal optical fiber into an oven which has a large temperature coefficient. The phase stability of the 100m long normal optical fiber is equivalent to a 5km long PSOF. The measured results are shown in Fig. 5. The variation of the feedback phase is ~50°(250ps) and the variation of the received phase is ~0.5°(2.5ps) when the temperature range is from 0°C to 40°C. However, the

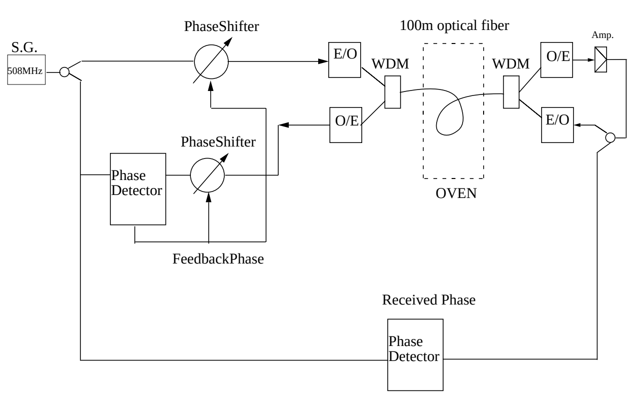

Fig. 4 Measurement set up of the PLL feedback using the optical link.

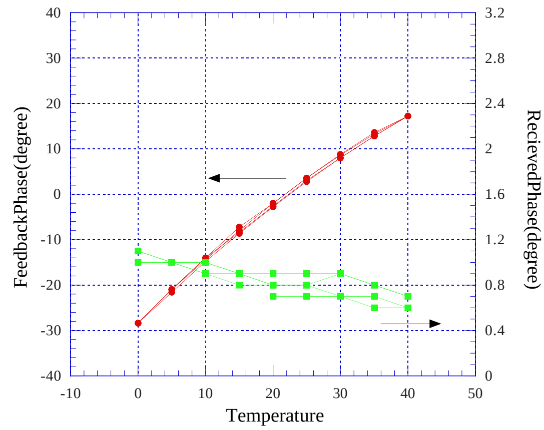

Fig. 5 Measurement of the feedback phase and the received phase

stability of the received phase is not as good as expected. The study of the system is still in progress.

5 SUMMARY

We constructed the timing system of the KEKB accelerator. The system works well. The software trigger system provides synchronization pulses to each local control room and generates interrupt signal to the IOCs located at each local control room. The precise triggers and reference clock are distributed using phase stabilized optical fibers and an optical link system. We confirmed the stability of the PSOF over temperature changes. A test of the PLL feedback using the optical link was made. A phase stability of 0.5° was measured as the preliminary result.

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REFERENCES

[1] T.Naito et. al., “Synchronization scheme for KEKB the KEKB", ICALEPCS'97, Beijing, Nov. 1997.
[2] A.Akiyama et. al., “KEKB Power Supply Interface controller module", ICALEPCS'97, Beijing, Nov. 1997.
[3] M.Tejima et. al., “Beam Position Monitor System for KEKB ", The 11th Symposium on Accelerator Science and Technology, Harima, Japan, Oct. 1997.
[4] J.Odagiri et. al., “Performance Evaluation of EPICS on Power PC", ICALEPCS'97, Beijing, Nov. 1997.