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CONSTRUCTION AND COMMISSIONING OF EVENT TIMING SYSTEM AT SUPERKEKB

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Abstract

KEK linac upgrades its Event Timing System for the coming SuperKEKB project. The Event Timing System is required more complicated injection control. The damping ring is used to suppress emittance in the positron injection. The number of top-up filling rings is increased. We installed the new configuration of Event modules at Main Trigger Station for satisfying the new requirements. Besides, the upgrade of software, rearrange of optical wiring, and feasibility study are performed as the upgrade work. We conclude the new Event Timing System becomes valid. The commissioning of beamline and operation for injections with new system will be performed soon.

INTRODUCTION

The Event Timing System [1] is one of key technology for the injection control at KEK linac (LINAC) [2]. LINAC works as four different injectors since it provides beam-pulses into two main rings (KEKB-HER and KEKB-LER) for the KEKB collider [3, 4] and two light sources (PF [5] and PF-AR [6]). LINAC is requested the quite different types of beam-pulses from individual accelerator-rings as shown in Table 1.

The Event Timing System manages the scheduled injections by switching the beam modes frequently and delivering the timing-trigger. For switching the beam modes, the large number of devices installed separately along the LINAC beamline are controlled and more than 150 of operation parameters are changed. This alternation must be implemented in 50 Hz since LINAC performs top-up filling into more than one rings simultaneously [7].

The Event Timing System is upgraded in 2013 and 2014. The new configuration of Event modules is installed at Main Trigger Station without removing the current configuration. The new system satisfies the new requirements for SuperKEKB [8, 9].

In this paper, we introduce the upgrade activities of Event Timing System.

NEW CONFIGURATION OF EVENT TIMING SYSTEM

The configuration of Event Timing System is upgraded. In this section, we introduce the requirements to injection control and how we realize with new configuration of Event modules.

Table 1: Beam Mode List

Ring	Particle	Energy	Charge
KEKB-HER	Electron	7.0 GeV	5.0 nC
KEKB-LER	Positron	4.0 GeV	4.0 nC
PF	Electron	2.5 GeV	0.2 nC
PF-AR	Electron	6.5 GeV	5.0 nC

Motivation for Upgrade

LINAC is upgraded in order to provide beam-pulses with more lower emittance and larger charge for the luminosity upgrade of SuperKEKB. We install a lot of new components in the beamline, so that the injection control becomes complicated.

One of major changes in the beamline is the damping ring (DR). The positron-pulses are once stored into newly constructed DR to suppress their emittance. Then, at least 40 ms later, they are injected into KEKB-LER. The entire process of positron injection become longer than one injection-period, 20 ms.

The first-half and second-half of LINAC[1] operate independently in case of positron-injection. The first-half works for generating positrons from primary electrons and injecting them into DR while the second-half works for transporting positrons from DR to KEKB-LER.

The Bucket Selection [10] needs to consider RF-buckets for both main rings and DR. The timing management for selection of RF-bucket to be injected becomes very much complicated.

Besides, the number of top-up filling rings will become increase. The top-up filling will be performed into PF-AR after the construction of its dedicated beam-transport is finished.

Configuration at Main Trigger Station

The configuration of Event modules, such as Event Generator (EVG) and Event Receiver (EVR) [1], at Main Trigger Station is upgraded to satisfy above requirements. The new system is configured by using the same types of modules as those in the KEKB period [11]. However we increased number of EVGs from one to three.

Figure 1 is schematic views of the Event Timing System and the new configuration of modules at Main Trigger Sta-

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[1] Note, the LINAC beamline has 8 sections and DR is constructed between 5th and 6th sections. However we call the beamline before DR and that after DR as "first-half" and "second-half", respectively.

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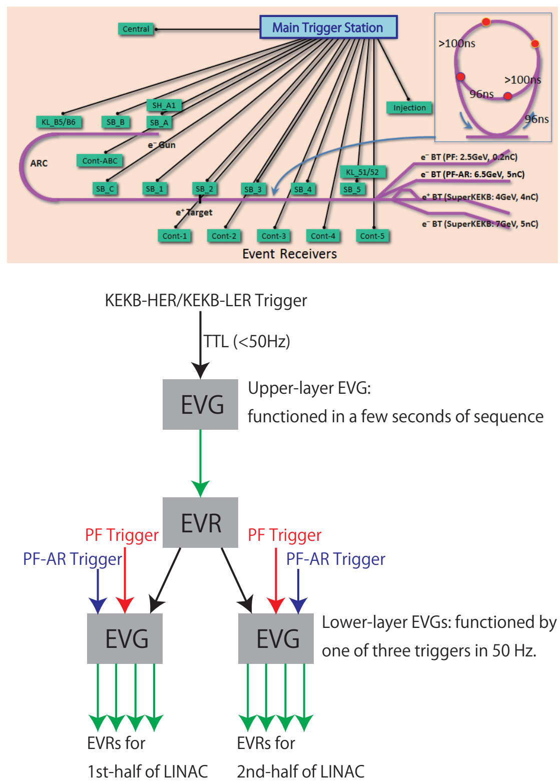

Figure 1: Schematic views of Event Timing System (up) and module configuration at Main Trigger Station (low): the star-topology optical network is utilized for frequent switching of beam mode. The two-layers of EVGs configuration is installed at Main Trigger Station.

tion. Two-layers are configured with three EVGs. One master EVG is placed in the upper-layer (upper-EVG) while two EVGs are placed in the lower-layer (lower-EVGs).

Upper-EVG is functioned with a few second of sequence. The Events for ~100 injections are scheduled together on one sequence. Therefore, the entire process of positron-injection is managed in the same sequence.

Two lower-EVGs are placed in parallel. They manage first-half and second-half of LINAC, respectively. They are functioned in different ways in the positron-injection.

Lower-EVGs are triggered in 50 Hz with Pulse-to-Pulse Modulation. They receives three kinds of triggers which are related with the revolutions of KEKB, PF, and PF-AR. The input channels are switched in 50 Hz. The appropriate input channel is chosen for each beam mode. Then, injection is implemented by the trigger related with injection-ring.

The timing adjustment for Bucket Selection is implemented at lower-EVGs. Two lower-EVG implement the different adjustments in case of positron injection. The first lower-EVG adjusts timing for selecting DR-bucket while the second lower-EVG adjust timing for selecting that for the main ring. They implement the equivalent adjustment in case of electron injection.

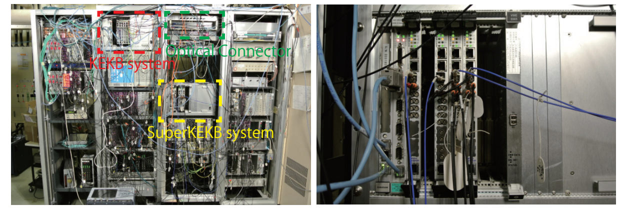

Figure 2: Pictures of Main Trigger Station (left) and new configuration (right): the two-layers of EVGs configuration is installed without removing the current configuration. The Event Timing System becomes redundant.

UPGRADE ACTIVITIES

The upgrade started from installation of new Event modules at Main Trigger Station. The following activities are accompanied as the upgrade work. We upgraded version of firmware and software, rearranged the optical wiring optical among Event modules, and studied feasibility of new configuration. They are explained in the following subsections.

Redundant System

Figure 2 is pictures of Main Trigger Station and the new configuration of Event modules. The new configuration of Event modules are installed at Main Trigger Station without removing the KEKB system. Therefore, the Event Timing System become redundant at Main Trigger Station.

This redundancy is essential since we must upgrade the Event Timing System without disturbing beam operation. LINAC provides beam-pulses to PF and PF-AR even during shutdown period of KEKB for the upgrade. Besides, the LINAC beamline itself needs commissioning runs for newly installed components.

Upgrade of Firmware and Software

We upgraded the version of EVG and EVR firmware. The above-mentioned new function at lower-EVGs, "switching input channels in 50 Hz", needs the upgrade of firmware. It causes the series of upgrades for device/driver software [12, 13] and EPICS [14]. The software used at both KEKB and SuperKEKB are summarized in Table 2.

We developed the new EPICS record, transferArray [15], for Pulse-to-Pulse Modulation and Bucket Selection. This record copies a part of waveform-elements and pastes them into another waveform. The sequence RAM of EVG is set with waveform record. It is renew in 50 Hz for Pulse-to-Pulse Modulation with the transferArray record.

Table 2: Summary of Software Version

	KEKB	SuperKEKB
EVG firmware	E403	0005
EVR firmware	D507	0005
Device/driver	mrfioc [12]	mrfioc2 [13]
EPICS	R3.14.9	R3.14.12.1

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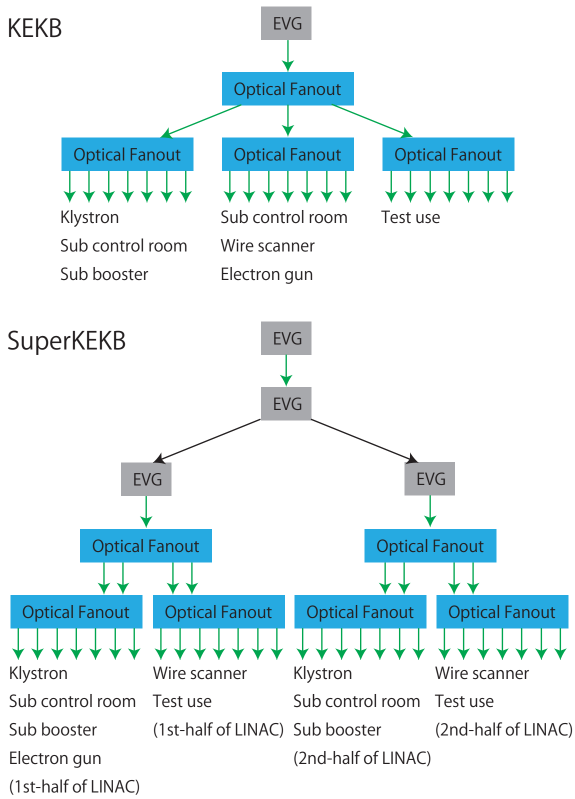

Figure 3: The configuration of optical fanout modules for the current (up) and upgraded (down) systems: the fanout module is increased for SuperKEKB. Two of them are used to connect with EVRs in the first-half of LINAC while the remains are used to connect those in the second-half.

Upgrade of Optical Network

The Event Timing System uses the star-topology optical network for Event delivery as shown in the up of Figure 1. The output Events from EVG are once split into tens of optical cables with the dedicated optical modules [11] and are delivered to the EVRs along beamline.

Both the current (KEKB) and upgraded (SuperKEKB) network connections are shown in Figure 3. We installed further fanout modules since the number of frequent control devices in the beamline are increased. Then we rearranged the wiring for independently operating the first-half and second-half of LINAC. The cables from first-half are bundled on two of modules while those from second-half are bundled on the remains.

The new connection is decided to enhance the merit of redundancy of Event Timing System. The four lower-level fanout modules can receive the Events from either current or upgraded configurations of Event module. Therefore, for example, the commissioning of first-half of beamline can be controlled with the SuperKEKB system while the injection to PF and PF-AR can be controlled with the well-established KEKB system. We can revise, upgrade, and commission the new Event Timing System during the beam injection.

Feasibility Study

The feasibility of two-layers of configuration is studied in terms of timing precision [16] and stability of real-time process [17].

The precision of timing-triggers delivered from this configuration is determined to be ~10 ps. However we observed timing drift caused by fluctuation of room temperature. The magnitude of drift is to be 18 ps/degree. The results satisfy the required precision to the Event Timing System[2] nevertheless we consider above two kinds of timing deteriorations.

The stability of real-time process which controls operation parameters for Pulse-to-Pulse Modulation is studied at Main Trigger Station. This study could be performed during the injection run of LINAC thanks to the redundant Event Timing System. From the result, it is expected that the real-time process of Event Timing System is stable and makes less failure for long term operation. The study is repeated when we modify operation software for commissioning.

CONCLUSION AND FUTURE PROSPECTS

The configuration of Event Timing System at Main Trigger Station is upgraded for satisfying the new requirements to injection control at SuperKEKB. The two-layers of EVGs configuration is installed at Main Trigger Station and the Event Timing System becomes redundant with current and upgraded system. The upgrade of firmware and software, rearrange of optical network connection, and feasibility study are performed as the upgrade work. Then we conclude the new Event Timing System becomes valid. The beam commissioning and injection with new Event Timing System will be held soon.

Although the new configuration of Event modules has already installed, the modifications of operation software will be continued. The redundant Event Timing System enables them without disturbing the beam injection.

The new Event Timing System has capability to perform top-up filling toward PF-AR. It will be begun after finishing the construction of new beam transport line.

[2] The required precision of $O(100)$ ps satisfies most of LINAC components. Only a few components require more precise timing. For those components we make timing-trigger re-synchronize with RF clock to produce more precise timing.

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