EVENT-SYNCHRONIZED DATA-ACQUISITION SYSTEM FOR SPring-8 XFEL

M. Yamaga*, Y. Furukawa, T. Hirono, M. Ishii, T. Masuda, T. Ohata,
R. Tanaka, A. Yamashita, JASRI/SPring-8, Hyogo, Japan
T. Fukui, N. Hosoda, RIKEN/SPring-8, Hyogo, Japan

Abstract

We report an event-synchronized data-acquisition system for the accelerator control of the SPring-8 XFEL. So far, more than 100 signals from the beam monitoring systems and RF systems have been successfully collected in synchronization with beam cycles of up to 60 Hz at the SCSS test accelerator, an XFEL prototype machine. The collected data could be effectively used for the fast feedback correction of the beam energy and trajectory. The same scheme will be introduced for the 8-GeV XFEL.

INTRODUCTION

The SPring-8 X-ray Free Electron Laser (XFEL) facility is being constructed at the SPring-8 site aiming to generate an extremely high-intensity X-ray laser having a wavelength of less than 0.1 nm using an 8-GeV linear accelerator [1]. The 8-GeV XFEL will commence operations in 2011. The SPring-8 Compact SASE Source (SCSS) 250-MeV test accelerator, which was constructed as a proof-of-principle machine for the XFEL, has been successfully operating to generate a ∼50 nm VUV laser since 2006.

Because the accelerator equipment for the XFEL is driven with the pulsed operation, the stability of each equipment is crucial for stabilizing the FEL intensity. Precise and fast control with feedback correction for the equipment contributes greatly to its stabilization.

For the fast control of the accelerator equipment, we have integrated an event-synchronized data-acquisition (synced DAQ) system into the SCSS test accelerator to collect data from the equipment shot-by-shot for every beam cycle.

EVENT-SYNCHRONIZED DAQ AT THE SCSS TEST ACCELERATOR

Conceptual Scheme

Figure 1 shows the conceptual scheme of the synced DAQ system. This scheme is based on the synced DAQ system already being used the SPring-8 linac [2]. The accelerator equipment is driven in synchronization with the master-trigger timing. At each control station, the trigger module counts the master trigger to generate the trigger number. The trigger number is set to be identical for the same trigger timing for all control stations at the beginning of the operation. The trigger module also issues an interrupt signal to the CPU when triggered. The CPU reads data from the digitizer modules and the trigger number from the trigger module when it is interrupted. Then, the CPU places a set of trigger number and data on the shared memory on the network that is shared between the distributed CPUs. The event-builder process runs on the workstation to synchronize the data from each CPU online. It collects the data that has the same trigger number on the shared memory, and then stores them together as an event in the relational database.

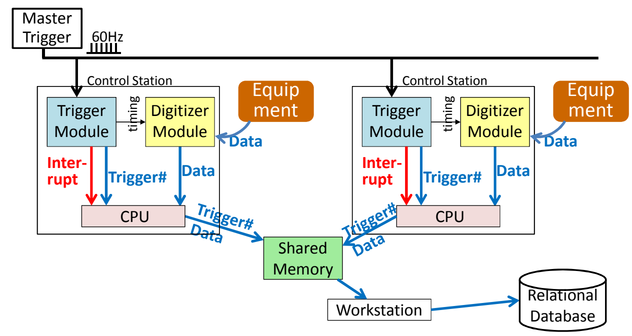

Figure 1: Conceptual scheme of the event-synchronized data-acquisition system.

Implementation to the SCSS Test Accelerator

For the control of the SCSS test accelerator, the VME system with the MADOCA software framework has been selected [3]; this system has been developed and been operating at the SPring-8 accelerator complex for a long time. The Solaris 9 operating system runs on a Sanritz-SVA041 VME CPU-board at each control station. For the trigger module, we use the ARKUS Axvme4900 interrupt register board. The Advanet Advme2616 waveform digitizer can take either a waveform of the signal from the equipment or a sampling-point data at any point of the waveform as a representative value of the signal. The reflective memory board enable real-time data sharing between the distributed CPUs. We use the GE-Funac VMIVME-5565 reflective memory board in our system. The MySQL relational database can be used to store data at a rate of 60 Hz, the maximum beam cycle at the SCSS test accelerator.

* e-mail: myamaga@spring8.or.jp

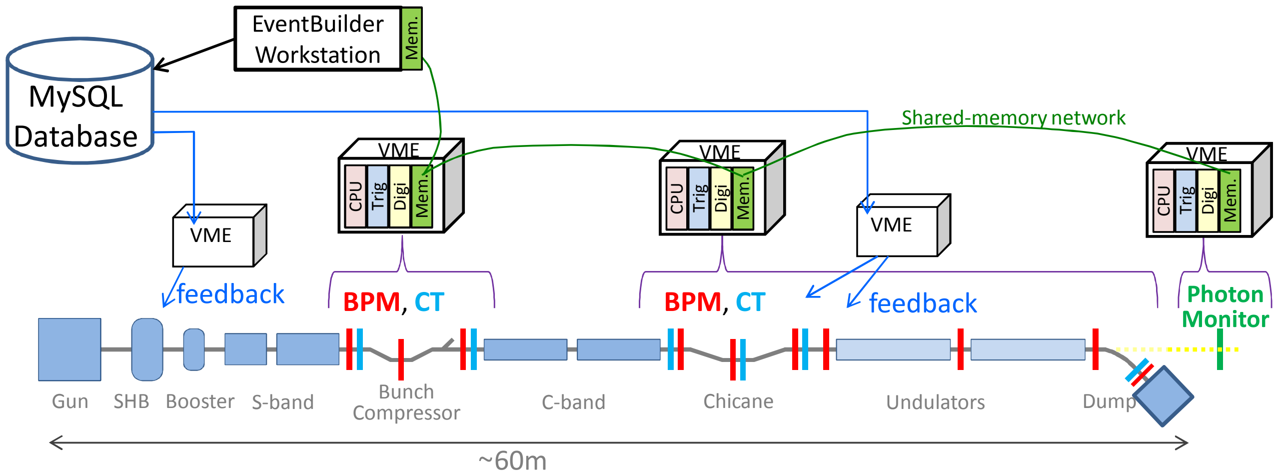

Figure 2: Schematic view of the event-synchronized data-acquisition system for the beam monitoring system at the SCSS test accelerator.

Application to the Beam Monitoring System

Three VME units are used for the beam monitoring system at the SCSS test accelerator. The positions of the electron beam measured by the Beam Position Monitors (BPMs) and the beam current measured by the Current Transformers (CTs) are collected as sampling-point data from the Advme2616 digitizer by the synced DAQ system. The FEL intensity is measured using a photon-monitor system by integrating the waveform of the photodiode signal. Figure 2 shows a schematic view of the synced DAQ for the beam monitoring system at the SCSS test accelerator.

The synced DAQ system has been fully operational since October 2008 for a beam cycle of up to 60 Hz to collect 54 channels of data from the BPMs, CTs, and the photon-monitor system. The data rate is approximately 60 kB/sec for a 60 Hz beam cycle.

Modification for the RF System

The event-synchronized data-acquisition system is also useful for the RF system. However, the utilization of the shot-by-shot data is somewhat different from that in the beam monitoring system. Here, its main use is to investigate the causes of problems or malfunctions in the equipment. The history of the data for each beam shot is valuable for determining exactly when the equipment began malfunctioning. The waveforms of the RF modulators, RF cavities, and dummy loads, etc., in the same beam shot are quite important for determining which component malfunctioned during a the beam shot in which some problem occurred. In these cases, the real-time data-sharing capability is not very critical. Instead, capturing data in the same beam shot is more valuable.

Therefore, we implemented a synced DAQ system for the RF equipment without using reflective memory boards. No additional workstation is required for the event-builder process. Instead, the collected data are directly sent to the MySQL database sever from each VME CPU. Therefore, the event synchronization is not carried out online, but is instead carried out offline by the data-analysis process by collecting the data having the same trigger number from the database. Using this scheme, we can suppress the cost of the synced DAQ at a facility with many RF systems, such as the 8-GeV XFEL, while satisfying the requirement of data acquisition for RF systems. Figure 3 shows the conceptual scheme of the synced DAQ for the RF system.

This system has recently commenced operations in September 2009 at the SCSS test accelerator. 48 sampling-point data of the signals from 5 VME units are successfully collected in synchronization with the beam cycle. 25 waveforms of the same beam shot from the RF equipment are also collected using the synced DAQ at a rate of 0.1 Hz. The data rate is approximately 60 kB/sec for a 60 Hz beam cycle. We expect that the collected data will be useful when the RF systems malfunction.

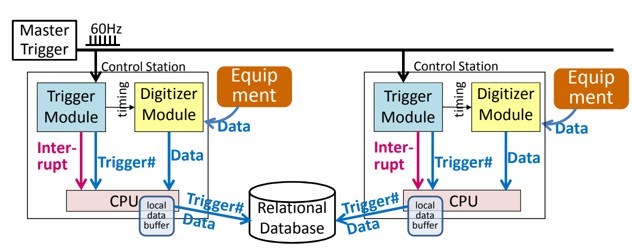

Figure 3: Conceptual scheme of the event-synchronized data-acquisition system for the RF system. It does not include shared memory on the network and event-builder workstation.

FEL STABILITY IMPROVEMENTS THROUGH FEEDBACK CORRECTION

The data collected from the beam monitoring system by the synced DAQ are used for feedback correction of the beam energy and trajectory at the SCSS test accelerator [4].

The correction of beam trajectory is currently restricted to the undulator section. The displacement of the entrance position to the undulator measured by the BPMs shot-by-shot at the entrance of the undulator section is returned to an upstream steering magnet. The trajectory within the undulator is corrected by the steering magnets just upstream of the undulator section.

For beam energy correction, we utilize shot-by-shot data of the BPM at the middle of the first stage of the magnetic chicane. The energy variation measured as the displacement of the beam trajectory at the middle of the magnetic chicane is returned to the phase of the 238-MHz subharmonic buncher (SHB) [5].

Figure 4 shows the vertical drifts of the beam trajectory measured at the middle of the undulator section with and without correction. Figure 5 shows the FEL intensity and the beam energy variations measured at the middle of the first magnetic chicane with and without correction. The trajectory of the electron beam within the undulators and the beam energy can be stabilized by the feedback correction. As a result, the variation of the FEL intensity is also suppressed to some extent.

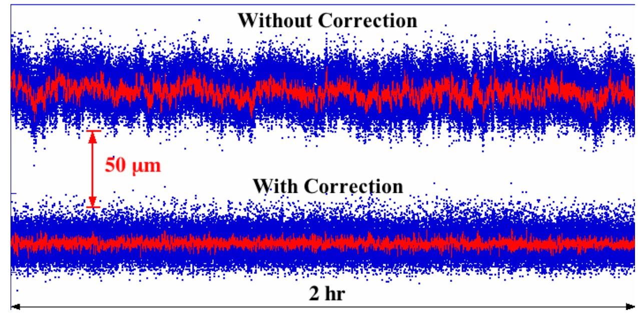

Figure 4: Vertical drifts of beam trajectory measured at the middle of the undulator section with and without correction. The red lines shows the moving average with 45 shot-by-shot data.

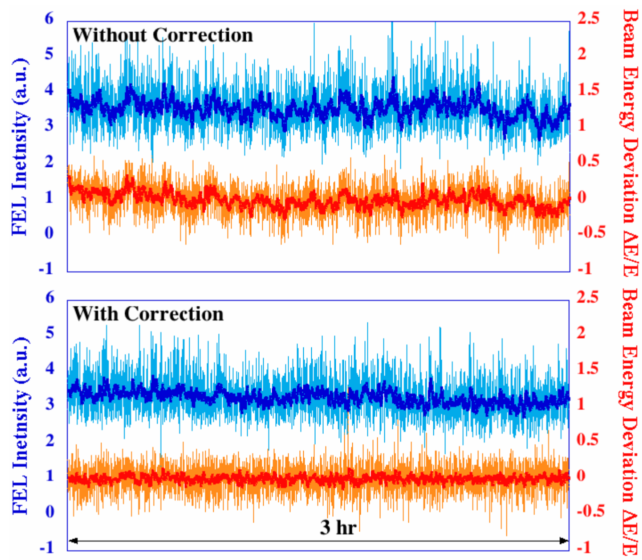

Figure 5: FEL intensity and beam energy variations measured at the middle of the first magnetic chicane with and without correction. The bold lines show the moving average with 45 shot-by-shot data.

APPLICATION TO THE 8-GEV XFEL

The 8-GeV XFEL will have more than 70 VME units for the RF systems and about 30 VME units for the beam monitoring systems. The total number of signals to be read by the Synced DAQ will be 10 times greater than that at the SCSS test accelerator. The total data rate from all these units is estimated to be 1.2 MB/sec . By scaling up the number of control stations, the same scheme of the synced DAQ system as the SCSS test accelerator will be adequate for this data rate at the 8-GeV XFEL.

SUMMARY

An event-synchronized data-acquisition system with a VME-based distributed system has been successfully operating for more than 100 signals with a beam cycle up to 60 Hz at the SCSS 250-MeV test accelerator. The electron-beam trajectory and the beam energy can be stabilized by feedback correction using the data collected by this system, and this in turn can suppress the variation of the FEL intensity. The system will also be useful for investigating the causes of problems or malfunctions in the equipment. The same scheme of the event-synchronized data-acquisition system will be introduced in the 8-GeV XFEL.

REFERENCES

[1] T. Shintake et al., X-ray FEL project at SPring-8 Japan, Proceedings of 8th International Conference of Synchrotron Radiation Instrument (SRI2003), 227 (2004).

[2] T. Masuda et al., Event-synchronized data acquisition system for the SPring-8 linac beam position monitors, Nucl. Inst. Meth. A 543 (2005) 415.

[3] R. Tanaka et al., The first operation of control system at the SPring-8 storage ring, Proceedings of ICALEPCS97, Beijing, China, 1 (1997).

[4] H. Tanaka et al., to appear in the Proceedings of FEL09, Liverpool, UK (2009).

[5] Y. Tajiri et al., "Energy Feedback for SASE-FEL Stabilization in SCSS Test Accelerator", the 5th annual meeting of Particle Accelerator Society of Japan (2009).