DESIGN AND IMPLEMENTATION OF CONTROL INTERFACE AND TIMING SUPPORT OF TPS PHASE-I BEAMLINES

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Abstract

Taiwan Photon Source (TPS) with low emittance provides extremely bright X-rays. Seven advanced phase-I beamlines of TPS are being constructed and commissioned. The control interfaces for a beamline or experimental station and support from the accelerator control system are designed and are being implemented. The beamline control interface and supports include a beamline interlock status monitor, accelerator timing transmission, broadcast of accelerator operating status, transmission of the beam-current reading and control of insertion devices. This report summarizes the efforts in implementing the beamline EPICS IOC and support from the accelerator control system during beamline commissioning in TPS phase-I.

INTRODUCTION

Taiwan Photon Source (TPS) with low emittance will provide extremely bright X-rays at Taiwan's National Synchrotron Radiation Research Center (NSRRC). Seven advanced phase-I beamlines of TPS are proposed and are being constructed for projects as follows: protein micro crystallography, resonant soft X-ray scattering, submicrometre soft X-ray spectra, coherent X-ray scattering, submicrometre X-ray diffraction, X-ray nano probe, and temporally coherent X-ray diffraction. These beamlines are scheduled to open to users in mid 2016.

The control system of insertion devices (ID) -- seven in-vacuum undulators (IU22), two elliptically polarized undulators (EPU48 and EPU46) -- were developed and are implemented for the TPS phase-I beamline project.

The beamline experimental physics and industrial control system (EPICS) input / output controller (IOC) will provide interlock status monitor of beamline, beamline enable, top-up injection gating signal and an EPICS gateway.

An event-based timing system is applied for TPS [1-2]. Implementing timing support of the beamlines is in progress. Various synchronization clock delivery with low jitter and low drift for beamline experimental stations is under design.

EPICS IOC FOR BEAMLINES

The EPICS IOC for a phase-I beamline is based on a fanless embedded computer with PCI/PCIe slots. The beamline EPICS IOC that handles interlock status monitor of beamline, beamline enable, top-up injection gating signal and EPICS gateway is shown in Fig. 1. The TPS timing system is an event-based system; a central EVG generates events from an internal sequence RAM and external sources. These events are distributed over optical-fibre links to multiple event receivers (EVR). The PCIe-EVR-300 is used to accompany a fanless embedded EPICS IOC for a beamline timing interface.

The DI/DO module of the beamline EPICS IOC monitors the interlock status and controls the beamline enable. The beamline monitors accelerator operating parameters and controls insertion devices through the EPICS gateway of each beamline.

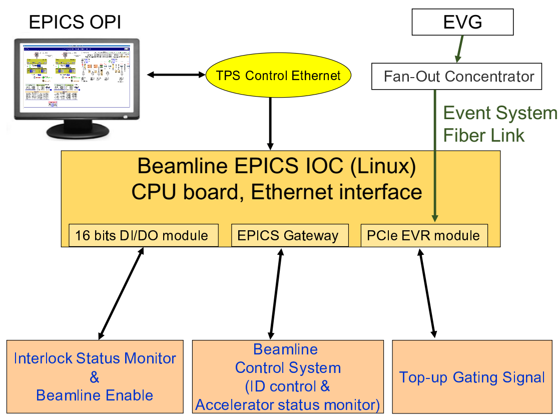

Figure 1: Architecture of a beamline EPICS IOC.

MACHINE STATUS BROADCAST

A web page has been created using the Hypertext Preprocessor (PHP) and Asynchronous JavaScript and XML (AJAX) technique to broadcast the TPS machine status. Beamline users can use web browsers of PC or smartphones to watch the machine status directly; its update rate is once per second. The trend graph is a necessary component to show the historic variation of the beam current and the beam lifetime on the web page of the TPS machine status. The TPS web-based machine status broadcasting and trend graphs that include the beam current, beam size and status of insertion devices are shown in Fig. 2.

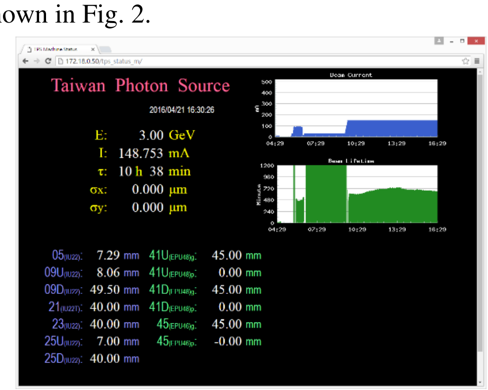

Figure 2: Web-based machine status broadcasting of TPS.

BEAM CURRENT VALUE DISTRIBUTION TO BEAMLINE

Of two ways to transmit the beam current value to the beamline, one is to read the beam-current process variables (PV) via an EPICS gateway, at updating rate 10 Hz, and the other is to use a voltage-to-frequency converter (VFC) to translate analogue signal of the beam current to frequency signal which is propositional to beam current. The frequency signal is distributed by distributed bus of the event system.

The analogue signal produced by a beam monitor is fed into the VFC unit; the output pulses relative to the beam current are sent to a pulse counter of that beamline. The number of pulses from a VFC accumulated by the counter during a given interval is then directly proportional to the time integral of the beam current. This arrangement is particularly convenient for beamlines as it allows acquiring signals from the beam current, various monitors and photon-counting detectors into a digital pulse counter and implementing synchronized integration.

In TPS, we use ACQ1001 with a V2F module that is a VFC recently designed at NSRRC and contracted to D-TACQ Solutions Ltd [3], able to operate with a full-scale output frequency 10 MHz. The functional block diagram of a VFC is depicted in Fig. 3.

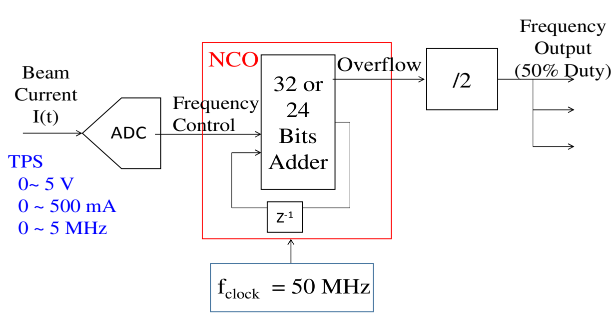

Figure 3: Functional block diagram of a VFC.

TIMING SUPPORT

An event-based timing system is applied for TPS [1-2]. The timing system is based on the events coming from an event generator (EVG) that handles the accelerator synchronization, trigger and revolution clock. To provide a revolution clock and top-up gating signals, the event receiver (PCIe-EVR-300) is installed in the beamline EPICS IOC.

The configuration of the event-system link for a beamline is shown in Fig. 4. The link length of the OM3 fibre between the timing master and each equipment room is about 120 ~ 350 m. The connection to the EVR module of a beamline EPICS IOC from each equipment room is with OM3 fiber, length less than 140 m. The jitter of the EVR output is about 25 ps for the TTL output as shown in Fig. 5. The delay of event links from an event generator to an event receiver of beamline is less than 2.5 µs.

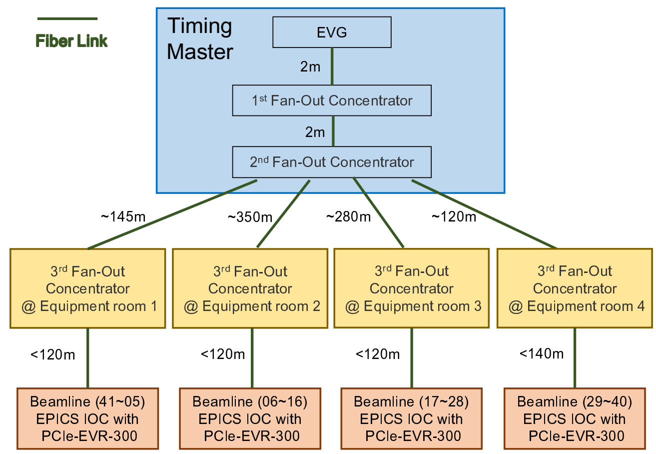

Figure 4: Configuration of an event system link for a beamline

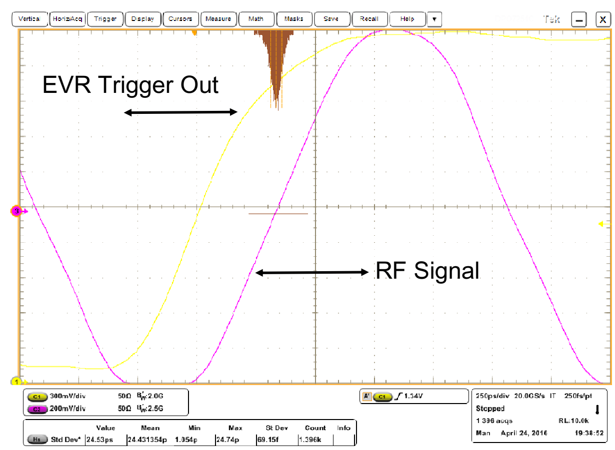

Figure 5: Jitter of PCIe-EVR-300 TTL output relative to the RF clock.

The timing drift of the TPS timing system is about 20 ps for temperature range 25±1 ºC. If the timing drift or jitter cannot be accepted in some time-resolved experiments, another temperature-compensated sub-picosecond fibre RF link or phase-stabilized optical-fibre (PSOF) RF link is used to send a RF reference to an experimental station for such applications. A clock with jitter a picosecond can regenerate at an experimental station for laser and instrument synchronization.

A perturbation of the beam orbit due to kickers or septums fired at top-up injection decreases the X-ray brightness. To avoid such a perturbation of the beam orbit affecting a beamline experimental result, the top-up injection gating from a beamline EPICS IOC is used. The short gating for top-up injection plays every injection cycle trigger at rate 3 Hz. Figure 6 shows the top-up injection short gating and long gating signal versus the ionization-chamber signal of a beamline at every injection cycle. The width of the top-up injection short gating is configurable and depends on the injection transition time.

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The top-up injection long gating that begins before a top-up injection and stops after a top-up injection is finished.

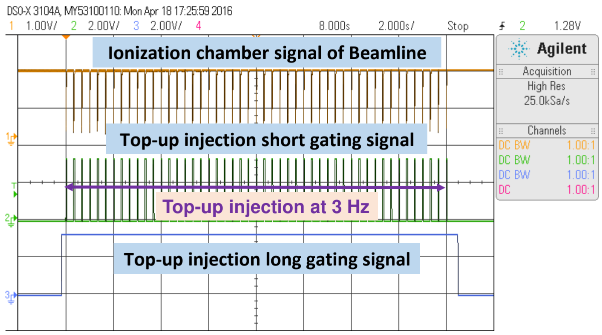

Figure 6: Top-up injection short gating and long gating signals versus ionization-chamber signal of beamline during top-up injection.

INTERFACE TO CONTROL INSERTION DEVICES

The control page of the double EPU48, installed at a long straight section of TPS, is shown in Fig. 7. The control pages of the EPU48 show the ID and front-end status, and a gap position adjustable for general operation.

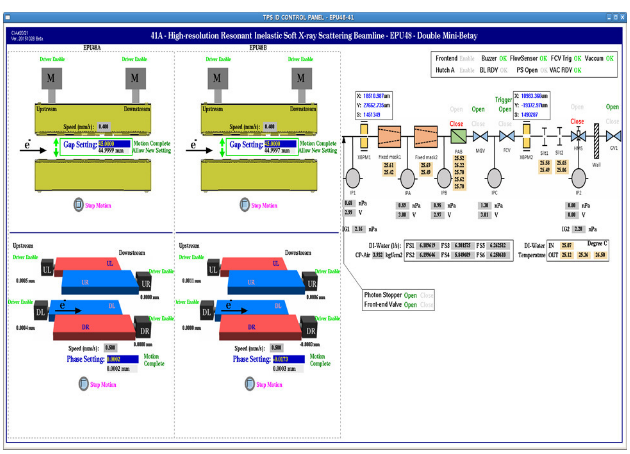

Figure 7: GUI of a double EPU48 installed at a long straight section of TPS.

To allow the beamline to set a gap demand position for automatic beamline scanning, an EPICS gateway for each beamline is allocated to provide the necessary connectivity and isolation.

To increase the productivity and to fulfill requirements for scientific objectives [4-5], on-the-fly experiments that synchronize the ID gap and the energy scan of a monochromator have recently been conducted. The present arrangement between the ID controls and the beamline controls is to set the ID as master to provide the ID information; the beamline monochromator follows and undertakes an energy scan.

Two schemes are available to share the ID gap information for on-the-fly experiments, as shown in Fig. 8. The first approach is for the beamline or experimental station computer to read the gap position over the network through the EPICS PV channel access (100 updates /s or more). The second method is for the ID control system to provide the SSI encoder signal and to deliver it to the beamline or experimental station via an optical-fibre link (1000 updates / s).

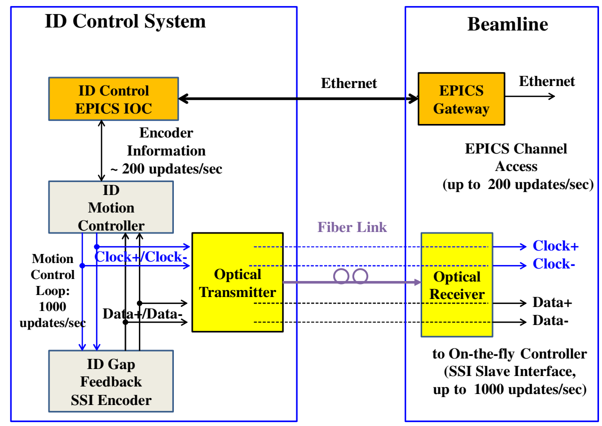

Figure 8: Support of insertion devices for on-the-fly or continuous scan

SUMMARY

EPICS IOC and event fibre links of beamline were implemented recently for the TPS phase-I beamline project. Tests of functionality of the beamline control interface are in progress accompanying beamline commissioning. Preliminary results show that the beamline interlock status monitor, top-up injection gating and EPCIS gateway meet the requirements for beamline commissioning and operation. Beam current translation to frequency via VFC and distribution to each beamline are in progress.

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