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INTRODUCTION TO THE CONTROL SYSTEM OF THE PAL-XFEL BEAMLINES

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Abstract

The PAL-XFEL beamlines are composed of two different types of beamlines: a hard X-ray beamline and a soft X-ray beamline. The hard X-ray beamline generates free electron lasers with pulse energies ranging from 2-15 keV, pulse lengths of 10-35 fs, and arrival time errors of less than 20 fs from 4-11 GeV electron beams for X-ray Scattering & Spectroscopy (XSS) and Nano Crystallography & Coherent Imaging (NCI) experiments. On the other hand, the soft X-ray beamline generates free electron lasers with photon energies ranging from 0.25-1.25 keV, and with more than 10^{12} photons, along with 3 GeV electron beams for soft X-ray Scattering & Spectroscopy (SSS) experiments. To conduct experiments using the XFEL, precise beam alignment, diagnostics, and control of experimental devices are necessary. The devices of the three beamlines are composed of control systems based on the Experimental Physics and Industrial Control System (EPICS), which is a widely-used open-source software framework for distributed control systems. The beam diagnostic devices include QBPM (Quad Beam Position Monitor), photodiode, Pop-in monitor, and inline spectrometer, among others. Additionally, there are other systems such as CRL (Compound Refractive Lenses), KB mirror (Kirkpatrick-Baez mirror), attenuator, and vacuum that are used in the PAL-XFEL beamlines. We would like to introduce the control system, event timing, and network configuration for PAL-XFEL experiments.

INTRODUCTION

Introduces the configuration of the PAL-XFEL beamlines and the experimental techniques used in each experiment hutch, introduces the event timing system for devices requiring synchronization, introduces network configuration for device control and data transmission, and introduces EPICS IOC for controlling experimental devices. finally, we will introduce the data monitoring system for EPICS IOC management.

PAL-XFEL Beamlines

The PAL-XFEL beamlines is composed of HX (Hard X-ray) and SX (Soft X-ray) FEL beamlines. The HX beamline consists of a 780-meter-long accelerator line, a 250 meter-long undulator line, and 80-meter-long experimental halls. The SX beamline branches off at the 260-meter point from the beginning and includes a 170-meter-long accelerator line, a 130-meter-long undulator line, and a 30-meter-long experimental hall [1].

Figure 1 below is a schematic diagram of the PAL-XFEL beamlines. HX has two experiment hutches and supports X-ray scattering and spectroscopy (XSS) and nano- crystallography and coherent imaging (NCI) experiments. XSS supports femtosecond X-ray scattering (FXS)/femtosecond X-ray liquidography (FXL), and NCI supports coherent X-ray imaging/scattering/spectroscopy (CXI)/serial femtosecond crystallography (SFX) experiment techniques. SX has two endstations and supports soft X-ray scattering and spectroscopy (SSS) experiments. X-ray emission/absorption spectroscopy (XES/XAS) and resonant soft X-ray scattering (RSXS) experiment techniques are supported.

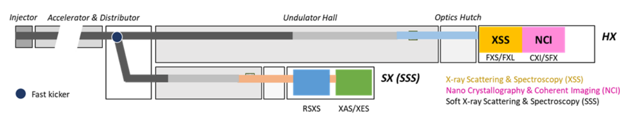

Figure 1: Schematic diagram of PAL-XFEL beamlines.

Table 1 below shows the beam parameter values of HX and SX, the photon energy of hard X-ray is 2 ~ 15 keV, and the repetition rate supports up to 60Hz. Band width of pink beam is ~0.4% and Photon flux (pink beam) is $>10^{11}$ phs/pulse. the photon energy of Soft X-ray is 250 ~ 1250 eV, and the repetition rate supports up to 60 Hz. Band width of pink beam is ~ 0.5% and Photon flux (pink beam) is $>10^{12}$ phs/pulse @ 800 eV [2-3].

Table 1: Conditions of Hard X-ray and Soft X-ray

	Hard X-ray	Soft X-ray
Photon energy	2.0 ~ 15 keV (0.6 ~0.8 nm)	250 ~ 1250 eV (5~1 nm)
Repetition rate	10 Hz, 30 Hz, 60 Hz	10 Hz, 30 Hz, 60 Hz
Band width of pink beam (ΔE/E)	~ 0.4 %	~ 0.5 %
Photon flux (pink beam)	$>1.0\times10^{11}$ phs/pulse	$>1.0\times10^{12}$ phs/pulse @800 eV

Event Timing System

The PAL-XFEL uses an event timing system developed by Micro-Research Finland (MRF). Essentially, this system is VME-based and comprises components such as the MVME6100 CPU, VME-EVG-230, VME-EVR-230, all running on the RTEMS operating system. However, owing to the recent discontinuation of the VME-EVR card, we are in the process of transitioning to a MircoTCA (MTCA)-based system.

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The PAL-XFEL beamlines is using an event timing system with the following configuration. The 119 MHz signal provided by the RF distributor and the 360 Hz signal from the AC power are go to the Event Generator (EVG) to generate the trigger signal [4]. When the trigger signal generated in EVG comes to the beamline through the FAN-OUT, the event signal is provided to the devices needed by EVR for UH, OH, EH1, EH2, PTL, etc. to the FAN-OUT located at each point of HX and SX on the beamline. Figure 2 below shows a recent event timing system diagram.

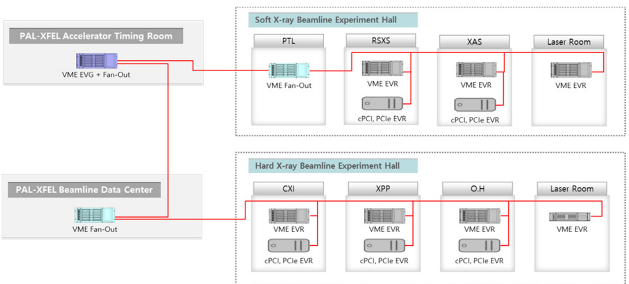

Figure 2: Event Timing System configuration diagram.

Network

The network connection of the beamline section is established as shown in Figure 3-4 below. It is constructed with public, control, and data networks. The public network is a network that communicates with the outside through port forwarding, and the control network is an independent network that cannot communicate with the outside and is used to control devices. The data network is a dedicated network for transmitting large amounts of data from the detector and is configured at a basic speed of 10 Gbps.

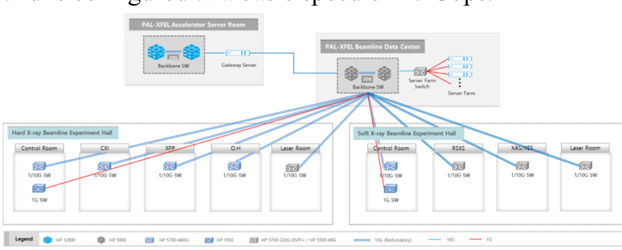

Figure 3: XFEL Beamline control network configuration diagram.

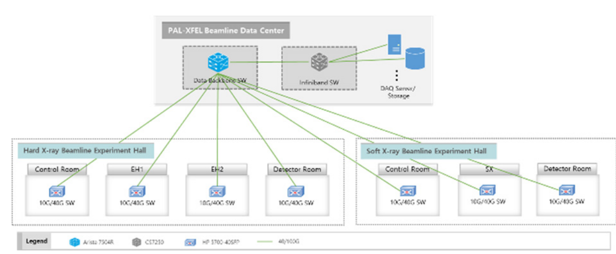

Figure 4: XFEL Beamline data network configuration diagram.

Control System

The control devices of the PAL-XFEL beamline are diverse, as shown in Fig. 5. There are motors, cameras, diagnostic devices, experimental devices, etc. it is controlled using various communication interfaces (Ethernet, RS232, RS485, USB) of various devices in the PAL-XFEL beamline. In order to provide this interface to EPICS, EPICS IOC is developed using a converter for specific communication interfaces. For example, for RS232/RS285, using the RS232/482 to Ethernet converter provided by MOXA, communication is possible even if the device and the EPICS IOC server are not physically located in the same location. In the case of the USB interface, EPICS IOC was configured using Raspberry Pi to facilitate maintenance in the event of a failure. in the case of Popin, camera (Manta-046B) is used and was built separately using a private network to reduce data traffic and congestion on the control network. in the case of PD, Event Timing synchronization is essential. To this end, PCIE-EVR was installed on the EPICS IOC server, LinuxRT patched, and PD signals were developed to be synchronized to XFEL timing. It is also provided to the accelerator as BSA. in the case of NI-digitizer, PXI-EVR is installed and used. Additionally, the beamline department uses proxmox, an open source virtualization machine, to build and operate EPICS IOC, boot server, DHCP server, and CA Gateway server.

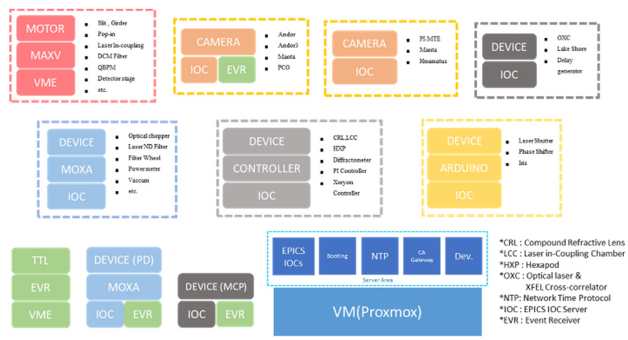

Figure 5: is a diagram of the overall control system of the PAL-XFEL beamline. It shows the equipment managed by EPICS IOC for each section of HX and SX.

Figure 6 below is a diagram of the overall control system of the PAL-XFEL beamline. It shows the equipment managed by EPICS IOC for each section of HX and SX.

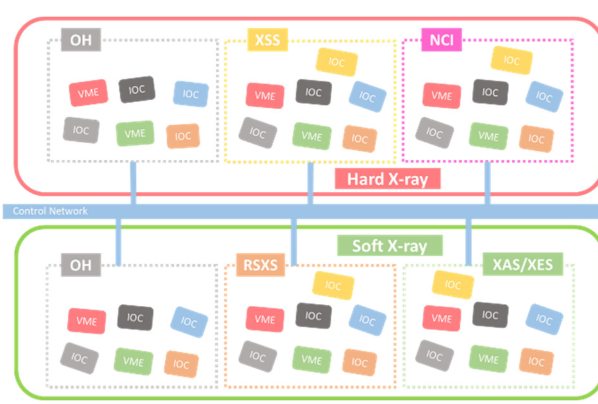

Figure 6: XFEL beamline control system configuration diagram.

Monitoring System

The PAL-XFEL beamline is operating a monitoring system using Zabbix for efficient manage to the EPICS IOC, NTP, Booting, EPICS CA gateway servers. In particular, the current status and events of servers can be checked in real time with the Grafana dashboard, allowing quick response in the event of a failure as shown Figure 7.

Figure 5: Control-related server monitoring system using Zabbix.

CONCLUSION

The control system of the PAL-XFEL beamline section was introduced. In particular, network congestion and data bandwidth were secured by building a dedicated data network to transmit large amounts of experimental data from the detector to the storage. In addition, through system advancement, the number of EPICS IOC servers in remote locations is reduced and the system is being improved to make maintenance convenient by using VM.

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