1. Accelerator

1. Accelerator status and activities

The machine operation of SPring-8 and SACLA was completed without any serious trouble in FY2023. A CeB_6 cathode of the SACLA electron gun, which provides electron beams to both SACLA and SPring-8, was replaced during the summer shutdown period. A newly developed gun tank exchange system allows quick and smooth replacement of the gun cathode. The beam startup and tuning procedure after the cathode replacement was established, and it proceeded as scheduled. Since more than 25 years have already passed since SPring-8 started its operation in 1997, troubles due to the aging of the accelerator and surrounding facilities have become noticeable in the SPring-8 storage ring facility.

As many fourth-generation synchrotron radiation facilities are being operated and constructed worldwide, calls for SPring-8-II have recently been increasing. In Japan, the construction of NanoTerasu in Sendai has been completed, and commissioning of the accelerator began in FY 2023. In contrast to NanoTerasu, which primarily targets the soft X-ray region, SPring-8-II is positioned as the next-generation synchrotron radiation source for hard X-rays. Equipment and technologies developed for SPring-8-II are being utilized at NanoTerasu. The insights gained from the experience with NanoTerasu can be applied to the upcoming construction of SPring-8-II. Preparations for the construction, such as detailed vacuum and magnet designs, were advanced and the procedures of component installation and beam commissioning were discussed in FY 2023.

Regarding SACLA, the concept of the SACLA upgrade, which would come after SPring-8-II, was discussed. The outline of the SACLA upgrade plan is a kHz pulse repetition using room-temperature linear accelerator technologies without increasing power consumption. Technical issues that must be overcome to realize this concept were surveyed in FY2023. In the daily user operation, pulsed quadrupole magnets were newly introduced in SACLA to smoothly change the beam energy and XFEL wavelength, thus facilitating XFEL beam tuning for user experiments. Efforts were also made to improve the reliability of the SACLA linear accelerator, which is also used for the electron beam injection to the SPring-8 storage ring. An old electron-tube-based RF source of a 476 MHz cavity was updated to more reliable semiconductor amplifiers. In preparation for accidental trouble with the electron gun, spare electron gun tanks have been set up to enable a quick exchange within a few hours.

2. Control system

2.1 Status

In FY2023, we continued to improve the control system for SPring-8 and SACLA. Several components of the control system were replaced.

· The Parameter Database server for SPring-8 and SACLA was upgraded to a fault-tolerant server during the summer shutdown period with the aim of avoiding the end of support and maintenance.

· The Archive Database server for SACLA was upgraded with 256 GB memory and 90 TB SSD during the spring shutdown period with the aim of avoiding the end of support and maintenance.

· The accelerator control network for SACLA was replaced with a full gigabit ethernet switch. This was aimed at avoiding the deterioration of communication capability for PC servers with 10G ethernet interface which can not connect to 100M ethernet.

· At SACLA, there was a demand for the frequent switching of multiple screen monitors for spatial profile optimization using machine learning methods. To address these issues, we transferred from Camera Link to GigE Vision cameras for readout screens [1]. We developed camera control software using open source libraries to integrate various vendors. A grabbed image is stored in the file server, and properties, such as camera settings for images and event numbers, are stored in the database. Figure 1 shows the setup for GigE camera control. Switching of multiple screen monitors is controlled by the EMA daemon process with 1 Hz interval. An image and camera properties are communicated via shared memory (SHM).

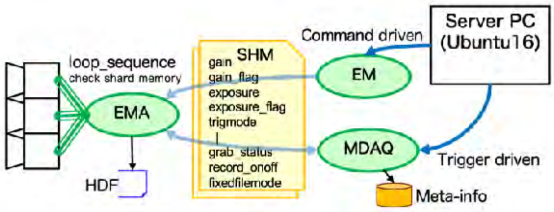

Fig. 1. Schematic of the control system for screen monitor.

· The display wall of the central control room was changed from fifteen 43-inch display panels to eight 65-inch display panels.

· The operation console for beamline control was replaced with four servers. Each server hosts 16 virtual machines corresponding to beamlines. The management of those servers will be transferred from the accelerator control team to the beamline team in FY2024.

· The control system for ID15 was replaced because a new insertion device named IVU-II was installed in SPring-8. This system is based on the EtherCAT protocol with a VME based EtherCAT master for pulse motor control. Figure 2 shows a schematic view of the motor control system. The vacuum system and RF BPM system continue to use VME I/O boards for compatibility with the existing ID control system.

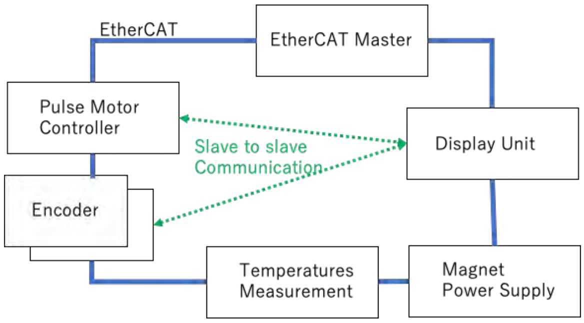

Fig. 2. Schematic view of the control system for an insertion device. The EtherCAT master is used with a VME CPU board.

2.2 Development of the management for the database system

The database system of the accelerator control is working well, but several parts need further modification.

· Backing up and restoration of the parameter database

· Deletion of old tables of database

To manage the parameter database, such as deleting old tables, backing up tables, and restoring from backup, we developed several sets of script to prevent human errors. Figure 3 shows a schematic of the management script in the operation environment. Backup is automatically executed by the cron daemon process, and a dump file is created before execution.

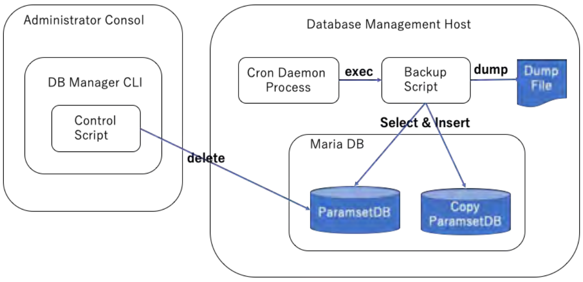

Fig. 3. Schematic of the management and backup script at operation.

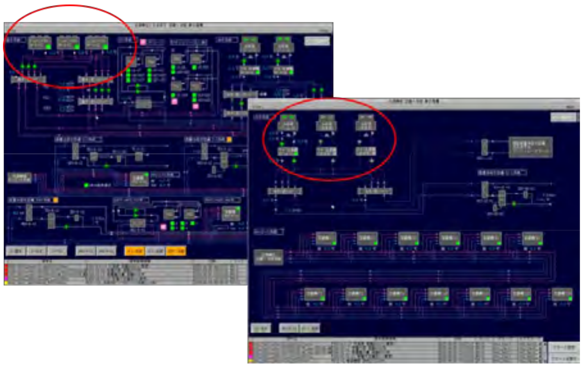

Fig. 4. User interface for SACLA facility. Red circles show installed heat pumps.

2.3 Development of software for the accelerator control system

We plan to replace the operating system of the operator console from SuSE Linux Enterprise to Ubuntu Linux. We use accelerator control GUIs with X-Mate graphic builder on SuSE Linux Enterprise 11 and GUIs with the Qt framework on SuSE Linux Enterprise 15. We will move to Ubuntu 22 running with X-Mate and Qt. In advance of replacing the operating system, we developed the following.

· X-Mate graphic builder for Ubuntu 22 to keep existing GUIs

· Qt plug-in for accelerator control for ease of use

We tried to use a Qt plug-in to modify the GUIs of the SACLA facility as a test case because several sets of heat pumps were installed in the SACLA utility. Figure 4 shows GUIs for the SACLA facility.

We will start to replace the operating system during the next summer shutdown period.

To avoid the end of software support of Ubuntu 16, we developed the following device drivers with Ubuntu 22 for equipment control.

· Trigger Delay for MTCA.4

· AD/DA for MTCA.4

· Trigger Delay board for PCI Express

· ADC readout board for PCI Express

· EtherCAT Master for MTCA.4 and PCI Express

These device drivers will be used in the SPring-8-II project.

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Reference:

[1] Kiyomichi, A. et al. (2023). *Proceedings of the 20th Annual Meeting of Particle Accelerator Society of Japan*, Funahashi, Japan, Aug. 2023, p.494.