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DEVELOPMENT OF NEW TAG SUPPLY SYSTEM FOR DAQ FOR SACLA USER EXPERIMENTS

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Abstract

This paper presents development of a new tag supply system for the data-acquisition (DAQ) system for SACLA user experiments. The X-ray Free-Electron Laser facility in SPring-8, SACLA, has delivered X-ray laser beams to users since March 2012. For the user experiments at SACLA, a dedicated DAQ system has been developed. The DAQ system is currently capable to operate with maximum twelve sensors of multiport charge-coupled device (MPCCD) for X-ray detection. The data of twelve sensors are read out with individual readout modules. We implement a new tag supply system to ensure the reconstruction of the diffraction image of the user experiments. The tag data are used to synchronize the data obtained by SACLA user experiments. One master server receives a signal given by accelerator and the delivery of the tag data follows to five experimental halls at SACLA and some of monitors at SACLA accelerator. We employ dedicated communication lines to deliver the tag data. The longest distance to deliver the tag data is about one kilometre. The new tag supply system has been operating stably since April, 2014.

INTRODUCTIONS

SPring-8 Angstrom Compact Free Electron Laser (SACLA) is designed to generate an X-ray free electron laser (XFEL) with a wavelength as short as 0.062 nm [1]. The accelerator commissioning began in February, 2011. The shortest wavelength, 0.063 nm, was achieved in June 2012 [2]. The characteristics of an XFEL, such as the high-peak brilliance, perfect spatial coherence, and an ultra-fast X-ray pulse shorter than 30 fs will open up wide opportunities in a variety of scientific fields. SACLA has been delivering an XFEL beam to public user experiments since March, 2012. A dedicated data-acquisition (DAQ) system for SACLA user experiments has been developed. The current DAQ system is capable to operate with maximum twelve sensors of multiport charge-coupled device (MPCCD) for X-ray detection. And the data of ten sensors are read out with individual readout modules. The collected data are needed to synchronize each other to form the X-ray image observed with MPCCD. We had resynchronized trigger counters each time we change the experimental setup. Now we have implemented the tag number in the distributed front-end system to re-synchronize the individual data.

In the following section, we briefly describe the SACLA DAQ system. Then new tag supply system is discussed for its characteristics and network topology. The illustrations of individual equipment of the tag supply system follows.

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SACLA DAQ SYSTEM

An X-ray laser is generated as a pulsed beam by Self-Amplification of Spontaneous Emission (SASE) at SACLA. It results in fluctuations of the X-ray laser characteristics, such as the pulse intensity, spectrum, etc. In many experiments, a single shot of the X-ray pulse will damage the sample specimen. To analyze the experimental results taking them into account, the data and the beam shot must be tagged and associated with each other. The shot-by-shot DAQ is indispensable for correlating the recorded data with the specimen characteristics, such as orientation, size, etc. Most of the experiments produce one-dimensional (1D) data, such as a pulse shape from a waveform digitizer, and two-dimensional (2D) data from optical cameras or MPCCD, specially developed for SACLA [3] for X-ray imaging. With 12 MPCCD sensors operating simultaneously at the 60 Hz operation cycle, data rates reach 5 Gbps. The beamlime optical components consist of mirrors, a monochromator, attenuators, and beam monitors for intensity, position and arrival time.

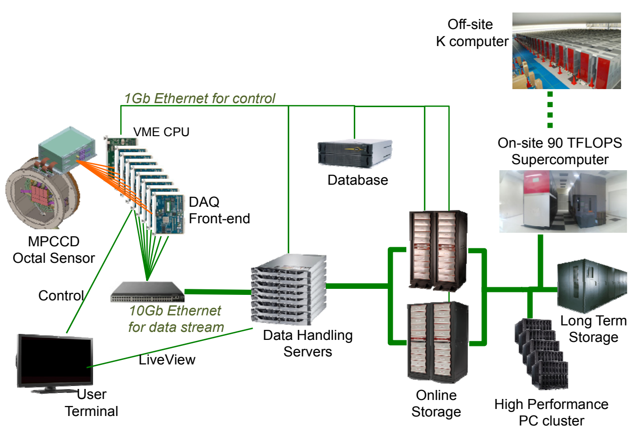

Figure 1: A schematic view of the DAQ system for user experiments at SACLA as of May, 2014.

Figure 1 shows the schematic of the DAQ system for the SACLA user experiments. The system overview is described elsewhere [4]. It consists of front-end electronics and computers, trigger distributors/counters, control and monitor systems, data-handling servers, relational databases, and hierarchical storage. The user network is indirectly connected to the DAQ network via a firewall, so that users may attach their own instruments to the DAQ system in a coordinated manner. This will add flexibility to the DAQ system.

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For experiments that require data preprocessing or data mining by high-performance computers for on-line data evaluation, the data can be transferred to a PC cluster, with 13 TFLOPS and high performance I/O storage (8 GB/s). In 2014, a 90 TFLOPS supercomputer was added to increase the analysis power.

NEW TAG SUPPLY SYSTEM

The DAQ setup should be changed according to the user because the experimental apparatus and setup conditions are different user by user. We need to re-synchronize trigger counters each time we change the experimental setup. Furthermore, the trigger counter may suffer from interference due to noise on the trigger signal or other electrical disturbances. To reduce the cost for re-synchronization of the tag number in the distributed front-end system, we have developed the tag-data-master/distributer/receiver modules to replace the present individual trigger counter systems. Below we briefly summarise the tag supply system and then explain individual modules of tag supply system.

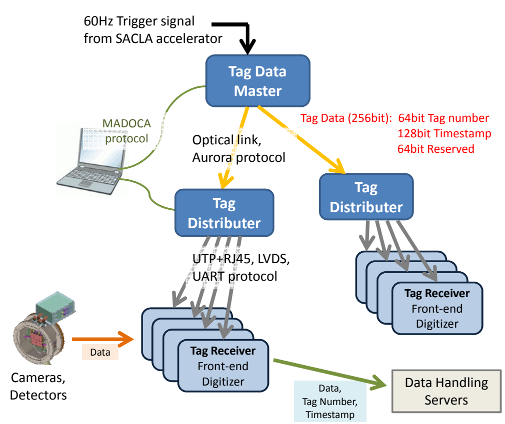

Figure 2: A schematic view of the tag data supply system.

Overview of New Tag Supply System

Figure 2 shows the schematic view of the tag supply system. With the tag-data-master/distributor/receiver modules we can automatically embed the identical tag-number for the same beam shot into the data of the system. A re-synchronization procedure of the tag-number for trigger counters would not be necessary, even if the detector configuration was changed. We employ tree network topology for the tag data supply to have robustness and to achieve high reliable operation of the tag data transfer. With the network topology, part of the system still can supply tag data even if one of modules in the system has some problem. A tag-data-distributor module is installed in each bunch of the racks for experimental equipment. And the one of the tag-data-distributor modules is used for a monitor system located in the SACLA accelerator. The longest distance to deliver the tag data is about one kilometre. Hence we employ optical connection between the tag-data-master and tag-data-distributor modules.

The tag-data-master and tag-distributer modules have an embedded Linux system running on an ARM CPU. MADOCA framework [5] is running on those systems so that they could be controlled directly with the MADOCA command protocol. The required characteristics of the tag data supply system are summarized in Table 1. Next we will discuss the sequence of tag data supply operation.

Table 1: Characteristics of Tag Supply System

Item	Value
Repetition frequency	60Hz
Maximum repetition frequency	300Hz
Longest distance to send tag data	1km
Control framework	MADOCA
Length of tag data	256bits

Sequence of Operation

The timing chart of the tag data supply system is illustrated in Figure 3. Once the trigger signal delivered by the SACLA accelerator timing system fires, then the tag-data-master module generates the tag-number and timestamp data in a predetermined 256 bits format. These tag data are transmitted to the multiple tag-data-distributer modules via optical connection by the Aurora protocol. The tag-data-distributor module replies the status of the tag data reception. If the tag-data-distributor module succeeds in the normal receive of the tag data from the tag-data-master module, the tag-data-distributor transfers the tag data to the front-end digitizer modules, the tag-data-receivers. The tag-data-receiver module replies the status of the tag data transfer to the tag-data-distributor module. All of the above sequence has to be finished within 15msec, before the XFEL beam arrival.

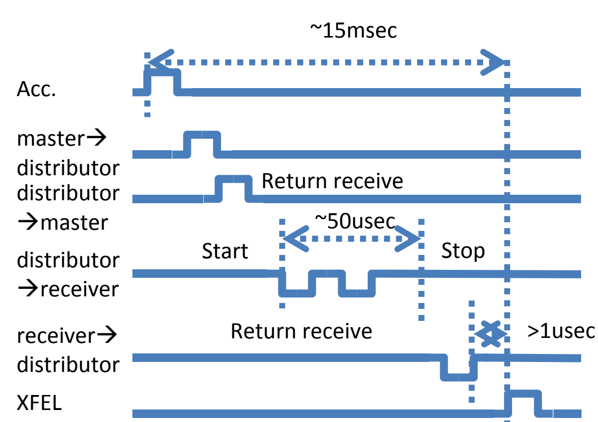

Figure 3: A schematic view of the tag data supply system.

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Tag-data-master Module

Only the tag-data-master module can generate the tag-number and timestamp data to the tag supply system. The tag-data-master module uses COTS as possible and consists of TB-7K-325T-IMG, TB-7Z-020-EMC and TB-BD-FMC-OPT4 [6]. TB-7K-325T-IMG receives the accelerator signal and manages tag supply sequence. TB-7Z-202-EMC communicates with TB-7K-325T-IMG and is implemented embedded Linux to manage MADOCA control functions via Ethernet. TB-BD-FMC-OPT4 is used to distribute tag data via optical communication. There are four optical communication ports.

Tag-data-distributor Module

The tag-data-distributor module receives tag data from the tag-data-master via optical communication and spread out the tag data to tag-data-receiver modules via an unshielded twisted-pair (UTP) cable with an RJ45 connector or camera link cable. We employ low voltage differential signalling (LVDS) for tag data transfer via UTP and camera link cables to have robustness against noise. We also employ universal asynchronous receiver transmitter (UART) for the communication protocols of the UTP and camera link cables. A tag-data-distributor module sends tag data to a tag-data-receiver module and then the tag-data-receiver module replies the result of the tag data reception. If it fails, the tag-data-distributor module can resend the tag data only for one time.

The tag-data-distributor module has four SFP ports, one for input and others for outputs. The tag-data-distributor module has a functionality of cascade chain for optical connection to transfer the tag data. The tag-data-distributor module also has 16 ports with RJ-45 connectors and ten ports with camera link connectors to supply tag data to tag-data-receive modules. Each of ports can delay tag data outputs up to 100msec with the resolution of 100μsec, to calibrate the timing to attach the tag data into data obtained by front-end digitizer modules.

Tag-data-receiver Module

We have developed four types of tag-data-receiver modules. Two modules are for camera data readout. One module is to handle the tag data in VME bus system. And the last type of module is to give the tag data to computers via PCI express interface.

The new tag supply system has been installed since April 2014. Figure 4 shows one example of the tag-data-distributor and tag-data-receiver modules installation.

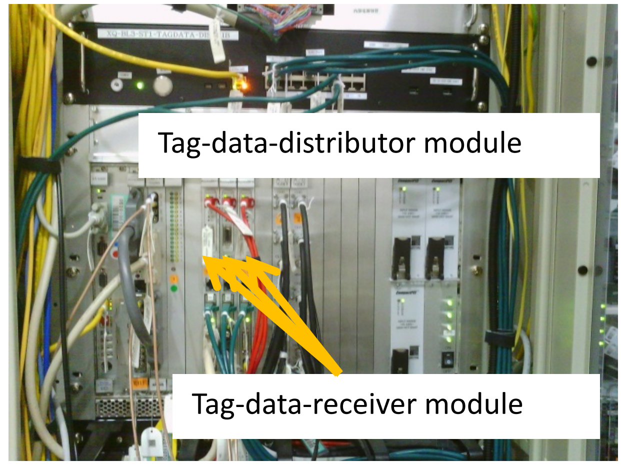

Figure 4: An example of the installation of tag-data-distributor and tag-data-receiver modules.

CONCLUSION

We have developed a new tag supply system for the DAQ system dedicated for SACLA user experiments. Various modules such as tag-data-master and tag-data-distributor modules are made and connected with tree topology. The new tag supply system has launched and has been operating stably since April, 2014.

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