SACLA
Beam Performance

During the period from April 2020 to the summer shutdown in August 2020, SACLA user experiments were severely affected by the global outbreak of COVID-19. Many of the experiments were cancelled not only by overseas users but also by domestic users. Even during this period, SACLA and SPring-8 accelerators were kept in operation to deliver X-rays to specially permitted experiments and R&D, contributing to a victory in the battle against the coronavirus pandemic. The above period was efficiently utilized for finalizing SACLA injection (beam injection from the SACLA to the storage ring) at a level applicable for user operations. After the long summer shutdown period, we continued test use of SACLA injection in regular user operations to confirm the stability of the performance over a long period of time.

At this point, there were still two major problems remaining. The first major problem is the purity deterioration of isolated bunches used for precise measurements of the time spectra. The purity deterioration is caused by dust electrons that are injected a few ns to tens of ns later than the main injection beam. We have investigated how the dust electrons are formed after the main beam and identified the following mechanism. Part of the electron beam is decelerated by a L-band APS cavity at the end of the buncher section and runs back towards the electron gun. Some of these electrons are captured by the upstream RF cavities and accelerated again with a distributed time delay from the main beam, forming dust electrons. A special dust electron sweeper was thus installed between the L-band correction and APS cavities to clean up the injection beam by kicking off the back-running electrons. This dust electron sweeper was able to efficiently purify the injection beam. Furthermore, in combination with the bunch cleaning system installed in the ring, highly purified isolated bunches have been constantly delivered to user experiments. Figure 1 illustrates the dust electron sweeper installed in the SACLA buncher section.

The second major problem is how to constantly deliver high-performance XFEL to experimental users by multi-beamline operations keeping top-up beam injections to the ring. During top-up operations, we can neither stop SACLA linac operations nor perform destructive measurements of beam profiles and RF phases, which severely restricts accelerator tuning.

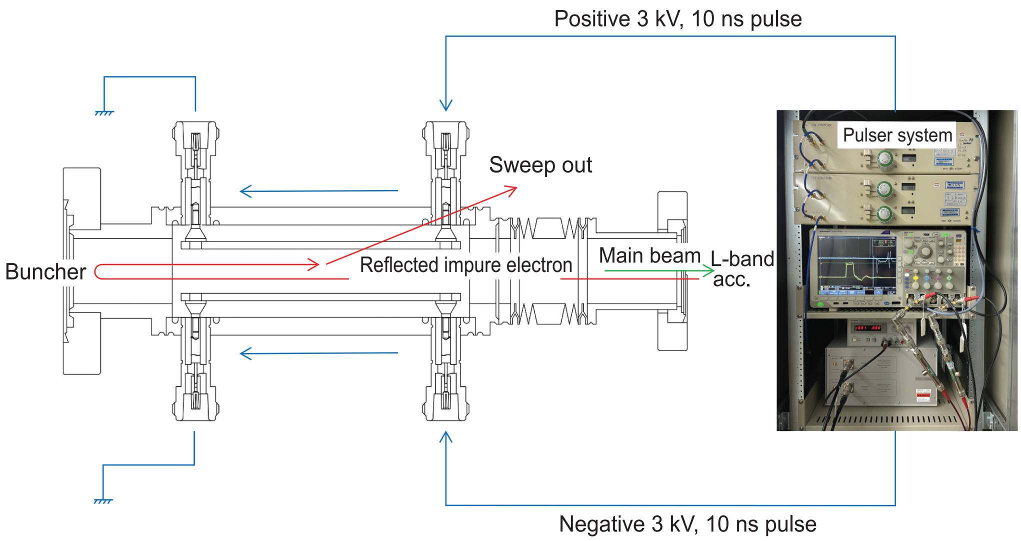

Fig. 1. Schematic of the dust electron sweeper installed in the SACLA buncher section.

To solve this problem, we should markedly improve the efficiency and transparency of accelerator tuning. As a first step towards highly efficient accelerator tuning to reproduce the XFEL performance, we have developed a model-free tuning tool using a Gaussian process regression (GPR) optimizer. To clearly define the target XFEL performance as a numerical value, several XFEL characteristics such as pulse energy, spectral bandwidth, and laser profile are numerated and linearly combined with arbitrary weights to form an objective function. We have also built a shot-by-shot data acquisition system that collects the necessary data from the photon beam diagnostic system, so that the GPR optimizer utilizes shot-by-shot data representing XFEL characteristics. The developed tuning tool is now in daily accelerator operations. As shown in Fig. 2, the developed optimizer can reproduce XFEL efficiently.

The performance of SXFEL at BL1 has been at a low level owing to the serious demagnetization of three undulators by electron bombardment. Although it is difficult to apply drastic measures in a short period of time, we plan to implement the following measures in March 2021. The two old in-vacuum undulators of the three will be removed, and one in-vacuum undulator will be moved from each of BL2 and BL3. The field distribution of the undulator not to be replaced will be adjusted on the basis of the SAFARI measurement result to reduce the phase error. With this improvement, we expect to be able to recover the pulse energy of SXFEL to about 50 μJ at a photon energy of 100 eV.

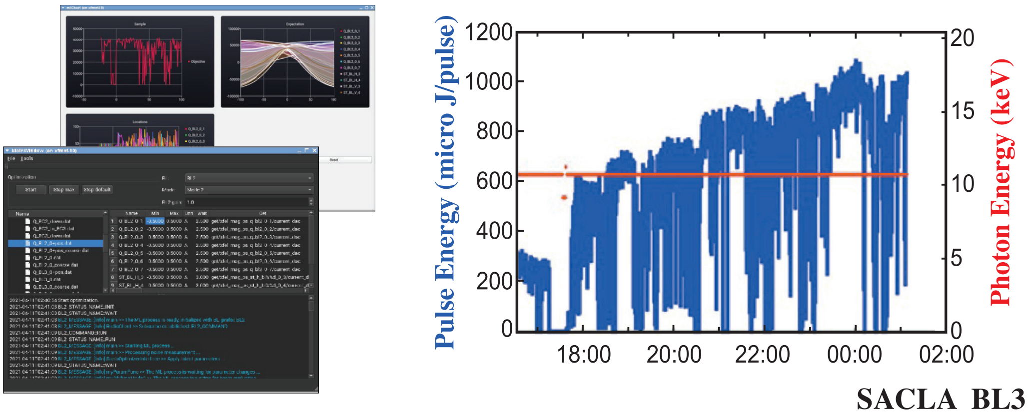

Fig. 2. Progress of pulse energy with the GPR optimizer during the startup period (right) and displays of the developed GPR tool kit.

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