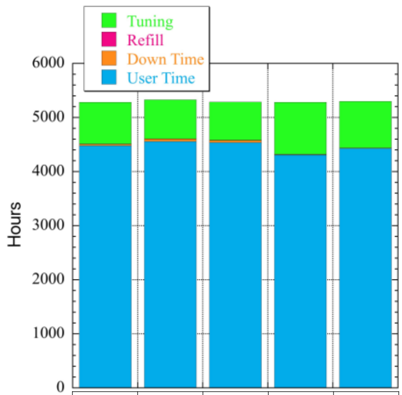
3. Operation Status

1. SPring-8

Figure 1 highlights the operation statistics for the last five fiscal years. In FY2021, the total operation time for the storage ring was 5,300 hours. 4,440 hours was allocated for user operations. The downtime due to machine troubles was 10 hours in addition to the planned downtime of 3.1 hours for switching the user operation modes with different patterns. The considerably short downtime led to an excellent user availability of 99.7%. More importantly, the mean time between failures (MTBF) of 553.4 hours was achieved by reducing the frequency of machine failures this year. Both the user availability and the MTBF this year were one of the highest since user operations of SPring-8 started in 1997.

Since the user time operation of SPring-8 with full-energy direct beam injection from the 8 GeV linear accelerator (linac) of SACLA started in 2020, the new injector has proved its high capability of a stable and reliable beam injection to the storage ring. In FY2021, 99.6% of the achieved user time (4426.9 hours) was operated in the top-up mode with the stored beam current of 100 mA. The top-up operation availability is now in the same or even better level than the original beam injection setup by the 1 GeV linac and 8 GeV booster synchrotron as indicated in Fig. 2. The injection from the SACLA linear accelerator in FY2020 and 2021 resulted in the availability of around 99.5%, which is slightly higher than the average obtained in FY2012 to 2019.



	FY2017	FY2018	FY2019	FY2020	FY2021
Acc. Operation Time	5281.6	5329.8	5285.7	5284.6	5300.2
SR Operation Time	5270.4	5316.7	5271.2	5274.8	5300.2
Tuning&Study (Acc.&BL)	769.6	721.8	701.7	964.6	860.2
Refill	4.6	5.3	5.6	3.6	3.1
Down Time	28.7	43.1	40.5	7.4	10.0
Mean Time between Failures	194.7	168.9	206.3	718.2	553.4
Achieved User Time	4478.7	4559.6	4537.9	4309.0	4426.9
Planning User Time	4512.0	4608.0	4584.0	4464.0	4440.0
Availability (%)	99.3	98.9	99.0	99.7	99.7

Fig. 1. SPring-8 operation statistics for the past five years.

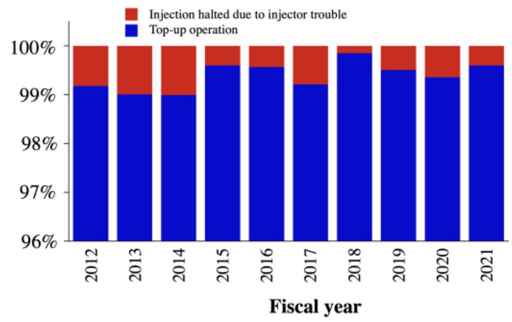


Fig. 2. SPring-8 top-up operation statistics for the past ten years. The injection from the SACLA linac started in FY2020.

The high operation statistics such as the operation availability, MTBF, and top-up operation availability can become worse anytime. In particular, signs of aging of the accelerator components have been extensively observed in recent years so that we have developed and implemented maintenance strategies based on thorough investigations of potential problems. Although these treatments have so far worked well, it is clearly necessary to completely renew most of the components before a big machine failure occurs.

2. SACLA

Since September 2020, the linear accelerator of SACLA has been used not only to drive XFEL beamlines, but also to provide 8 GeV electron beams to the SPring-8 storage ring. The total operating time in FY2021 was 5,814 hours, which is 99.5% of the initial plan. Although there were still several cancellations of user experiments, the impact of COVID-19 was much smaller than in FY2020.

Figure 3 is a schematic layout of the SACLA facility. There are three FEL beamlines (BL1, BL2, and BL3) in SACLA. BL2 and BL3 are X-ray FELs and BL1 is a soft X-ray FEL. BL1 is equipped with a dedicated 800 MeV linear accelerator, which was originally constructed as a prototype accelerator named SCSS. The electron beam of the SACLA main linear accelerator is shared by two XFEL beamlines (BL2 and BL3) and a beam injection line of the SPring-8 storage ring (XSBT) [1, 2]. The beam repetition rate of SACLA is 60 Hz, and electron bunches are distributed pulse by pulse using a kicker magnet [3].

The electron beam energy should be fixed at 8 GeV for beam injection, while the energy is often changed and fine parameter tuning is always needed for the XFEL beamlines. To enable the accelerator tuning for XFELs in parallel with the beam injection, a multi-energy operation scheme was developed at SACLA, in which electron beam energies are changed pulse by pulse [4].

Since the focusing magnets upstream from the kicker are common to all three beam destinations, the transverse beam envelops of BL2, BL3, and XSBT are readjusted downstream of the kicker. To improve accelerator tuning flexibility,

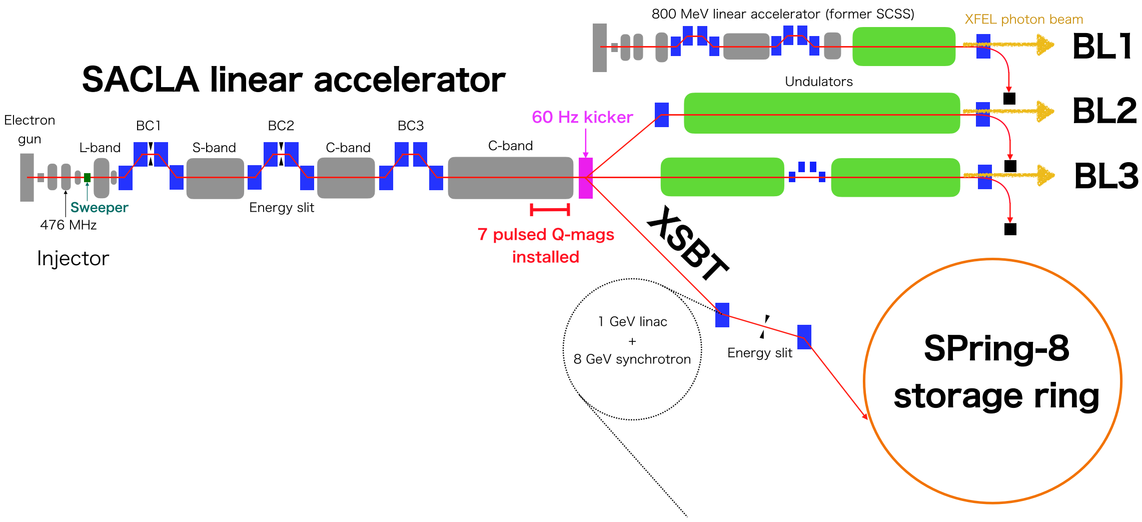


Fig. 3. Schematic layout of SACLA facility.

seven pulsed quadrupole magnets were installed at a C-band main accelerator section in FY2021 (Fig. 4). The pulsed quadrupole magnets can change their magnetic fields at 60 Hz with a stability of 3 ppm (RMS). Although the installation was completed in FY2021, the test of a control system remains and the pulsed operation started in September 2022. Together with another 14 pulsed quadrupole magnets planned to be introduced in FY2022, the transverse beam envelops will be independently controlled for different energy beams of the three destinations.

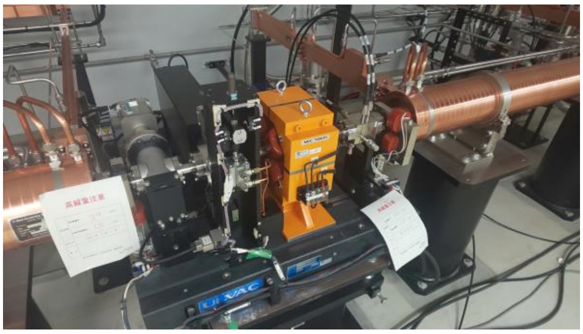


Fig. 4. Pulsed quadrupole magnet installed at a C-band main accelerator section.

Regarding diagnostics, a new single-shot spectrometer with a resolution of a few eV was introduced for BL3 [5]. This newly developed spectrometer gives pulse-by-pulse spectral brightness, and a machine-learning-based optimizer of accelerator parameters can now directly maximize the spectral brightness of XFEL [6].

Watanabe Takahiro[*1], Takano Shiro[*1], and Hara Toru[*2]

[*1] Accelerator Division, JASRI

[*2] RIKEN SPring-8 Center

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