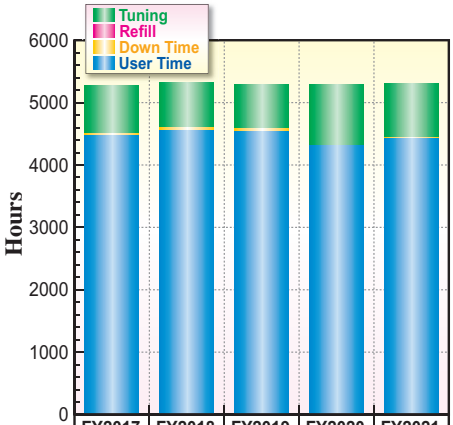
II. Machine Operation

The operation statistics for the last five fiscal years are shown in Fig. 1. The linear accelerator of the X-ray Free-Electron Laser (XFEL) facility, SACLA, has been used as a full-time injector for the SPring-8 storage ring since 2020. In FY2021, all the user time was taken up by beam accumulation and topping-up by beam injecting from the SACLA linac. The operation time of the storage ring was 5300.2 h, 83.5% of which (4426.9 h) was devoted to the SR experiments. This excellent figure for the user time represents a storage ring availability of 99.7%. The total downtime caused by failures amounted to 10.0 h, accounting for 0.22% of the total user time. For 99.6% of the user time in FY2021, the stored beam current stayed at 100 mA by the top-up operation wherein the stored beam was filled up on demand at any time. Extreme stability of the light source intensity of better than 0.1% was achieved by the top-up operation.



	FY2017	FY2018	FY2019	FY2020	FY2021
Accelerator Operation Time	5281.6	5329.8	5285.7	5284.6	5300.2
Storage Ring 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
Planned 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. Operation statistics for five most recent fiscal years.

Table 1. Operation modes in FY2021

	Single bunch current (mA)	Share of operation time (%)
203 bunches		41.1
4 bunch-train × 84		3.2
11 bunch-train × 29		30.8
1/7-filling + 5 single bunches	3	8.1
2/29-filling + 26 single bunches	1.4	0
1/14-filling + 12 single bunches	1.6	3.2
4/58-filling + 53 single bunches	1.0	0
406 × 11/29-filling + 1 single bunch	5	13.5

The variety of operation modes for the SR experiments is one of the characteristics of SPring-8. The operation modes are classified into two types, the several-bunch and hybrid-filling modes. The several-bunch mode consists of equally spaced bunches or trains of bunches such as 203 bunches or 29 trains of 11 bunches. The hybrid-filling mode is composed of a long train of bunches and isolated single bunches. The operation modes of SPring-8 are listed in Table 1 with the share of each operation mode in FY2021. In the operation with beam injection from the SACLA linac, the spurious bunch sweeping system in the SACLA linac and the bunch cleaning system in the storage ring are activated to maintain a sufficient isolated bunch purity. Table 2 summarizes the beam parameters of the storage ring.

Table 2. Beam parameters of SPring-8 storage ring

Energy [GeV]	8
Number of buckets	2436
Tunes (ν_x / ν_y)	41.14 / 19.325
Current [mA]:	
single bunch	12
multi bunch	100
Bunch length (σ) [psec]	13
Horizontal emittance [nm·rad]	2.4 *
Vertical emittance [pm·rad]	4.8 *
Coupling [%]	0.2
RF Voltage [MV]	14.4 ** ~ 16
Momentum acceptance [%]	3.2 (~256 MeV)
Beam size (σ_x / σ_y)* [μm]	
Long ID section	333 / 7
ID section	316 / 5
BM1 section	94 / 12
BM2 section	100 / 12
Beam divergence ($\sigma_{x'}$ / $\sigma_{y'}$)* [μrad]	
Long ID section	8 / 0.7
ID section	9 / 1.0
BM1 section	58 / 0.5
BM2 section	68 / 0.5
Operational chromaticities (ξ_x / ξ_y)	+2 / +2 ***
Lifetime [hr]:	
100 mA (multi bunch)	~250
1 mA (single bunch)	~30
Horizontal dispersion [m]:	
Long ID section	0.153
ID section	0.146
BM1 section	0.039
BM2 section	0.059
Fast orbit stability (0.1 – 200 Hz) [μm]:	
horizontal (rms)	~4
vertical (rms)	~1

* Assuming 0.2% coupling
** Power saving mode
*** With bunch-by-bunch feedback