Status of Taiwan Light Source

Introduction

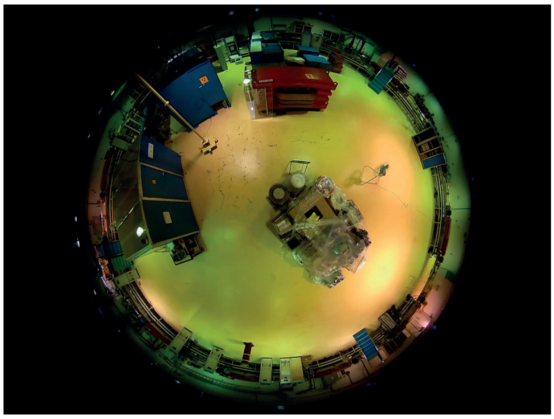
Taiwan Light Source (TLS) has a storage ring of circumference 120 m which operates an electron beam with current up to 360 mA at energy 1.5 GeV. Being a third-generation light source, its storage ring has six-fold symmetry with 6-meter straight sections for injection, RF cavity and insertion devices. As this machine has been in operation for more than two decades, a greater effort for maintenance is required, and high availability and stability are more difficult than previously. However, it still works excellently to deliver high-quality synchrotron light to users, thanks to top-up injection, a SRF module free of high-order modes, traditional and SC insertion devices, and continuous effort from all NSRRC staff.

Machine parameters

Table 1 lists the major beam parameters of the TLS storage ring. To accommodate the demands for increased beam time and increased brightness from the growing user community, not only an SC wavelength shifter located between injection kickers K3 and K4 at the injection section and an SC wiggler situated downstream from the SRF module but also three in-achromat SC wigglers (IASW) have been squeezed in between the bending magnets at the bending sections. Along with traditional insertion devices EPU56, U50, U90 and W200, amazingly nine insertion devices are thus equipped inside the compact storage ring of TLS as the layout in Fig. 1 shows. Table 2 also lists the main parameters of these insertion devices.

Table 1: Beam parameters of the TLS storage ring.

Energy (GeV)	1.5
Number of buckets	200
Current (mA)	360
Bunch length (ps)	31
Horizontal emittance (nm rad)	22
Vertical emittance (pm rad)	88
Tunes (ν_x/ν_y)	7.30/4.17
Vertical (rms) orbit stability (μm)	1
Coupling (%)	0.4
RF voltage (MV)	1.6
Lifetime (h)	6



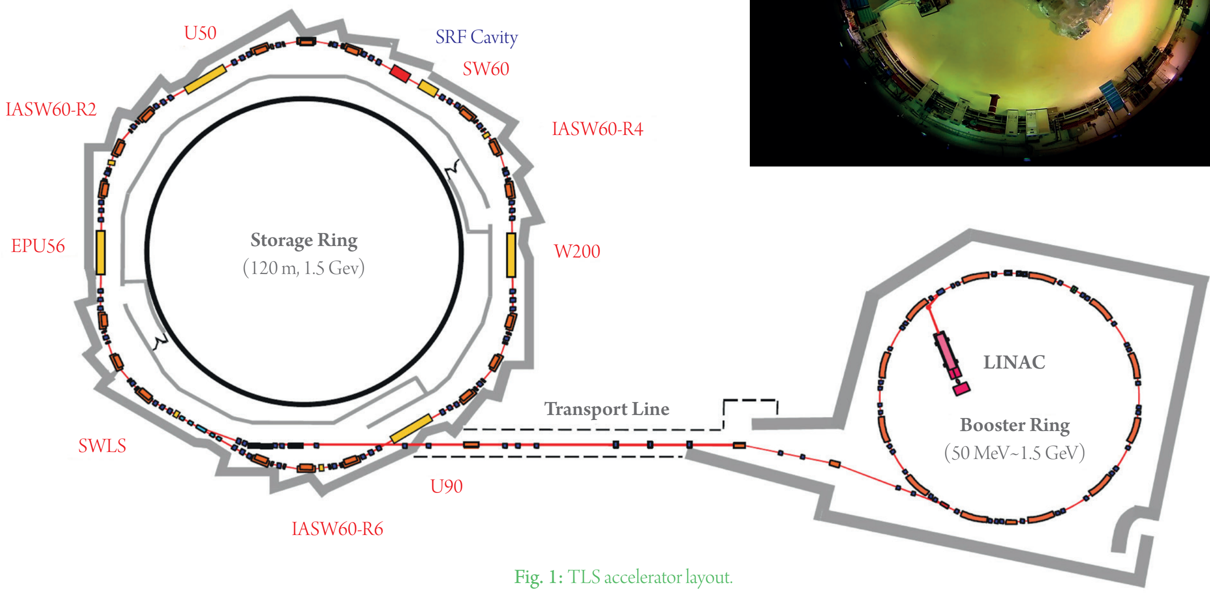


Fig. 1: TLS accelerator layout.

Table 2: Main parameters of insertion devices in the TLS.

	W200	U50	U90	EPU56	SWLS	SW60	IASWA	IASWB	IASWC
Type	hybrid	hybrid	hybrid	pure	SC	SC	SC	SC	SC
λ (mm)	200	50	90	56		60	61	61	61
Photon energy (eV)	800–15k	60–1.5k	5–500	80–1.4k	2k–38k	5k–20k	5k–20k	5k–23k	5k–20k
B_{max} (Tesla)	1.8	0.64	1.245	0.67(0.45)	6	3.2	3.1	3.1	3.1
Installation	12/1994	03/1997	04/1999	09/1999	04/2002	01/2004	12/2005	06/2009	02/2010
Location	sec. 5	sec.3	sec.6	sec.2	sec.1	sec.4	arc sec.6	arc sec.2	arc sec.4

Statistics of machine operation

Taiwan Light Source began operations with top-up injection 200 mA in October 2005; the stored beam current was subsequently raised to 300 mA, raised again to 360 mA in 2010 and was maintained there in the succeeding years. The next aim was to improve the performance of the facility as indicated by availability, mean time between failures (MTBF) and beam stability index. Availability is defined as the ratio of delivered user time to the scheduled user time; MTBF as the ratio of scheduled user time to number of faults, and the beam stability index as the variation of photon intensity shot to shot of the diagnostic beamline with a ratio better than 0.1 %. Together with the scheduled user time and the operating mode, these performance indicators for TLS operation from 2002 to 2015 are summarized in Table 3.

In 2015, the total delivered user time was 5256 h, while the delivered user beam time was 5327 h; the beam availability was thus 98.7 %. Not only the beam availability, but also the MTBF 84.6 h and beam stability index 87.7 % are all worse than the previous two years as the summary year by year shows in Fig. 2. Mostly, some old components aged or even failed in the first three operational months of that year, which adversely affected the operation. They were then either replaced with spares or upgraded to new models so that the beam performance gradually recovered. Table 4 presents the monthly beam- stability index. Figure 4 shows the scheduled user time, beam availability, beam stability index 0.1 %, and MTBF in each month of 2015. The beam performance of the machine in the second half year is obviously much improved.

Table 3: Summary of performance indicators for TLS operation.

Year	Scheduled user time (h)	Availability (%)	MTBF (h)	Operation mode	Beam stability (%) $\Delta I/I_0 < 0.1\%$
2002	4785	95.8%	154.4	Decay	47%
2003	5017	97.2%	313.6	Decay	86%
2004	4235	97.5%	132.3	Decay	85%
2005	4576	96.8%	81.7	Decay/Top-up	76%
2006	5552	96.7%	40.8	Top-up	81.3%
2007	5219	98.1%	85.6	Top-up	98.1%
2008	5726	97.9%	112.3	Top-up	98.5%
2009	5402	97.9%	77.2	Top-up	89.2%
2010	5286	97.4%	81.3	Top-up	82.1%
2011	5818	95.9%	55.4	Top-up	89.4%
2012	5197	98.1%	44.8	Top-up	91.4%
2013	5178	99.5%	140	Top-up	95.5%
2014	5645	99.4%	182.1	Top-up	94.1%
2015	5327	98.7%	84.6	Top-up	87.7%

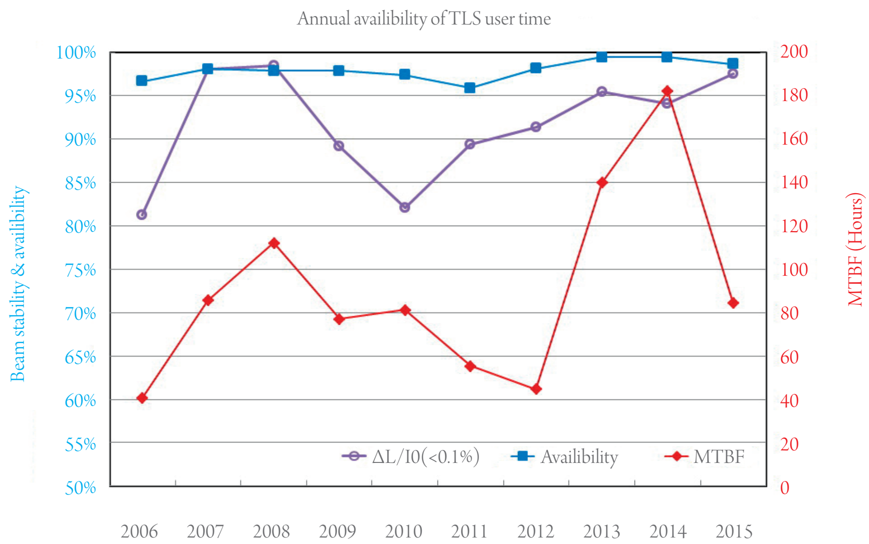


Fig. 2: Summary of the beam-stability index at 0.1 %, beam availability and MTBF from 2006 to 2015.

Table 4: Monthly beam-stability index of the TLS. The power supplies of three quadrupole families were attached to a power regulator in July and thus improved the beam stability.

Month	< 0.2 %	< 0.1 %	Month	< 0.2 %	< 0.1 %
1			7	99.1 %	98.6 %
2	90.2 %	75.1 %	8	99.2 %	98.5 %
3	93.8 %	70.5 %	9	99.6 %	97.2 %
4	97.4 %	67.7 %	10	99.6 %	97.7 %
5	97.9 %	82.6 %	11	99.8 %	97.9 %
6	97.9 %	84.4 %	12	99.9 %	97.9 %

Table 5: Summary of major trip events.

Subsystem	Event	Beam trips
others	partial beam loss without clear reason	19
others	sag of electric power	4
others	earthquake	2
others	multiple events at the same time	2
Linac	incorrect firing of kickers	9
Linac	aged thyrotron tube and cathode	4
I&C	transverse and longitudinal feedback	5

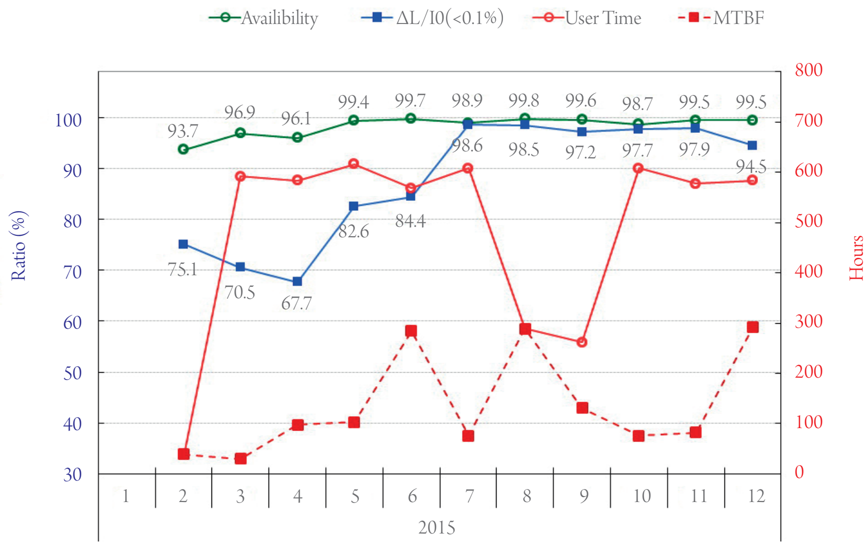


Fig. 3: Monthly user time and beam performance indicators of the TLS in 2015.

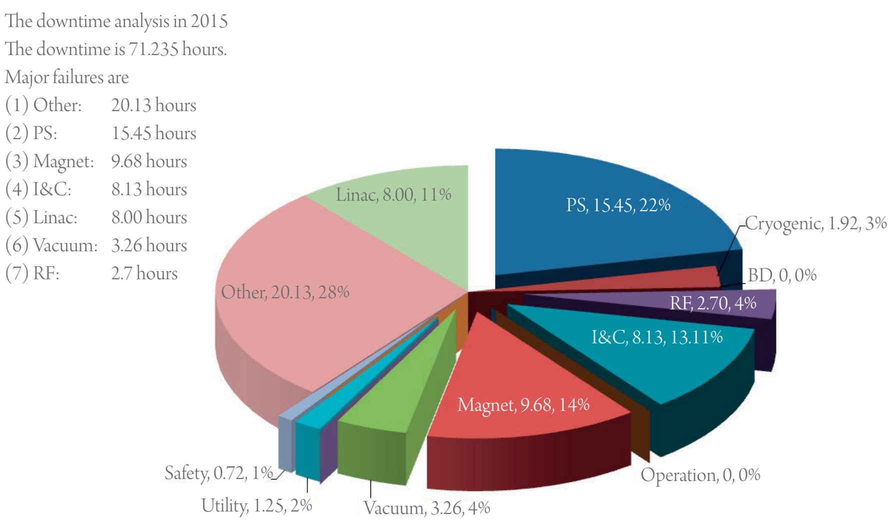


Fig. 4: Downtime of each subsystem in 2015.

Replacement and improvement of main components in 2015

Linac:

1. The cathode and thyrotron tube were replaced with new components.
2. The circuit performance for noise rejection of the TL kicker was improved.

Power supplies of magnets:

1. Some crates for power supplies of correctors were replaced with new ones.
2. Quadrupole power supplies (QPS) of families 1, 2 and 3 were upgraded to a new model.

Instruments and controls:

1. The power amplifier of the transverse feedback system was refreshed to a new model.
2. The control interfaces of QPS were updated.

Downtime and failure analysis

In 2015, in total there were 63 beam trips with an average recovery time 1.13 h for each trip event. As Table 5 illustrates, 27 beam trips were attributed to others, including partial beam loss and sag of electric power, 13 faults to the injection system, including incorrect firing of kickers and aged cathode and thyrotron tube, and four to the transverse feedback system because of parameter optimization at the beginning of 2015.

The downtime of each subsystem is shown in Fig. 4. In a comparison with the trip events listed in Table 5, some subsystems are shown to have a low trip rate but a long recovery period. For example, there were only two trips on the superconductivity magnets, but nine-hour downtime was required. Another case is the power-supply system that took 15-hour downtime after four trips.

In 2014, TLS suffered much from 20-Hz vibration during refilling of liquid helium to superconducting wiggler SW6, which perturbed or even tripped the SRF system. This effect was temporarily solved on modifying the control algorithm of the RF tuner through applying a stepping frequency less than 20 Hz on the tuner motor. In 2015, the SRF module was processed at various tuning angles for large beam currents before the TLS was opened to users. This action completely solved the gas-loading problem on the SRF cavity; the 20-Hz perturbation is thus no longer a problem for TLS operation. (Reported by Chang-Hor Kuo)