Accelerator Availability and Reliability

Machine Parameters

Taiwan Light Source (TLS) has a 1.5 GeV electron storage ring of circumference 120 m, and 6-fold symmetry, of which every straight section of length 6 m is occupied by an insertion device. The major beam parameters of the storage ring are presented in Table 1. A superconducting wavelength shifter is located between injection kickers K3 and K4 in the injection section. Downstream from the SRF cavity section is situated a superconducting wiggler; the remaining sections are equipped with EPU56, U50, U90 and W200. Figure 1 shows the layout of the TLS accelerator. To accommodate the increasing demands for beam time and higher brightness from the NSRRC user community, three identical superconducting wigglers (IASW) were built and installed at locations between the first two dipole magnets of the second, fourth and sixth TBA cells. The main parameters of the insertion devices are listed in Table 2.

Table 1: Beam parameters of the 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

Statistics of the Machine Operation

Operation of Taiwan Light Source in a top-up mode with injection 200 mA began in October 2005; the stored top-up beam current was subsequently increased to 300 mA, and in 2010 to 360 mA. The per-

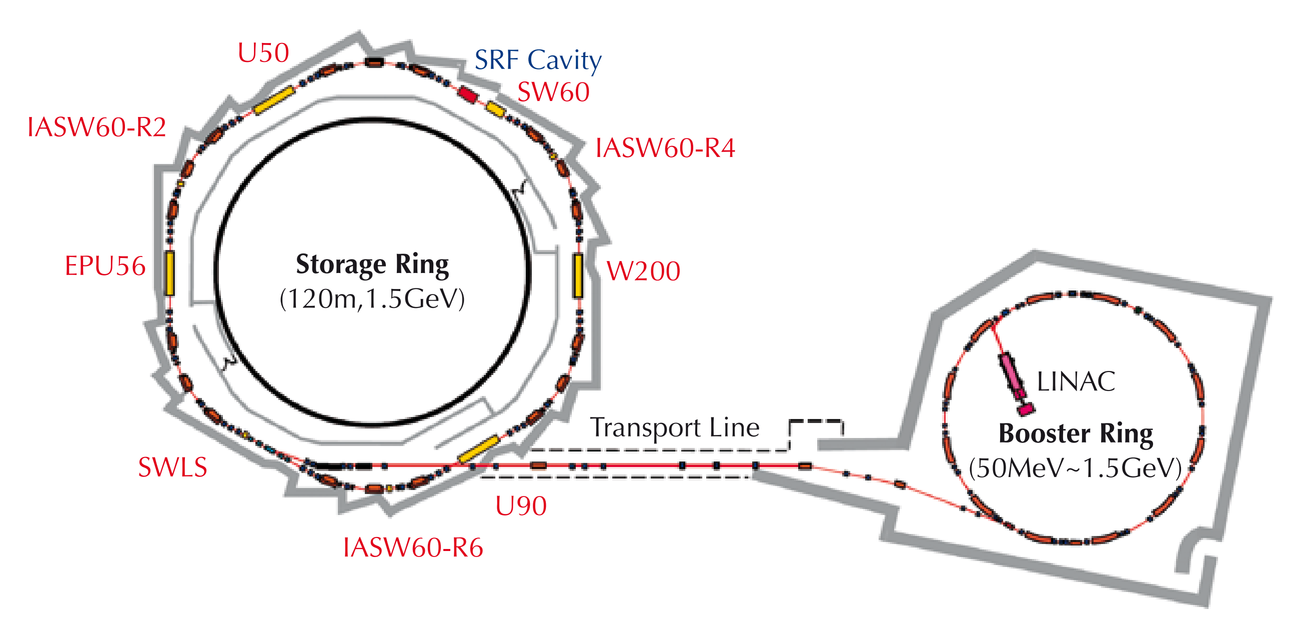

Fig. 1: Layout of the TLS accelerator.

Table 2: Main parameters of insertion devices in 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

formance of this facility is assessed by its availability, the mean time between failures (MTBF) and the beam stability index. The availability is defined as the ratio of delivered user time divided by the scheduled user time. MTBF is defined as the ratio of scheduled user time divided by number of faults. The reliability of the accelerator is measured according to the MTBF. The beam instability index is measured according to the variation (shot-shot) of the photon intensity of the diagnostic beamline. The MTBF continuously decreased in 2011 and 2012. A summary of the operational performance of TLS from 2002 to 2012 is presented in Table 3.

The scheduled user beam time was 5,178 hours in 2013; the delivered beam time was 5,150 hours. We attained a beam availability 99.5 % and set the best record in the history of TLS user operation. The MTBF was 140 hours and the mean time to recover was 0.65 hour according to the 37 faults in total. Figure 2 depicts a summary of machine operation from 2006 to 2013.

Table 3: Summary of TLS operation performance.

Year	Scheduled user time (h)	Availability	MTBF (h)	Operating mode	Beam stability $\Delta I/I_0 < 0.1$ %
2002	4,785	95.8 %	154.4	Decay	47.0 %
2003	5,017	97.2 %	313.6	Decay	86.0 %
2004	4,235	97.5 %	132.3	Decay	85.0 %
2005	4,576	96.8 %	81.7	Decay/Top-up	76.0 %
2006	5,552	96.7 %	40.8	Top-up	81.3 %
2007	5,219	98.1 %	85.6	Top-up	39.9 %
2008	5,726	97.9 %	112.3	Top-up	95.7 %
2009	5,402	97.9 %	77.2	Top-up	89.2 %
2010	5,286	97.4 %	81.3	Top-up	82.1 %
2011	5,818	95.9 %	55.4	Top-up	89.4 %
2012	5,197	98.1 %	44.8	Top-up	91.4 %
2013	5,178	99.5 %	140	Top-up	95.5 %

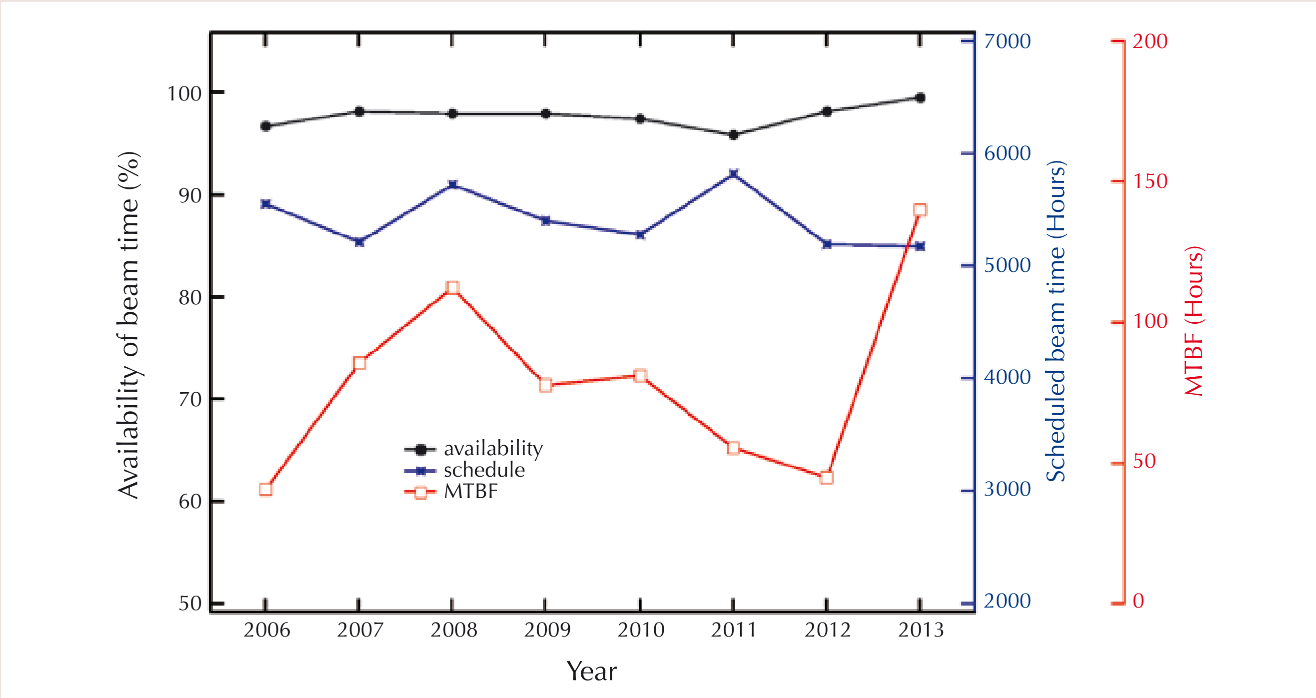

Fig. 2: Summary of delivered beam hours, availability and MTBF from 2006 to 2013.

Downtime and Failure Analysis

In 2013, 37 faults in total that contributed to downtime lasted 24.2 hours, which occupied about 86.3 % of total downtime. Table 4 gives a brief summary of the failures.

We deduced the cause of a partial beam loss during the injection period as resulting from a strong crosstalk between two loops of transverse bunch-by-bunch feedbacks. The two fully decoupled bunch-by-bunch feedback loops work well, and now provide adequate suppression of those beam instabilities. The partial beam loss of this kind has disappeared, whereas 39 faults were attributed to phenomena of this kind in 2012.

The U90 controller and encoders have been upgraded to rectify the process hanging problem of that U90 controller, which occurred frequently and amounted to 8.88 hours downtime in 2012.

The problem of a rapid change of the tuner phase related to Robinson instability has been solved on

Table 4: Summary of failures in 2013.

	I&C	OP	Linac	RF		PS
Number	2	1	1	3	3	3
Cause	BPM synchronized	Human error	PS fault	Reflection power	Interlock	SW6 overload (1) R12QPS2 overload (2)
	Utility	**Magnet**	**Other**			
Number	1	1	6	7	3	5 (1)
Cause	Temperature high	Quench	Instability	Earth quake	Voltage sag	Vibration (unknown)

increasing the operational bandwidth of the low-level RF; the detailed mechanism of the phenomena have been studied and demonstrated in 2013. The statistics of the downtime and subsystem faults are shown in Fig. 3.

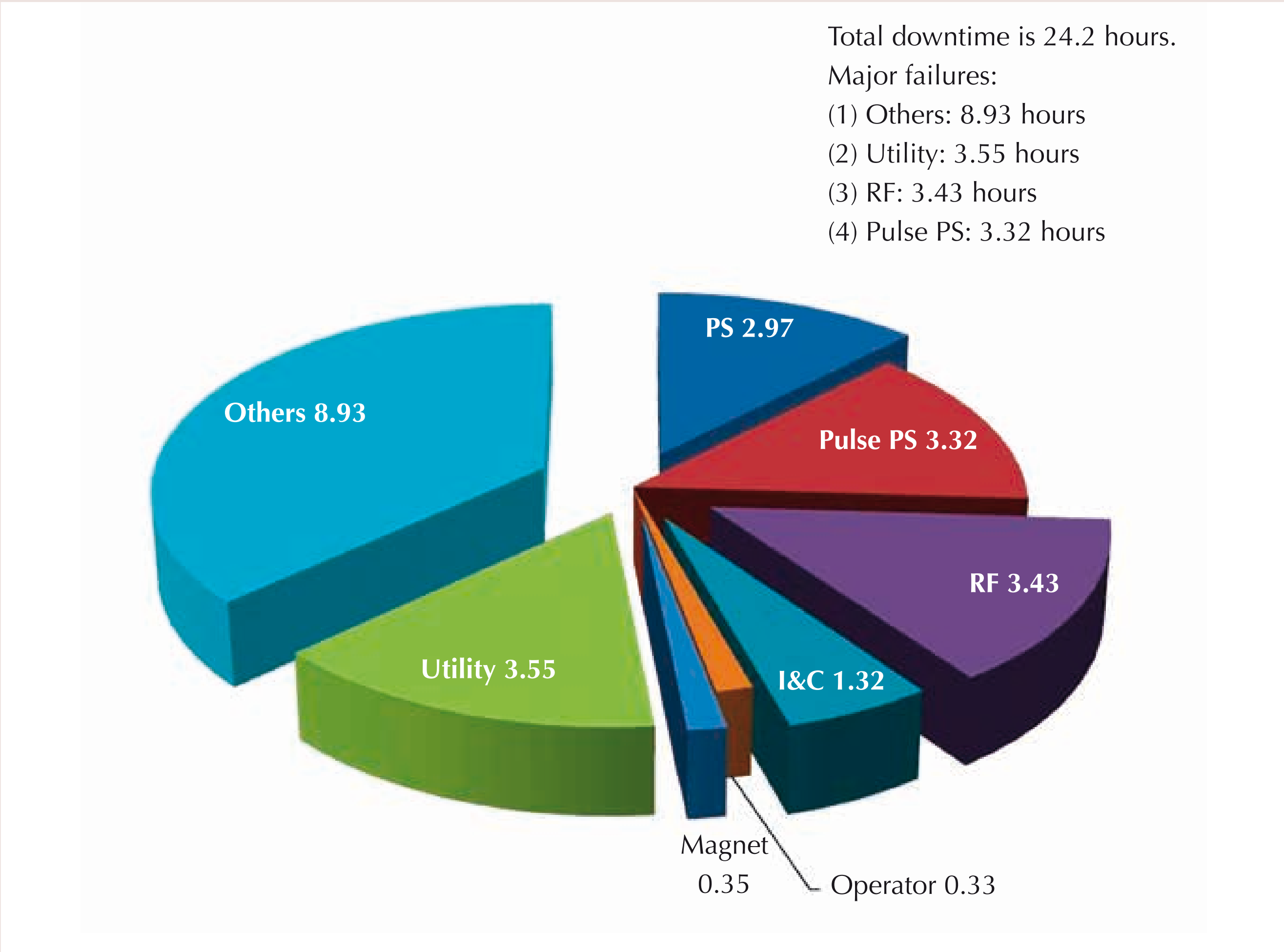

Fig. 3: Statistics of downtime and subsystem faults in 2013.

Beamline for Hard X-ray Photoelectron Spectroscopy

Taiwan Beamline BL12XU at SPring-8 is one of two contract beamlines between NSRRC and Japan Synchrotron Radiation Research Institute (JASRI, Japan). It has an undulator source, a mainline with two branches and a side line (see Fig.1 in the next page). The mainline, which has been fully operational since 2001, is used by many domestic and foreign scientists from Japan, Taiwan, Germany, USA... Inelastic X-ray scattering (IXS) experiments are performed mainly at BL12XU; several other experiments such as high-resolution diffraction or coherent diffractive imaging are also conducted. The side line is dedicated to hard