OPERATIONAL PERFORMANCE OF THE TAIWAN LIGHT SOURCE

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Abstract

The Taiwan light source (TLS) is a 1.5 GeV third generation light source at the National Synchrotron Radiation Research Center (NSRRC) in Taiwan. It has been routinely operated since its opening in 1993. Several major machine upgrade projects have been undertaken and successfully completed in last 5 years, including implementing of digital bunch-by-bunch feedbacks, superconducting accelerating RF cavity, top-up mode injection, etc. The light source now moves forward to its era of mature operation. It delivers more than 5000 hours user time in 2007 with an up-time of more than 98% and a mean time between failures better than 80 hours. Here, we review its annual operational performance with detailed statistics and discuss the possible improvement directions of machine performance.

OVERVIEW

The Taiwan light source (TLS) at the National Synchrotron Radiation Research Center (NSRRC) is a 1.5-GeV third-generation light source, operated routinely since its opening in 1993. The facility had been running at an energy of 1.3 GeV and at 200 mA in a decay-mode before an upgrade took place in 2005. Several major machine upgrades have been undertaken and successfully implemented, including the digital bunch-by-bunch feedback system to suppress couple-bunch instabilities, a superconducting accelerating RF cavity to decrease the impedances of higher-order cavity modes, top-up mode injection to improve the temperature stability of the accelerator as well as instrumentation. As a result, an increased average beam current has been obtained ever since. The machine now is operated steadily with a beam current of 300 mA. For the record, it also has been demonstrated to achieve the target of 360 mA for a long-term stable operation. With such operational history and continuous improvement, the facility has, as recognized, entered an era of mature operation, delivering user beam time of more than 5000 hours in 2007 with an operational up-time greater than 98 percent and a mean time between failures greater than 80 hours. Concurrently, a seven-year construction project for a new 3-GeV light source, the Taiwan Photon Source (TPS), was launched at NSRRC in 2007. To continuously improve the machine stability and reliability of the 1.5-GeV TLS operation with minimum manpower under a decreasing operational budget became a major challenge. The annual operational performance of TLS in 2007 is presented in the following paragraphs.

MACHINE AVAILABILITY AND DOWN-TIME ANALYSIS

The TLS has offered a machine time up to 6902 hours in 2007, as shown in Table 1. A total of 75.6 % of the machine time is allocated to users, whereas 98.1% of those designated user beam time is actually delivered, an equivalence of 5219 hours, excluding unfulfilled schedules due to a typhoon. Regular machine maintenance and machine studies accounts for the remaining 24.4 %.

The mean time between failures (MTBF) doubled in 2007, compared to that of the prior year. The annual machine down-time in 2007 totals less than 100 hours. In Fig. 1a and 1b, the number of trip events and the periods for machine recovery in terms of sub-systems for unscheduled beam aborts are given.

There are 61 occasions of unscheduled beam aborts accounted in 2007 during the scheduled user shifts, as displayed in Table 2. Among them, six (6) are due to a drop of the AC line voltage provided by the Taiwan Power Company. The AC line voltage decrease of less than 10% might result in a fault of a SRF module and the superconducting insertion devices. A significant decrease of AC line voltage will cause malfunction of cryo-plants, resulting in a major recovery period for the machine to restart the cold box from cold and to refill liquid helium (LHe) into superconducting devices. Of the same six (6) events of encountering such a drop of AC line voltage, one triggered a fault of the cryo-plant. The feasibility study of using a combination of accumulators and alternators, similar to what has been adopted at the European Synchrotron Radiation Facility (ESRF), with a capability larger than 1 MVA for a period of 1 second, to improve the quality supply of electric power is under way.

Another six (6) fault events of the cryogenic plant were experienced in 2007, owing mainly to a fault of a frequency driver, which functions originally for the purpose of energy saving when the cryo-plant is under-loaded. Other incidents include a false alarm of an arc detector protecting the RF window of the SRF module and mis-firing of injection kickers, K3 and K4, contributing to 18 occasions of beam trip. A trip event of a superconducting magnet IASW alone causes no loss of user beam and is thus not accounted in the statistics of unscheduled beam aborts. Nevertheless, the vertical global orbit feedback consequently needs to be restarted and the user time on those associated beam lines was unavoidable affected. An intelligent design of interlock threshold is under test to eliminate such a false alarm, mostly due to electromagnetic interference (EMI) apparently generated by the high-voltage pulse power supply system due to temporal coincidence.

Table 1: Machine Availability of Taiwan Light Source.

	Year	Annual Machine Time (hr)	Annual Beam Dose (A-hr)	User Time			Opertion Mode	I0 Stability (%) ($\Delta I_0/I_0$<0.2%)
				Annual User Time (hr)	Up-time (%)	MTBF (hr)		
TLS	2002	6927	N.A.	4785 (69.1%)	95.8%	154.4	Decay Mode	47%
	2003	6749	897.0	5017 (74.3%)	97.2%	313.6	Decay Mode	86%
	2004	6283	772.4	4235 (67.4%)	97.5%	69.4	Decay Mode	85%
	2005	6659	943.4	4576 (68.7%)	96.8%	83.2	Top-up Mode(3/12)/SRF	76%
	2006	7370	2012.9	5552 (75.3%)	96.7%	40.8	Top-up Mode/SRF	99.0%
	2007	6902	1964.7	5219 (75.6%)	98.1%	85.6	Top-up Mode/SRF	98.6%

Table 2: Reasons for unscheduled beam aborts and impacts on the machine operation of TLS

	Number of Events	Machine Recovery Period
Sag of AC line voltage	6 (9.8 %)	17.41 h (17.6 %)
Cryo-plant	6 (9.8 %)	11.5 h (11.6 %)
EMI (K2, K4, arcing)	18 (29.5 %)	9.0 h (9.0 %)
Component fault	6 (9.8 %)	26.0 h (26.2 %)
Reason unknown	14 (23.0 %)	9.2 h (9.4 %)
Other	11 (18.0 %)	26.0 h (26.2 %)

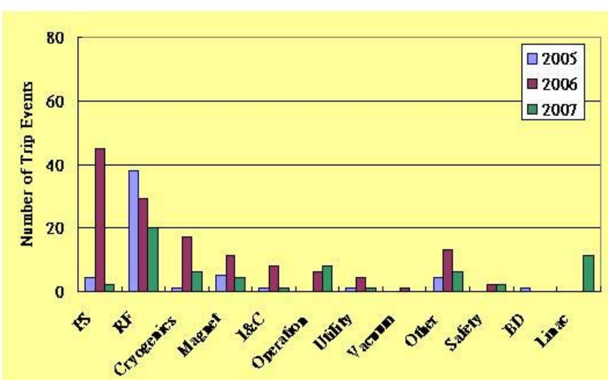

Fig. 1a: Analysis of unscheduled beam aborts: number of trip events vs. sub-systems.

STATUS OF SRF OPERATION

The accelerating RF cavity of the TLS storage ring was replaced by a SRF module of the CESR-III design at the end of 2004. Intensive manpower has been focused on improving the reliability of the RF plant. Based on the record of operation during the past three years, as shown in Fig. 2, the performance of the SRF module in general is satisfactory. Combing through 20 incidents of RF system trip occurring during scheduled user shifts in 2007, eight (8) events are resulted from the low-level RF system unstable and six (6) due to either window arcing or circulator arcing. Because of the nature of the SRF module, the RF plant is operated intrinsically with marginal phase stability against the Robinson instability. Whenever the feedback of the tuning loop cannot manage the errors of the tuning angle, the SRF module becomes detuned and eventually tripped by a quench interlock through decay of the RF voltage, over-drive of klystron pre-amp, or high reverse RF power. That kind of trip event was a serious issue at the early stage of the SRF operation and was solved mostly by detuning the cavity resonance frequency by a few degrees. Nevertheless, a rapid and large drift of the tuning angle on a time scale about 50 – 200 ms has been observed a few times in 2007; the trigger mechanism is so far unknown.

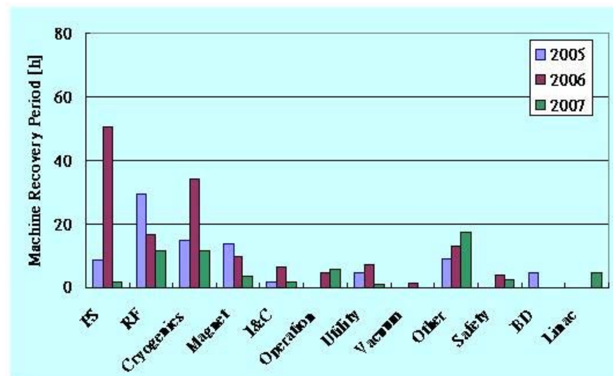

Fig. 1b: Analysis of unscheduled beam aborts: accumulated machine recovery periods vs. sub-systems.

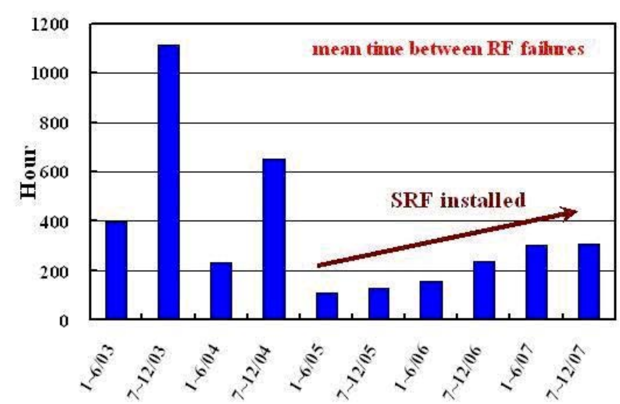

Fig. 2: Mean time between failures of the RF plant operating a SRF module at TLS

TOP-UP INJECTION

Partial loss of electron beam during top-up injection has been observed when the elliptically polarizing undulator, EPU5.6, is operated at a smaller magnetic gap and with only a horizontal magnetic field on-axis (vertical polarization), perhaps owing to shrinking of the dynamic aperture by a non-compensated dynamic first magnetic-field integral. A multi-pole correction magnet has been installed for proper compensation. Fine tuning is scheduled for 2008.

STABILITY OF THE PHOTON BEAM

Stability of the photon beam is crucial to obtain good quality user experiments. A temporary blowup of the vertical beam size or an anonymous drift of the electron beam orbit degrades the stability of the photon beam. Three (3) diagnostic beam lines have been set up as monitors of the stability of the photon beam, called I0 fluctuations at NSRRC. The characteristics of these three beam lines shows similar behavior but with various amplification factors. The diagnostic beam port at the Dragon beam line serves as a common reference, which has a pinhole of 50 μm diameter at a distance of 8.4 meters from the source point. We are still seeking a fully consistent interpretation of the I0 fluctuations in relation to the degree of instability of electron signals. It has been experimentally demonstrated that monitoring the I0 fluctuations is much more sensitive in term of reflecting the degree to which the users suffer from an unsatisfactory quality of the photon beam.

The instability of the photon beam can be categorized into two distinct types using the data of measured I0 fluctuations: base-line fluctuations and spontaneous spikes. Figure 3a shows the average photon intensity (I0) fluctuations by month measured at the diagnostic beam port at the Dragon beam line. By comparison with those of 2006, though the base-line fluctuations of the photon beam were amplified by a factor of nearly two (2) in 2007, conditions were recovered by the end of the same year with even greater photon stability. As indicated in Fig 3b, the TLS delivered more than 95 % of scheduled user beam time with a beam quality with the I0 fluctuations of approximate by 0.1 % and less than 0.2 % in 2006 and 2007, respectively.

Some spike-like I0 fluctuations of more than 10% had been observed now for a long time; these occasionally appeared because of a problem of temporal communication with the readout of the main coil current of the superconducting wavelength shifter, SWLS, which resulted in spontaneously an incorrect setting of its local correctors via a look-up table for orbit compensation. The residual spike-like I0 fluctuations are mostly less than a few per cent, as shown in Fig. 3c of I0 fluctuations in the last week of user shifts in 2007. The appearance of I0 fluctuations of this kind seems more sensitive to the optimal tuning of parameters of the transverse and longitudinal feedback systems against the working points of the storage ring lattice; which are on the other hand highly dependent on variation of machine operational parameters, for example, after changes of magnetic gaps of insertion devices.

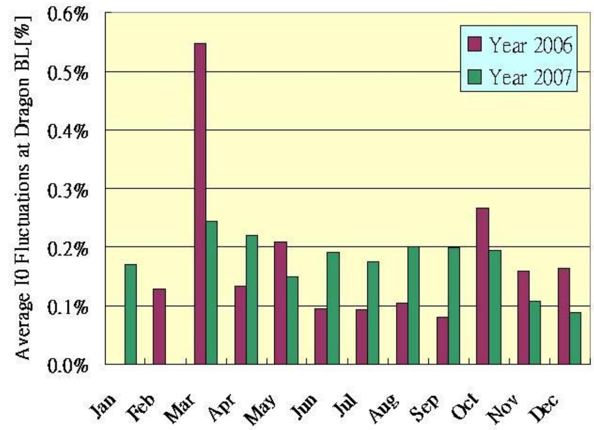

Figure 3a: Stability of the photon beam measured at the Dragon beam line of TLS.

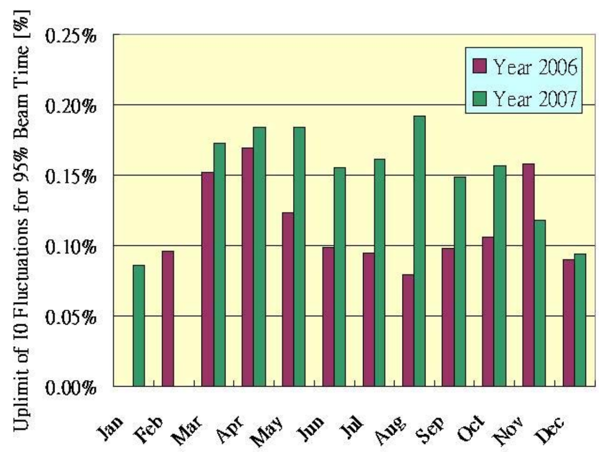

Figure 3b: Up–limit of photon beam fluctuations for 95% of available user beam time.

Figure 3c: Record of I0 fluctuations in the last week of user shifts in 2007. The periods of maintenance and machine study are marked in brown.