CURRENT STATUS AND FUTURE DEVELOPMENT OF SRRC

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Abstract

Current status and future development of SRRC are reported in this paper. Machine reliability, beam orbit stability, instrumentation and utility conditions have been significantly improved. The energy of the injector has been upgraded from 1.3 GeV to 1.5 GeV. The beam availability is 96% with a trip rate of once per month. Several Insertion Devices were installed to extend the synchrotron light property. To suppress the beam instabilities, the super conducting cavity and the longitudinal feedback system are currently underway. Some other activities at this facility are also described in this paper.

1 INTRODUCTION

Taiwan Light Source (TLS-I) of the Synchrotron Radiation Research Center (SRRC) is the first 3rd generation synchrotron light source in Asia. The machine, with its low emittance and being equipped with undulators, supplies high quality photons to users. The performance of the light source has been continuously improved due to the stringent requirements from users. Progress has been made since the first operation of the machine in 1993 [1]. Recently, the studies in orbit stabilities, beam instabilities, utility, superconducting wigglers and superconducting rf cavities have been carried out [2-9]. The performance of TLS-I will be further improved.

In addition to the vacuum ultraviolet users, many users demand more x-rays. At present three beam lines from a wiggler are in operation; two x-ray beam lines of SRRC have recently been constructed at SPring-8, under the collaborations between SPring-8 and SRRC. However, more beam lines are needed to meet future demands. The construction of a second synchrotron light source (TLS-II, 3-3.5 GeV) at SRRC has thus been proposed recently.

In this paper, the operations (section II) and the major tasks (section III) of TLS-I, the preliminary design of TLS-II (section IV) and some synchrotron light source related issues are discussed.

2 OPERATIONS OF TLS-I

TLS-I is a 1.5 GeV synchrotron light source. Table I lists the basic parameters of TLS-I. In addition to the machine itself, twenty beam lines are in operation. Approximately 1,500 users-runs engaged in this machine per year. The performance of the machine is continuously improving. Figure 1 shows the I • τ values (beam current × lifetime) of the machine. TLS-I operates twenty-one shifts (8hr/shift) a week, fifteen shifts for users and six shifts for machine studies or check-ups. Regular shutdowns for maintenance take up one week in every two months.

Table I: Basic parameters of TLS-I

Energy GeV	RF frequency	Tune H/V	Synchrotron tune	Energy spread
1.5	500 MHz	4.13/7.18	0.0106	$7.5*10^{-4}$
Current mA	**Emittance nm-rad**	**Bunch length**	**Compaction factor**	
200	25	0.92cm	0.00678	

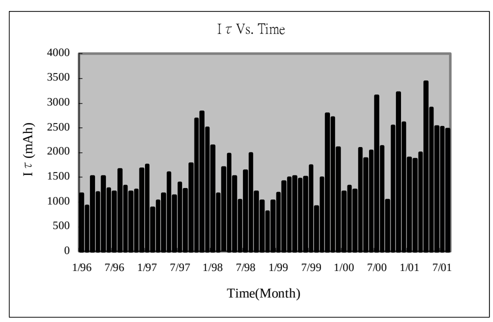

Figure 1: I • τ values (beam current × lifetime) of TLS-I.

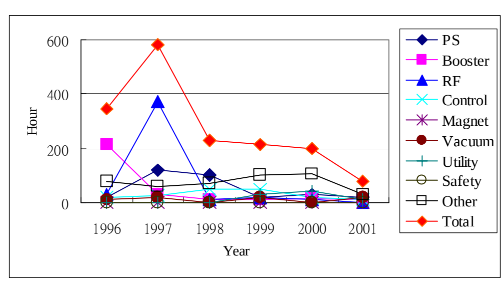

Figure 2: The reduction of machine faults (loss of user's time) of TLS-I.

Reliability is one of the most important factors for the synchrotron light source. Figure 2 shows the machine faults (loss of user's time) of TLS-I in the past few years. Due to the improvements on rf feedlines and the pressure control of cooling water to power supplies, the failure rate was significantly reduced in 1998. A reliability of ~96%has been achieved at TLS-I.

Table II: Basic parameters of the insertion devices at TLS-I

	W20	U5	U9	EPU	SWS	SMPW
Type Period, λ [cm]	Hybrid 20	Hybrid 5	Hybrid 9	Pure 5.6	SC 25	SC 10
No of periods, N	13	76	47	6	1.5	10
Min. Gap [mm]	22	18	18	18	56	14
Magnetic field [T]	1.8	0.64	1.245	0.67	6	5
Total length [m]	3	3.9	4.5	3.9	0. 625	1. 2
Installation	Dec. 1994	Mar. 1997	Apr.1999	Sep. 1999	Feb. 2002	Jul. 2003

Table III. Amplification factors of the air and water temperatures to the displacements of beam orbit and major components

	Current Temp. Variation	Amplification factor (Beam Orbit Displacement)	Amplification factor (component displacement)		
			Girder	Magnet	BPM
Air Temp.	< ±0.15℃	20-100 μm/℃	10μm/℃ (Ver.)	x	x
Water Temp. (Cu)	< ±0.15℃	5-50 μm/℃	x	~10 μm/℃	x
Water Temp.(Vac)	1.5℃	>50 μm/1.5℃	x	(To be measured)	~1 μm/℃

It was found that the trip rate of TLS-I was extraordinarily high since early 2000. After an improvement in the power line grounding system, the protection circuits of the rf circulator and the electrical power supplied to control room, the beam trip rate has been greatly reduced to approximately once per month since February 2001.

A major earthquake of magnitude 7.6 struck Central Taiwan in September 21, 1999. The machine was fortunately in a shutdown mode at that time. It was found hat the maximum movement of the lattice was ~ 1mm. No components or any subsystems were damaged. The machine was operated smoothly again, without realignment, after the recovery of the utilities one week later.

3 MAJOR TASKS AT TLS-I

3.1 Insertion Devices

Insertion devices are essential to a third generation synchrotron light source. A wiggler (W20), a 4.5 m undulator with 9 cm period (U9), and a 4 m undulator with period 5 cm (U5) have been operating for years at TLS-I. These insertion devices extend the user's applications to a higher photon spectrum, flux and brilliance. Recently, an in-house developed 4m elliptical polarized undulator (EPU 5.6) was installed to supply tunable polarized synchrotron lights to magnetism users. In order to provide more x-rays to the users, a superconducting wavelength shifter (SWLS) is under construction and a superconducting multipole wiggler has been designed and to be fabricated. Table II summarizes the basic parameters of the insertion devices.

3.2 Beam Orbit Stability

Improvements in mechanical stability and local feedback contributed significantly to beam orbit stability at TLS-I. It was observed that air- and water-temperatures severely affected the TLS-I beam orbit. Efforts have been put to upgrade the utility systems (see Section II.4). The amplification through the magnet girder, from air temperature to beam orbit variations, was the most significant transfer routes. The amplification factor could be as high as 10 μm/℃. The heat source from the cables of dipole magnets was the major contribution to air temperature fluctuations. The energy ramping up-and-down process during injection, injection at 1.3 GeV and operation at 1.5 GeV, were the major causes of the half-hour transient between two operation shifts. After the upgrade of the injector energy from 1.3 GeV to 1.5 GeV in 2000, the transient behavior was significantly reduced. Both air- and water- temperature fluctuations affected the beam orbit. Table III lists the air and water temperature effects to the mechanical displacement and the beam orbit variations. Temperature fluctuations have been improved from >±1℃ to <±0.1℃ for both air and cooling water. A vertical beam orbit fluctuation <1 μm (rms) and orbit drift of ~5 μm / 8hr have been achieved without any orbit feedback system.

The electronic circuits of the electron beam position monitors (EBPM) in the storage ring were successfully upgraded recently. A resolution of <1 μm was achieved for most of the EBPMs. Currently, the global feedback system is only engaged in vertical direction and is intentionally operated in a bandwidth ~ 10 Hz to avoid the interferences from other effects. The vertical beam orbit stability is ~ 3 μm / 8hr with the global feedback system (Fig.3). The bandwidth and dynamic range of EBPM is to be further upgraded in order to meet the future 400 mA operation.

In addition to the global feedback system, local feedback systems are also developed. Same control infrastructure is shared by both the global and local feedback systems. A local feedback system has been successfully tested to reduce the photon beam position drift in the beam line. The photon beam position monitor (PBPM), with a resolution of < 0.5 μ m, has been developed at TLS-I. Recently, nine sets of PBPMs (1D-vertical) and several compact correction magnets, part of the local feedback systems, have been installed. In the near future, more PBPMs will be installed at the same front ends, so that the data of beam angles can be obtained through the PBPM pairs at the same front end.

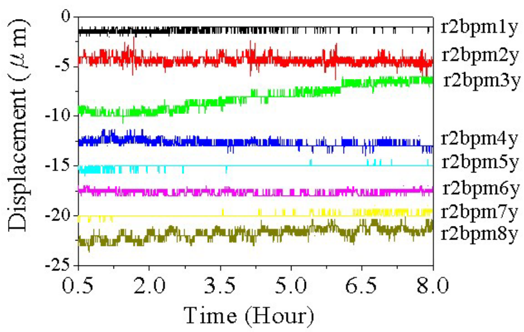

Figure 3: Beam orbit stabilities at TLS-I.

3.3 Beam Instability

Large variations of horizontal beam size were frequently observed at TLS-I. Beam instabilities were the major cause of the phenomena. Efforts have been put to solve the most challenging problems at TLS-I. A rf modulation method was adopted; a longitudinal feedback system has been preliminarily tested; a superconducting rf cavity is being constructed; beam diagnostic tools are improving and some other effects such as the interferences from the utilities are being investigated.

A longitudinal kicker was installed in 1998 to correct bunch phase errors. The kicker, featured with the compact, simple shape and external loads, is a pillbox cavity with nine striplines. Three of the nine striplines are fed with rf power, and six are terminated externally with matching loads. The kicker has a resonance frequency at 1125 MHz and a shunt impedance ~ 100Ω. The bandwidth of the system, with fast digital circuits, is 250 MHz. The kicker system has been successfully tested at a beam current of 80mA. However, it is being modified to reach the operational goals of 200 mA in the near future and 500 mA in the long run.

The rf voltage modulation technique has been used to suppress longitudinal instabilities for years. However, a sudden change of the horizontal beam size still exists. It was found that the phenomenon was correlated with the change of the beam (frequency) spectrum. The filling pattern also changed as the beam instability excited. No significant change in vertical beam size was observed accordingly. Simulation results indicated that the high order mode (HOM) of rf cavities was responsible for the instability. The instability disappeared after detuning the HOM by changing the working position of cavity-tuners in year 2000.

In addition to solutions mentioned above, utility improvements (see next section) also contributed to reducing beam instabilities. On the other hand, diagnostic tools have been continuously developed to study the instabilities at TLS-I. A bunch phase detection system and a turn-by-turn BPM system have been successfully implemented recently. Measurement data of the tune and phase space, both transverse and longitudinal, are helpful to address the non-linear effects and beam instabilities.

3.4 Utility System Upgrade

As previously discussed in Sections I and II.2, the performance of utility systems affected the machine reliability and orbit stability. In addition, utilities also affected beam instabilities. It has been found recently that the fluctuations of beam size, photon beams intensity through pinhole I_0 monitors, and the power supply outputs were strongly correlated with air-/water-temperature and/or power line voltage. It was observed that the mechanical structure of I_0 monitors, profile monitor and EBPMs, were affected by water temperature fluctuations. The wrong signals from the monitors mislead the feedback systems.

In addition to the improvements in the main subsystems of the storage ring, efforts have also been put to upgrade the basic items, air temperature stability, water temperature stability and electrical stability of the machine infrastructure. The air- and water- temperature fluctuations were decreased from 1℃ to <±0.1℃. “Instabilities” were significantly reduced after stabilizing the temperatures. A deviation of ~0.2% of the readings from I_0 monitors was reached.

The improvements of the electrical systems fall slightly behind those of the air and water systems. However, upgrade projects for grounding and electrical power systems are underway. Electrical power and grounding systems are to be re-organized, “clean” and “dirty” systems will be separated.

3.5 Superconducting RF System

Two Doris cavities are to be replaced by a single superconducting rf cavity developed at Cornell Electron Storage Ring (CESR). The main purposes of the new cavity are to reduce longitudinal beam instabilities and to increase beam currents to 500mA while maintaining the beam lifetime. Figure 4 shows the schematics of the 500MHz Nb cavity with its surroundings. The rf power is fed into the cavity through an alumina window and a coupler located nearby the center cavity. Two ferrite-tiles are located at both ends of the cavity to absorb HOMs. The adjustable frequency ranges are 1 MHz statically and 10Hz dynamically by a stepping motor driving mechanism.

A liquid helium cryogenic system, with refrigeration capacities of 400 W, is also under construction. Turbine expanders are located near to the rf cryostat to reduce the heat loss of the transfer lines. Screw compressors are located at a different building far away from the storage ring in order to minimize vibrations.

The construction of the building to accommodate the compressors and the related utilities is nearly completed. The cavity, as well as the cryogenic system and its piping are to be installed in 2003.

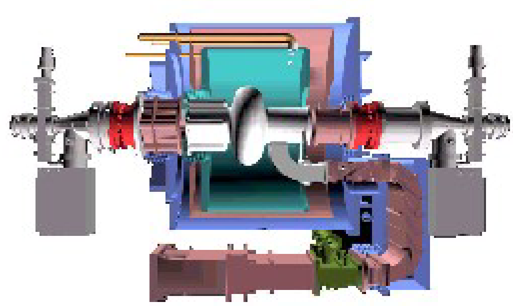

Figure 4: Schematics of superconducting rf cavity and the surroundings.

4 TLS-II

Due to the full occupation of straight sections at TLS-I and the increasing demands from x-ray users, the construction of a 3-3.5 GeV synchrotron light source, TLS-II, has been proposed at SRRC. The preliminary design parameters of TLS-II are listed in Table IV. The circumference is 240 m, due to the constraint of the space available. Double-bend-achromat lattice with sixteen straight sections are designed to meet the requirements of low emittance and sufficient number of insertion devices. Figure 5 shows the spectrum and brightness of the synchrotron light generated from some insertion devices to be installed at TLS-II. The spectrum and brightness of TLS-I are also shown in the figures for comparison. It is clear from the figures that the spectrum intensity and brightness of the synchrotron light from TLS-II are much higher than those from TLS-I in the x-ray range.

TLS-II will be a highly stable and reliable machine. A full energy injection scheme and superconducting cavities with reduced HOMs are to be adopted in machine operations. Our experience accumulated from TLS-I indicates that aluminum is a suitable material to be used in fabricating the vacuum chamber. Ante-chamber with discrete absorbers will be applied to increase beam lifetime. A beam orbit variation of less than 10% of beam size, roughly at a few microns, is a general guideline of the specifications on orbit stability. Due to the amplification of the lattice, the mechanical stability of TLS-II will be in the range of sub microns. To reach such a value, temperature fluctuations are to be controlled to within ±0.1℃. The global feedback, local feedback and beam base alignment systems are to be used to reduce beam orbit fluctuations.

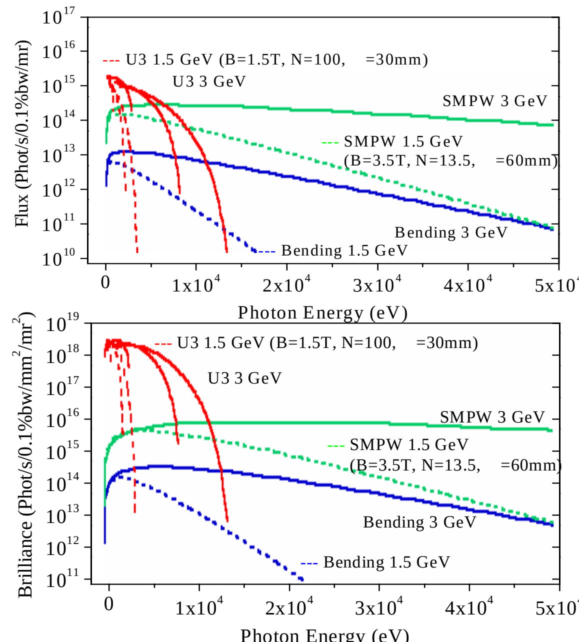

Figure 5: Spectrum and brightness of the synchrotron light from insertion devices.

Table IV. Preliminary design parameters of TLS-II

Design energy (GeV)	3		
Max. energy (GeV)	3.5		
Lattice type	Double-Bend-Achromat (DBA)		
Number of period	16		
Beam current (mA)	400		
RF frequency (MHz)	500		
SR loss per turn (dipole only)(keV)	878		
SR power loss @ 3GeV (dipole only) (kW)	350		
SR power loss @ 3.5GeV (dipole only) (kW)	650		
Circumference (m)	216	240	
Harmonic number	360	400	
ID length	3m*8+ 6m*8	6m*16	3m*8+6m*6 +14m*2
Emittance (nm-rad) (not optimized)	9.3~ 24.8	9.8~ 28.3	19.5~ 33.8
Tune (x, y)	12.20, 5.20	12.20, 5.20	12.20, 5.20
Number of dipoles	32	32	32
Number of quadruples	80	80	84
Number of sextuples	64	64	64
Dipole field/radius (T/m)	1.225/8.15		

Electron BPMs and photon BPMs with a resolution of <1 μm are to be implemented. In addition to the superconducting cavities with reduced HOMs, longitudinal feedback system, smooth beam ducts and low ripple power supplies are to be used when beam instabilities are concerned. To reduce beam instabilities, a coherent energy oscillation of <0.01% will also be included in the specifications.

5 CONCLUSION

The performance of TLS-I at SRRC has been continuously improved. The vertical orbit stability is able to be controlled to within ~3 μm in a shift (8 hr) after the improvements in air/water temperature stability and orbit feedback systems. A superconducting rf cavity and a longitudinal feedback system are to be adopted to reduce the longitudinal bunch instabilities. An operational reliability of 96%, a trip rate of once per month and a photon beam instability of ~ 0.2% indicate an improvement over that achieved in early years, around 89%, more than 10 times per month and ~ 2%, respectively.

The number of insertion devices has been continuously increasing. Four insertion devices are in operation, a superconducting WLS is to be installed and a superconducting multipole wiggler is designed. In order to meet the future requirements from users, the construction for a new machine, TLS-II, is proposed. The 3-3.5 GeV machine, with 16 straight sections and performances of low emittance and high stability, shall play a dominant role in the steps after TLS-I.

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