CURRENT STATUS OF THE 1.5 GEV SYNCHROTRON LIGHT SOURCE IN NSRRC

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Abstract

The current status of the 1.5 GeV synchrotron light source in NSRRC is reported. The machine is operated for approximately 5,000 hours per year, with availability >97%, trip rate <1.5/month and photon beam stability (fluctuation of intensity of photon beam) < 0.1%, during most of the user's beam time. A superconducting cavity and some superconducting wigglers are constructed to increase beam currents and reduce the instability of high order mode (HOM), and to offer harder x-rays to users. A top-up injection project is initiated to aim for increasing the electron and photon beam stabilities - particularly the mirror stability in the photon beam line. An IR-FEL facility is also planned, in the hope of opening up a new area of IR research. Machine improvements are also discussed herein.

INTRODUCTION

The status of the Taiwan Light Source (TLS) at the NSRRC has been operated for ten years since it was first used in 1993. Much effort has been made to increase the quality of the beam, and both the brightness and the energy range of the synchrotron light generated by the TLS to meet the stringent requirements of users. [1,2] Insertion devices, new components, operating techniques, utility systems, have been installed, developed or upgraded.

Programs that involve the superconducting wiggler, the superconducting rf cavity and the top-up injection mode have been recently initiated to increase further the energy and stability of the electron and photon beam. An infrared free electron laser (IR-FEL) facility will be built in the near future to provide high power IR-FEL to the users.

The following sections report the status of the TLS, including improvements in the machine's performance, the development of superconducting devices, and ongoing and future programs.

IMPROVING BEAM QUALITY

Reliability

The reliability of the TLS was found to depend strongly on the utility system. The fluctuations in the water flow parameters, including pressure, temperature and flow rate, triggered the interlock settings of the machine-subsystems and then tripped the machine in the early stage of TLS operation. The quality of ac electrical power and the grounding system strongly affected the reliability of the machine before 2001. Unknown (at that time) trips occurred numerous times per week, but the trip rate was found to be considerably reduced following improvements to the ac power and grounding system. (Fig.1) As well as the trips, associated with the instability of the utility system, failures of components, corrosion and aging contributed to the reduction in the reliability of TLS.

The pressure, temperature and flow rate of the de-ionized water (DIW) system have been improved in recent years. The fluctuations in the DIW pressure and the flow rate have been maintained within ±1%; the DIW temperature fluctuation was <±0.1°C. The PH value, the oxygen concentration and the resistivity of DIW are 7±0.5, ~20ppb and ~10 MΩ, respectively. Painting the corrodible components with glue isolates them from the humid air, reducing corrosion.

A new grounding system with a resistivity of 0.18Ω was recently established and the ac electrical system was reorganized to reduce the effect of the ac electrical and grounding noises. [3] The ac power distribution system was reorganized to be independent between the facility and the instrumentation. Less interference between the rf system and the magnet power supply system was observed after the ac distribution lines of these two systems were separated.

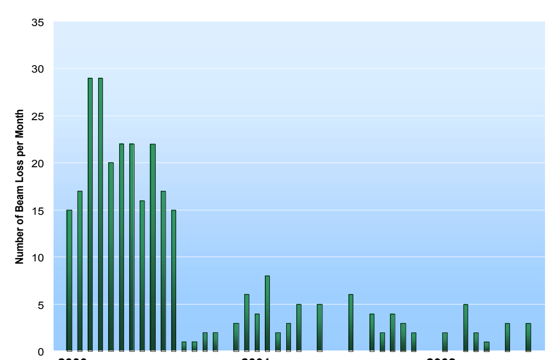

Figure 1: The reduction in trip rate of TLS.

The components of each subsystem of TLS are routinely checked to reduce the probability of failure. Not only are checks made in routine shutdown periods, but also an archiving system stores data in the performance of the subsystems. When irregular behaviour is observed, a judgment is made either to maintain the subsystem during the maintenance period or to request emergency maintenance. The TLS is operated for about 5,000 hours per year with availability >97% and trip rate <1.5/month, after the efforts to improve reliability.

Transverse Beam Quality

The stability of the beam orbit and that of the beam size are two of the most important factors to users. The beam orbit and beam size stabilities must be better than 5% and 0.1% of the beam size, respectively, to meet the required photon beam stability of < 0.1%, typical for a third-generation synchrotron light source. [4]

Beam orbit

Several actions were taken at TLS to improve the stabilities of the beam orbit and the beam size. Most of the causes and mechanisms of the thermo-mechanical effects on the variation in beam orbit and size were identified. The fluctuations of air- and water- temperature were improved from ~ 1°C to <0.1°C by improving the capacity of the cooling system, the linearity of the response of the device, and the temperature control parameters. The effect on the magnet girder assembly was carefully studied. The stabilities of the beam orbit and size were improved by reducing the thermal and mechanical fluctuations. [5]

The global orbit feedback system at the TLS was upgraded in the last few years. [6] The electronics of the electron beam position monitor (EBPM) were improved to yield a resolution of < 1 um with a band width of 1 kHz. The long-term stability and dependence on beam current were also improved to <±2 μm, over each operating shift (8 hr). The noise of the corrector power supplies was effectively reduced by replacing some parts and adjusting some of the settings of the power supply. Figure 2 shows the improvements in reliability, temperature fluctuation and beam orbit stability at TLS during 1997-2002.

The improvement yielded an electron beam orbit fluctuation of < 1 μm (rms) and a drift of ~ 5 μm / 8hr (one shift). Many photon beam position monitors (PBPM), with a resolution <0.5μm, have been installed at

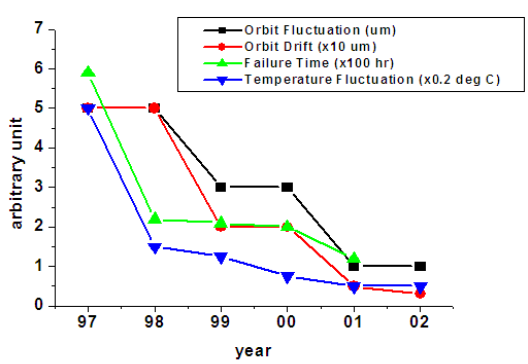

Figure 2: The improvements in reliability, temperature fluctuation and beam orbit stability at TLS.

the front ends of photon beam lines. The local feedback system with PBPM is planned to further improve the photon beam quality of TLS.

Beam size

Coupling, observed to be related mainly to misaligned sextupoles, is one important factor that governs the vertical beam size. Skew-quadrupoles and remote-controlled stages for sextupoles have been installed to study and reduce coupling errors. [7] Another possible coupling source - misplaced steering magnets is being investigated. It was also observed that the collective effect, possible the ion effect, influenced the vertical beam size. The vertical beam size of the TLS is maintained at ~50μm by properly setting the machine parameters.

A diagnostic beam line, with a vertical focusing mirror (3:1 reduction), a pin hole with a diameter of 50 μm and a photodiode detector (called the I_0 monitor), was built to monitor the stabilities of the beam orbit and the beam size. Figure 3 presents the photon beam fluctuations measured by this I_0 monitor. Increasing the thermo-mechanical stability of this monitor at a reduced noise level in a quadrupole power supply and electron BPMs reduced the photon beam fluctuation to ~0.06%. The reading of the I_0 monitor was <0.1% for ~85% of the users' beam time. This reading supports an estimated beam size fluctuation of ≤ 0.3 μm, which is consistent with the results obtained using a newly built monitor of beam size that operates by the synchrotron light interferometry method.

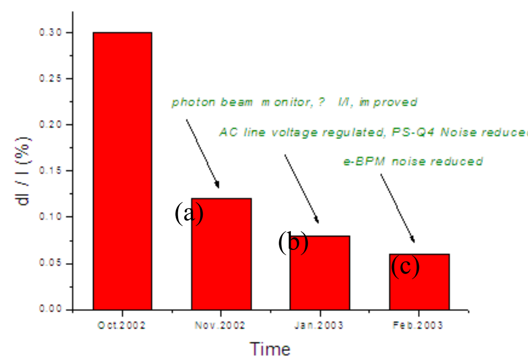

Figure 3: The reductions in photon beam fluctuations. Improvements of I_0 monitor (a), ripples reduction in Q4 power supply (b), and in electron BPMs (c).

Longitudinal Beam Quality

Five methods - rf cavity temperature control, rf voltage modulation, dual rf tuner adjustment, longitudinal feedback and HOM free superconducting rf cavity are used to improve the beam quality in longitudinal direction.

A strong correlation was observed between the size of the beam and the temperature of the rf cavity. The correlation became weaker after the temperature fluctuations were reduced from ±0.1°C to ±0.01°C. Both dual rf tuner adjustment and rf voltage modulation techniques have for many years been applied to suppress longitudinal instability. The rf modulation methods will be continuously used until the installation of the superconducting cavity. (See next section.) A new longitudinal feedback system is being built; the new longitudinal kicker system can handle a >200 mA beam current. The system is to be completed in 2004.

SUPERCONDUCTING DEVICES

Superconducting RF (SRF) Cavity

The operation the HOM free superconducting cavity is anticipated to double the beam current >400mA and improve the beam stability. [8] Two cavities (one spare) have been fabricated. Both niobium cavities showed favorable results in the low-power vertical test. The unloaded Q_0 was >1.4 x10^{-9} in a field of 7 MV/m. A pressure of < 10^{-9} mbar was obtained under cold conditions.

The subsystems, transmitter, rf feed-line, low level rf electronics, direct feedback, data acquisition, and other devices used to operate the SRF are almost completed. However, buckling of a niobium waveguide was observed in a high-pressure test at 1.8 bar for 20 min, because the external Q value, Qext, was reduced. The component is being repaired and the installation of the superconducting cavity is delayed to December 2004.

Superconducting Wigglers

Several superconducting wigglers (SW) have been built or are to be built to meet the increasing demand of X-ray users. Space in the long and short straight sections, which are almost all occupied by the currently used insertion devices, injection pulse magnets, rf cavity, quadrupoles, sextupoles, pumping ports and components, has been shrunk as much as possible to accommodate the SWs. A three-pole 6T wave-length shifter (SWLS) was installed in the injection section in April 2002. A 6cm-period (28 poles) 3.2 T wiggler (SW6) was installed in the rf section in January 2004. Three 3.2 T wigglers with a 6cm period (13 poles) (IASW6) are being constructed, and are to be installed in the arc section in Dec. 2005. Table 1 lists the dominant parameters of the three types of superconducting wigglers. The article of Chang et al. [9] in this record of proceedings provides more information on the wigglers.

Cryogenics Systems

Two cryogenics system are established to supply liquid helium to the SRF cavity and SWs. The first system, including a 315W compressor, a 45 W recovery compressor, a 10 kW refrigerator, a 2000L dewar, two 100 m^3 gas helium storage tanks, a 5m muti-channel transfer line and ~120 m of piping (to transport for) gaseous helium and liquid nitrogen, were installed and commissioned in early 2003. The first system, with a cooling capacity of 450W at 4.5°K and a mass flow rate of 73.9g/s, is dedicated to providing 80W of cooling power to the SRF cavity; a mass flow rate of 0.18g/s is provided to the wave guide. Liquid helium is transferred through a distribution valve box to the SRF module. The pressure fluctuations in the suction line and the dewar are ±2 mb and +3/-5 mb, respectively. Both values meet the SRF requirements [10].

The second cryogenic system, which is primarily for the SWs, a backup system for the SRF cavity, and nearly identical to the first system, is under construction and will be available for use in summer 2005.

Table 1: Basic parameter of the TLS SC-wigglers.

	SWLS	SW6	IASW6
Type	SC	SC	SC
Period, λ [cm]	32.56	6	6.0
Poles	3	28	13
Min. Gap [mm]	47	18	19
Beam pipe vert. Inner aperture [mm]	20	11	11
Magnetic field [T]	6	3.2	3.2
Total length [m]	0. 835	1. 4056	90
Installation	04/2002	01/2004	12/2005

TOP-UP INJECTION

A top-up injection project was initiated at TLS hope to relax the lifetime-restrictions, such as those related to the small gap insertion device and the low emittance operation mode. The project also aims to increase the electron and photon beam stabilities - particularly the mirror stability in the photon beam line. Various tests have been performed on the top-up injection, with a view to implementing the top-up mode in 2005. A working tune that is appropriate for both injection and the users' modes has been identified. Luo et al. [11], in this record of proceedings, details top-up injection at TLS.

Injection Efficiency

Injection efficiency-related issues, such as time jitter and aperture constraints, are the most important to resolve. The time jitter of the extraction kickers in the booster has been improved to 0.2ns. The kicker assembly of the storage ring is to be modified so that the peak current and the horizontal field strength will be greatly reduced, with a better field uniformity than available before improvement. A time jitter of ±1ns ((five to ten times better than before) was attained by applying the double pulsing method to the injection kicker power supply of the storage ring.

The alignment error in the inclined section of the beam transport line from the booster to the storage ring may importantly affect the injection efficiency. The difficulty of alignment is such that remote control stages are to be used for the quadrupoles in the inclined section. More radiation shielding is required around the injection region, because of the potential increase in radiation.

Linac and Booster

The energy dispersion at each point from the electron gun to linac is carefully investigated to reduce the number of useless electrons as early as possible, to reduce further the radiation. The reliability and reproducibility of the electron gun are improved to ensure that the number of electrons in each shot of refilling can be held constant. The reliability of the injection booster is also a major concern in top-up injection mode. Maintaining a stable beam in the booster is difficult because the conditions change during energy ramping. A more precise control algorithm is being implemented to reduce the beam fluctuations in booster.

IR-FEL

A high resolution IR-FEL (infrared free electron laser), to generate stable IR radiation from 2.5 to 50 μm, was proposed recently at the NSRRC to meet the requirements from some users. In addition to the high resolution and high power, the FEL laser pulses should also be with high repetition rate and synchronized with the synchrotron radiation from the U9 undulator at the TLS. A site located near to the end station of the U9 beamline has been decided.

Although an rf-gun has been set up and studied at the NSRRC [12], no project related to FEL was proposed until the IR-FEL. A study group has been formed since October 2003. The goal in the first phase is to complete a feasibility study with conceptual design parameters. The tentative parameters for the IR-FEL are listed in Table 2.

Table 2: Tentative parameters for the IR-FEL os TLS

Wavelength	2.5~50 μm
Linewidth	transform limited
Micropulse peak power energy duration rep. rate	 16 MW 0.5 mJ 33 psec 10 MHz
Macropulse peak power energy duration rep. rate	 > 10 msec > 1 J/pulse > 10 msec Flexible to CW
Wavelength stability	2.5x10-5
Intensity stability	< 0.1
	Two-color, frequency chirping options

SUMMARY

The TLS, with various insertion devices and beam lines, is operated for about 5,000 hours per year with an availability >97%, a trip rate <1.5/month and a photon beam stability < 0.1% for most of the users' beam time. A superconducting rf cavity is constructed to increase the beam currents and reduce the HOM instability. Two superconducting wigglers are installed and three are under construction, to provide more hard X-rays to users. The top-up injection mode is to be implemented to improve the stability of the machine and that of the mirror in the photon beam line. An IR-FEL facility is proposed to meet users' requirements. The site and parameters of the IR-FEL facility has been tentatively studied.

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