OPERATION EXPERIENCE OF TOP-UP INJECTION AT TAIWAN LIGHT SOURCE

G.H. Luo, H.P. Chang, C.T. Chen, Jenny Chen, J.R. Chen, C.C. Kuo
Keng S. Liang, Y.C. Liu, R.J. Sheu and D.J. Wang
National Synchrotron Radiation Research Center, No. 101, Hsin-Ann Road, Hsinchu, Taiwan

Abstract

The storage ring of Taiwan Light Source (TLS) has one Superconducting (SC) cavity, one SC wavelength shifter, and two SC wigglers installed during last two years. The operation mode was also upgraded to have the capability of top-up injection. Top-up is an operation mode in which the beam current is maintained above certain level by frequent injections in the storage ring. The current stability maintains in the range of 10^{-3} for long period of operation. It provides constant thermal loading on all components in the storage ring and the optics components of beamlines, as well as constant signal to the beam position monitor. The top-up injection is a routine operation mode during user shifts at TLS. Statistics and operation experience with superconducting devices will be discussed in this paper.

INTRODUCTION

The Taiwan Light Source (TLS) was designed to provide 200 mA, 1.3 GeV electron beam to generate photon source for academic and industrial research scientists. The storage ring is a six-fold symmetry Triple-Bend-Archomat (TBA) lattice with six straight sections. Four of the straight sections are occupied by conventional normal-conducting insertion-devices, U9, U5, W20 and Elliptical Polarized Undulator EPU5.6.

The strong demanding of synchrotron light in x-ray regime made the beam physicists to reduce the engineering margin and pushing the beam energy to 1.5 GeV and squeeze the space at injection and RF sections to accommodate super-conducting high-field insertion devices. A 3-poles and 5.3 Tesla superconducting wavelength shifter was installed at downstream of the injection kicker #3 to provide high photon flux in x-ray regime. One 29-poles and 3.5 Tesla superconducting multipoles wiggler was installed at the RF straight section next to the Super-conducting RF (SRF) cavity to generate high flux x-ray.

It was also a strong demand to increase the photon flux and reduce the photon fluctuation due to the Higher-Order-Modes (HOM) excitation from Dories cavity. An SRF cavity was installed to replace two Doris cavities at the end of 2004. The SRF cavity was designed to be a HOM free cavity and had the capability to provide 8 MV/m accelerating gradient with power handling capability up to 200 kW. The SRF cavity extends large flexibility for tuning the cavity to optimise the operation parameters. Figure 1. shows the schematic layout and timeline of the TLS facility.

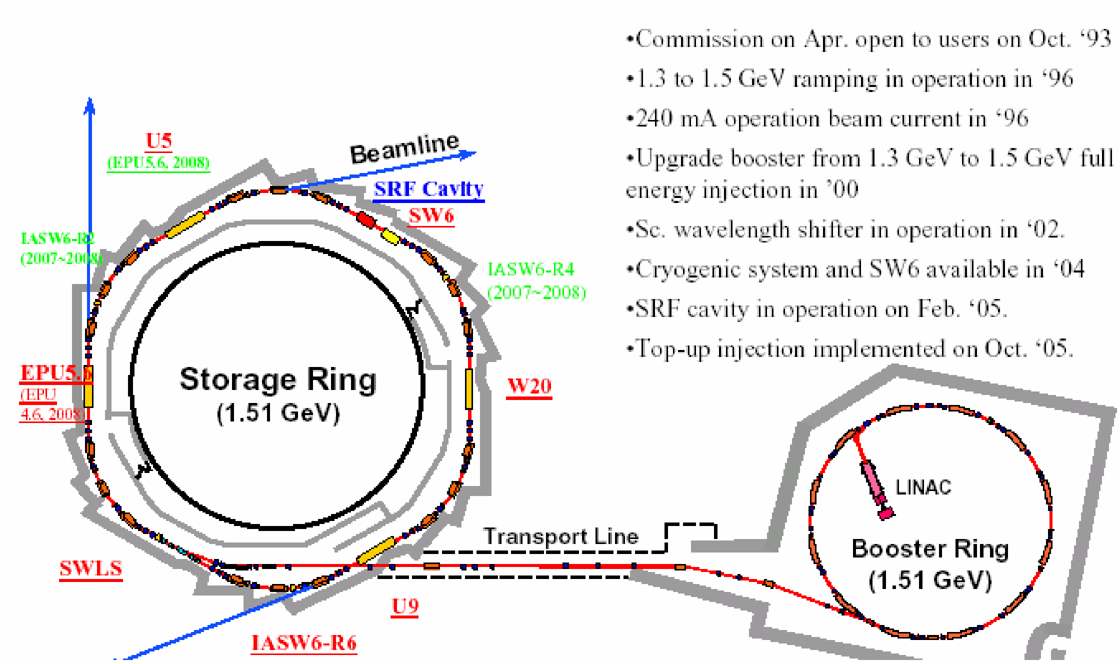

Figure 1. Schematic layout and timeline of the accelerator facility of Taiwan Light Source

There were several top-up injection experiments carried out at TLS [1] since 1995. The operation conditions of storage ring and injector were modified at various stages, e.g. energy ramping at storage ring, adding strong field insertion device and separated injection and user's working point, which made the top-up operation impractical at TLS.

The Advanced Photon Sources [2,3], Swiss Light Source [4] and SPring-8 [5] have demonstrated a successful operation in partial or full time with top-up mode for the third generation light source in recent years. A task force was formed to tackle the technical challenges and obstacles at NSRRC.

STORAGE RING AND STATISTICS OF OPERATION

Demanding of lower emittance, small gap insertion device and doubling the stored beam current made the beam physicists re-evaluate the feasibility of top-up operation at TLS. In normal operation before 2003, the injection working point was different from the user's working point at TLS. Merge the injection and operation lattices are the first step to reach the goal.

Two modes, fixed current bin and fixed time interval, of top-up injection were evaluated during accelerator development period. The chosen of stored beam current bin as key parameter means system will trig injection as stored current lower than a specified value. The injection will cease as the stored current higher than a specified value. In considering the user's data acquisition convenience, the top-up injection was chosen to be in fixed time interval. The injection is synchronized with Network Time Server every minute such that the user can gate out the disturbed data points, if there is any.

During the normal operation, the injection time interval was set to every 60 seconds. The maximum stored beam current was limited to 302 mA. The recorded current bin is ~1.2 mA. Figure 2 shows top-up operation at 350 mA during one section of accelerator development. The stored current variation is less than ± 0.2%.

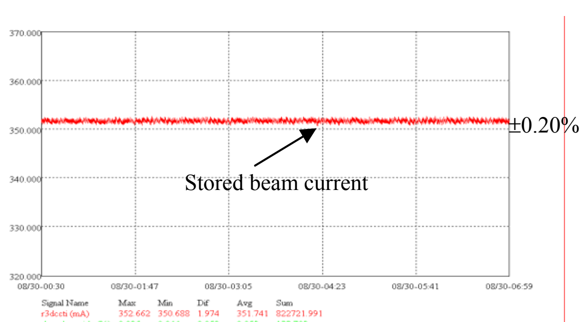

Figure 2. Top-up operation at 350 mA, the injection interval is set to every 60 seconds.

With the help of longitudinal and transverse feedback system, the beam stability measured by a 50 um pinhole detector shows a very stable photo-current during users shift. About 95% of the users beam time has $\delta I/I_0$ ratio better than 0.1%. The operation current was then increased to 400 mA. The transverse feedback system and SRF system are functioned as expected to suppress the instability and provide enough power to the stored beam during accelerator development time. To leave some engineering margins, the target operation current is set to 350 mA in coming year. Figure 3 shows the photon stability, 90% of time has $\delta I/I_0 < 0.07\%$, which was measured by one of diagnostics beamline during the 350 mA top-up operation.

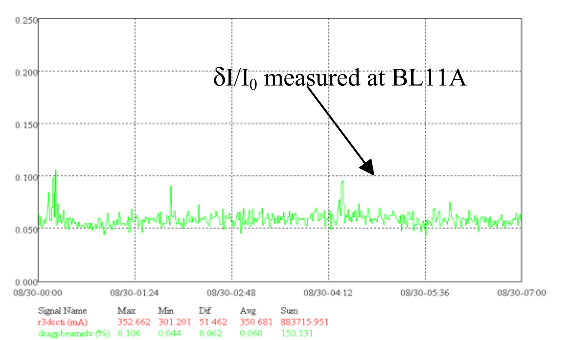

Figure 3. Photon stability measured by one of diagnostic beamline during 350 mA top-up operation.

From simulation, we understand that the transverse acceptance and time jitter of injection components are the key factors that affect the injection efficiency and filling pattern. By using a double trigger method in thyratron tube of the kickers, the jitters from injection bump reduced from ±10 ns to ±1 ns. This greatly improved the tuning of the injection process. The matching condition of injection components, jitter and amplitude, has been optimised to minimize the effect on filling patterns and maximize the injection efficiency. After very frequent injections, we can keep a reproducible filling pattern. However, we still found infrequent beam loss during the first year of top-up injection. The monthly statistics of unexpected beam loss number is shown in Figure 4. The major contributors of unexpected loss mainly came from kickers, SRF and noises during injection. The quality control of kickers system is under evaluation in order to reduce the number of unexpected beam loss. The fine tune of SRF feedback loops and preventing injection noises getting into interlock system is under way to have better tolerance in operation. The final target is to reach mean-time-between-failure better than 80 hours as short term goal. The statistics of scheduled, delivered and availability ratio in 14 years of TLS operation is shown in Fig. 5.

The beneficial of the constant stored beam in a storage ring is very obvious. The thermal gradient and deformation in time domain of top-up operation of optical components along the beam line can be minimized. The thermal expansion and contraction of girder and supporting structure along the storage ring chamber can be minimized either. This will help in the orbit control and also stabilize the launching condition of photons from the source. Figure 6 shows the absolute displacement of Beam Position Monitor (BPM) relative to the ground. In decay mode, the stored beam current decayed from 200 mA to 100 mA, the position displacement of BPM can be as large as 15 μm in horizontal direction and 5 μm in vertical direction. However, in top-up mode the displacement of the BPM relative to the ground can be reduced to within sub-micron meter range as shown in Fig. 6.

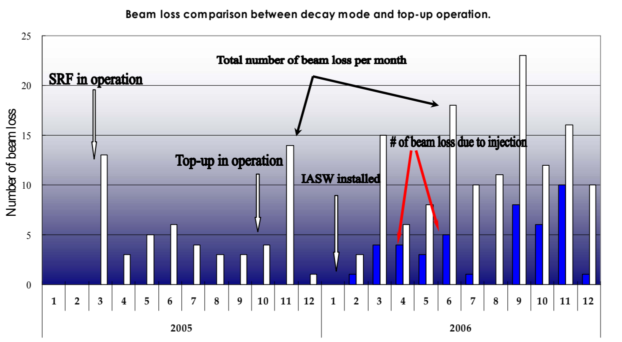

Figure 4. The statistics of unexpected beam loss before-and-after the top-up operation.

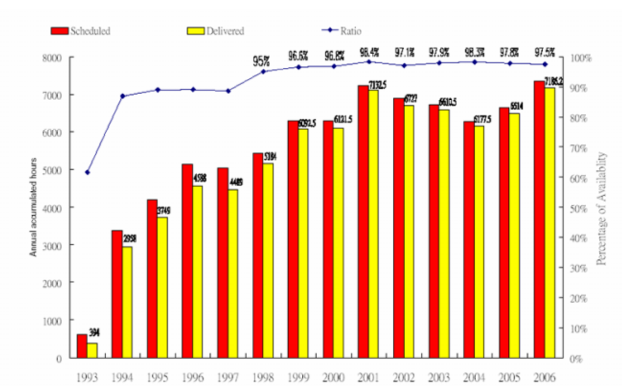

Figure 5. Statistics of scheduled, delivered and the availability ratio in 14 years of TLS operation.

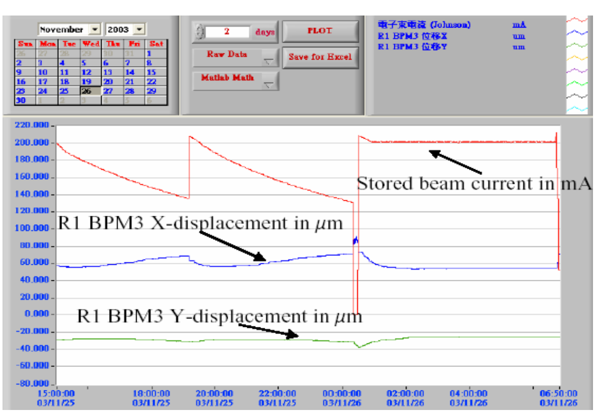

Figure 6. Recorded absolute position displacement in vertical and horizontal directions of BPM during decay and top-up mode.

RAIDIOLOGICAL CONSIDERATIONS

It is the first priority to keep the experimental area as a non-radiation controlled working environment. The basic design parameters of shield wall are according to the specification of Design Handbook [6] which was targeted to operate at beam energy of 1.3 GeV and maximum current of 400 mA in storage ring. The shielding wall was enhanced along the storage ring especially at the injection section. The exclusion zones of beamlines' front-end have been extended outward to keep the radiation dosage under controllable range. Additional radiation safety interlock systems, e.g. integrated dosage meters and dipole current margin, were implemented to abort the injection, if accumulated dosage or injection period excess the specified value.

Through devoted effort from NSRRC staff, the trip-off numbers due to radiation interlock is minimized during the test period of the third quarter of 2005. Not a single interrupt of top-up operation has been recorded due to excessive radiation dose since the machine start up in 2006. All the surveillance results and the TLD readings of the staff and users in NSRRC demonstrate that the radiological impact to personnel and environment due to top-up operation is well controlled and over-estimated at the beginning of the project.

SUMMARY

To reach the ultimate goal of third generation light source, TLS has prepared all the necessary steps to provide top-up operation mode to the users. The top-up mode provided the best thermal solution to the beamlines' optical components and locked the launching condition of the synchrotron light to users. Top-up injection also extends the new opportunities in probing better operation condition, for example lower the emittance, lower the gap of insertion device and increasing the bunch current without worrying the impact of beam lifetime. The top-up mode is routinely operated with SRF and three superconducting insertion devices successfully at TLS. It lays a solid foundation for the construction of a new 3~3.3 GeV Taiwan Photon Source.

REFERENCES

[1] T.S. Ueng, et al., "Topping Up Experiments at SRRC, "EPAC'96, 1996.
[2] L. Emery and M. Borland, " Upgrade Opportunities at the Advance Photon Source Made Possible by Top-Up Operations,"EPAC'02, Paris, 2002, p.218.
[3] L. Emery, M. Borland "Top-Up Operation Experience at the Advance Photon Source," PAC'99, 1999, New York, p. 200.
[4] A. Ludeke, M. Munoz, "Top-up Operation Experience at the Swiss Light Source," EPAC'02, 2002, Paris, p.721.
[5] H. Tanaka, et.al. "Top-up Operation at Spring-8," EPAC'04, 2004, Lucerne, p. 222.
[6] SRRC Design Handbook