THE STATUS OF TOP-UP INJECTION AT NSRRC

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Abstract

Several top-up experimental tests were carried out at various stages of Taiwan Light Source's (TLS) upgrade path. However, there were too many obstacles laid ahead at various stages to prevent the realization of top-up injection routinely. During last one and half years, a series of beam parameters measurement, subsystem checkout, installing various sensors, control program modification and hardware upgrade made the top-up injection seem more likely in routine operation. Discussions on the results of some measurements of booster and storage ring, the requirement of hardware upgrade and the future executable plan will be presented in this paper.

INTRODUCTION

The Taiwan Light Source (TLS) provides 200 mA, 1.5 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 machine designers to 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 will be installed at the RF straight section next to the Super-conducting RF (SRF) cavity to generate high flux x-ray.

It was a strong demand to increase the photon flux and reduce the photon fluctuation due to the Higher-Order-Modes (HOM) excitation from Dories cavity at the same time. A SRF cavity will be 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.

There were several top-up injection experiments carried out at TLS [1,2] since 1995. The working condition of storage ring and injector was changing at various stages. A series of improvement and upgrade were implemented in the storage ring, e.g. energy ramping at storage ring, adding strong field insertion device and separated injection and user's working point, made the top-up operation impractical at TLS.

The Advanced Photon Sources [3,4] and Swiss Light Source [5] have demonstrated a successful operation in partial or full operation 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

The demanding of lower emittance, small gap insertion device and doubling the stored beam current made the machine physicist 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. The cycling between injection and user's working points can solve the magnets' hysteresis effect with very good and reproducible operation condition in the operation. A purify process, which included re-establishing the ID operation tables, optimising the orbit, re-adjusting the injection parameters and optimising chromaticity, of the injection working point was carried out to make sure the injection working point qualified the user's operation condition without hitting any serious resonance lines. Fortunately, the injection working point can be optimised to satisfy the users' requirement with very good beam quality.

Two modes, fixed current bin and fixed time interval, of top-up injection were evaluated. 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. Figure 1 shows two user's shifts with decay mode and one top-up injection mode during machine-study. The zoom-in of stored beam current is

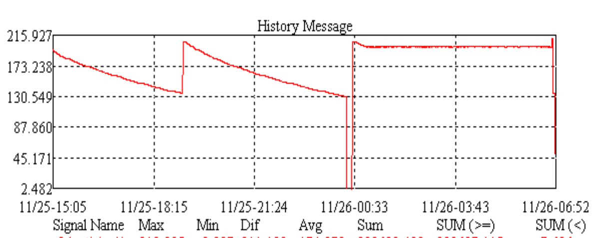

Figure 1: User's shift in decay mode and machine study in top-up injection.

shown in Fig. 2. During the test, the injection time interval was set to every 2 minutes. The maximum stored beam current was limited to 200 mA. The recorded current bin is ~0.6 mA.

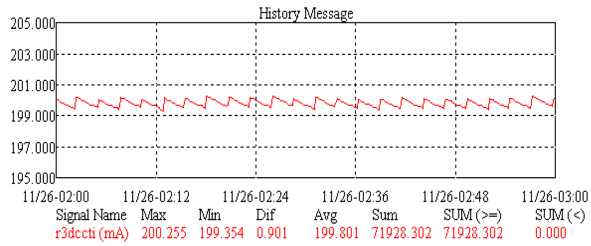

Figure 2: Zooming the top-up injection. The injection interval is 2 minutes, maximum beam current is 200 mA and the current bin is ~0.6 A.

One of the key factor affects the beam lifetime is the bunch distribution pattern or filling pattern in a storage ring. 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. Figure 3 shows the filling pattern at the beginning of the top-up mode. The matching condition of injection components, jitter and amplitude, has been optimise to minimize the effect on filling patterns. After very frequent injections, we have a reproducible filling pattern as shown if Fig. 3.

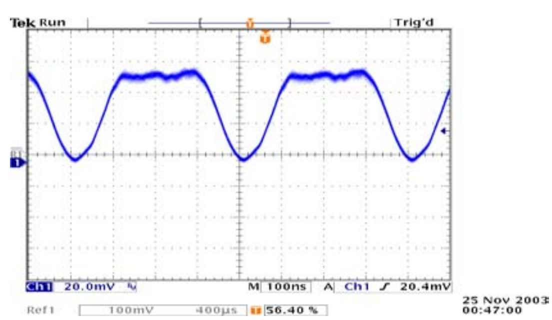

Figure 3: Filling pattern at the beginning of top-up injection. Filling pattern is identical to the shown pattern at the end of the test.

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 4 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. 4. Most of the BPMs, from the sensor heads to the position analysing electronics, have current dependent effect. Figure 5 indicates the current-dependent behaviour of BPM. The readings of the two BPMs drifted more than 3 µm during decay mode. If these BPMs were used in orbit feed back system, the source point will be varying according to the beam current. In top-up injection, the quasi-constant beam current eliminates the current-dependent effects in the reading of BPMs as shown in Fig. 5. The position change dropped to less than micron meter in the whole testing.

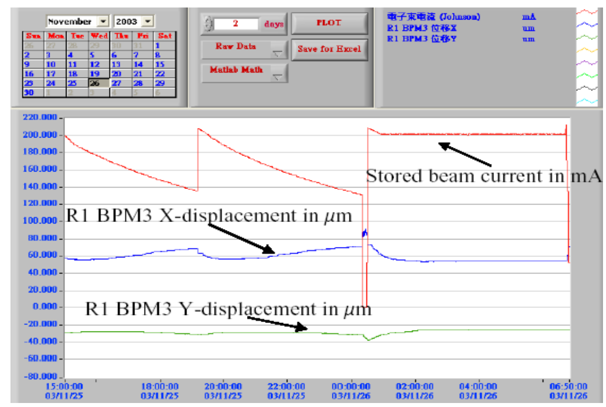

Figure 4: Recorded absolute position displacement in vertical and horizontal directions of BPM during decay and top-up mode.

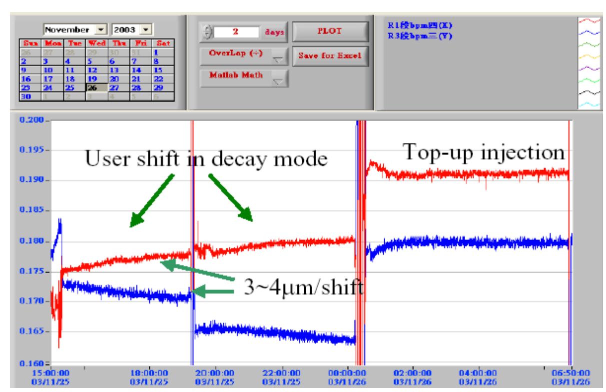

Figure 5: Reading of BPMs in the storage ring indicates the current-dependent effects. The reading of beam position can drift as much as 3-4 µm in one user's shift, if the effect was calibrated correctly.

INJECTOR

A 140 keV E-Gun, 50 MeV Linac and 1.5 GeV booster make up the injector at TLS. The injector, using white-circuits, injects the beam to storage ring at 10 Hz rate. If we run the injector continuously, the temperature of dipole magnets will raise at rate of ~1.5 ^{o}C/hour due to the eddy current of rapid cycling. The temperature of in-vacuum extraction septum will also increase at the rate of ~2 ^{o}C/hour due to very limited cooling capability. Due to the thermal effect [6], the current setting of dipoles magnets needs to be adjusted accordingly. Otherwise, available beam current to storage ring will drop significantly.

A revised intermittence operation mode of injector was found, which could stabilize the operation temperature of dipole magnets and extraction septum. The setting compensation of magnets' current, due to the thermal effect, can be avoided. Figure 6 shows the temperatures of dipole magnet and septum core under the new top-up control program at injector.

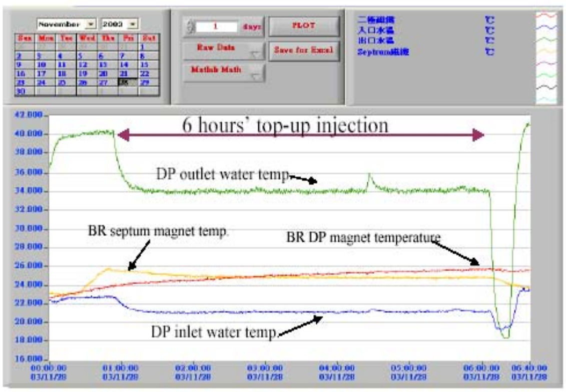

Figure 6: The temperature readings of dipole magnet and septum core under intermittence operation mode of injector at TLS.

A pair of vertical scrapers was used to measure the minimum aperture available to the future insertion devices. Two pairs of scrapers, horizontal and vertical direction, were installed at RF section. Black dots are the beam lifetime verses the scraper position in vertical direction showing in Figure 7. The red line is the Gaussian fitting curve of black dots. From the fitting curve, we can find that the relative offset between scraper centre and beam centre was 0.88 mm and the minimum gap of chamber should be made larger than 10.4 mm to avoid the interference with beam lifetime. The blue dots indicated the injection efficiency verses scraper positions. The estimated injection clearance in vertical direction should be 10~15% larger than the minimum gap from fitting curve without jamming the injection efficiency.

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 design handbook [7] at 1.3 GeV and 400 mA stored beam current in storage ring. The shield wall under operation of 1.5 GeV and 400 mA is exceeding the original design parameters. The shielding wall will be enhanced along the storage ring especially at the injection section. The exclusion zone of the beamlines will extend outward to keep the radiation dosage under controllable range. Additional radiation safety interlock system will be implement to abort the injection, if accumulated dosage or injection period excess the specified value.

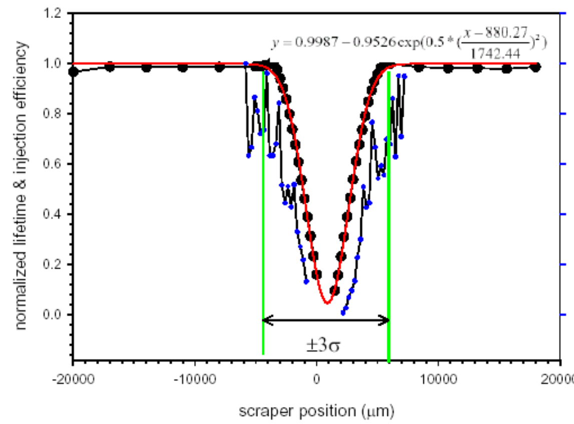

Figure 7: Vertical scrapers were used to measure the minimum aperture size of the ring without affecting the beam lifetime and the effect on injection efficiency.

SUMMARY

In order to improve the thermal relaxing problem during the energy ramping era at TLS, the injector was upgraded to have the capability to be full energy injection to the storage ring. This provides a chance to evaluate the feasibility of top-up injection at TLS again. The installation of SRF cavity also makes the ring have the capability to provide more photon flux with better beam quality to the users.

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 will provide 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.

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