

FEASIBILITY STUDY OF CONSTANT CURRENT OPERATION AT TLS STORAGE RING

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Abstract

Top-up injection is an operation mode in which the beam current in the storage ring is maintained above certain level by frequent injections. The routine current stability is in the range of 10^{-3} to 10^{-4} for long period of operation. During last eighteen months, 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 at Taiwan Light Source. 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 photons source for academic and industrial research scientists. The storage ring is a six-fold symmetry Triple-Bend-Arcomat (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 accelerator physicists try all the efforts to squeeze the space at injection section and RF section 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 a higher x-ray photon energy to users. 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 Doris 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] 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 [2] and Swiss Light Source [3] have demonstrated a successful operation in partial or full operation time with top-up injection 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 us to re-evaluate the feasibility of top-up operation at TLS. In users' operation shifts 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. It is essential to merge the injection and working tune for top-up. 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.

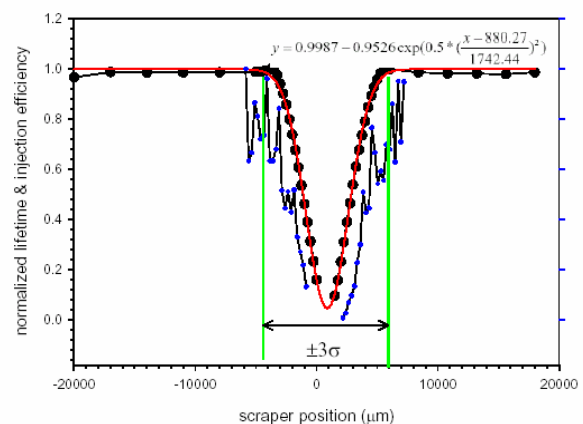


Figure 1. Vertical scrapers were used to measure the minimum aperture size of the ring and the effect on injection efficiency.

A pair of vertical scrapers was used to measure the minimum aperture available to the 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 1. 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.

TOP-UP INJECTION

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 system, the top-up injection was chosen to be in fixed time interval.

Figure 2 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 shown in Fig. 3. 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.

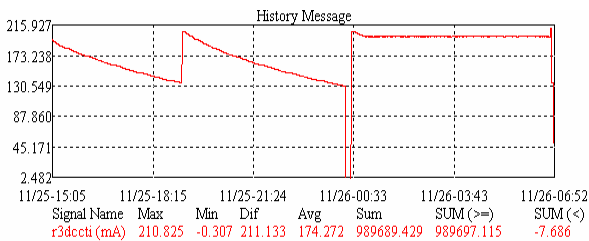


Figure 2. Stored beam current at user's shift in decay mode and machine study shift in top-up injection.

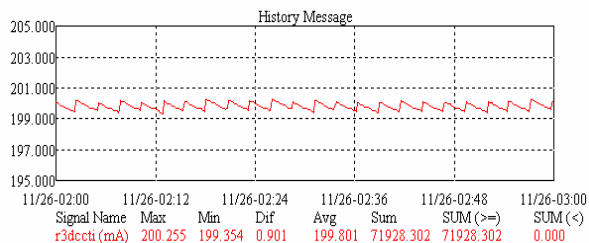


Figure 3. Zoom-in beam current at the top-up injection. The injection interval is 2 minutes, maximum beam current is 200 mA and the current bin is ~0.6 A.

One of the key factors that affect the beam lifetime is the bunch distribution pattern or filling pattern in a storage ring. We have a new injection program, which can control the filling pattern very well, to keep the lifetime eventually constant during the test of top-up injection.

From particles tracking simulation, we also understand that the transverse acceptance and time jitter of injection components are the key factors that affect the injection efficiency and filling pattern.

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.

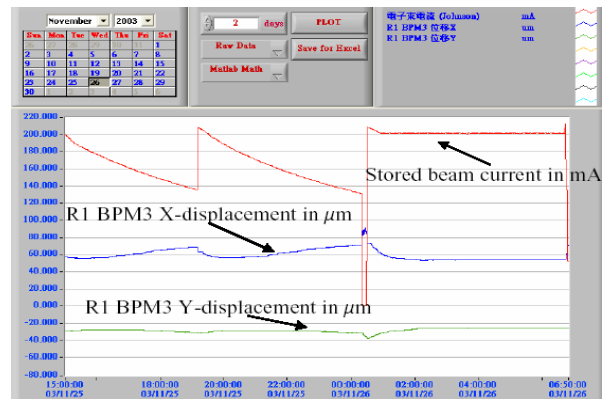


Figure 4. Recorded absolute structure displacement in vertical and horizontal directions of BPM during decay and top-up modes.

In decay mode, the stored beam current decayed from 200 mA to 100 mA, the structure 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 structure displacement of the BPM relative to the ground can be reduced to within sub-micron meter range as shown in Fig. 4. In top-up injection, the quasi-constant beam current eliminates the current-dependent effects in the reading of BPMs.

A beam-intensity pinhole detector is set up at BL08 beam line giving an indication of the photon stability during users' shift. Figure 5 shows the beam stability during the top-up injection. The photon instability can be

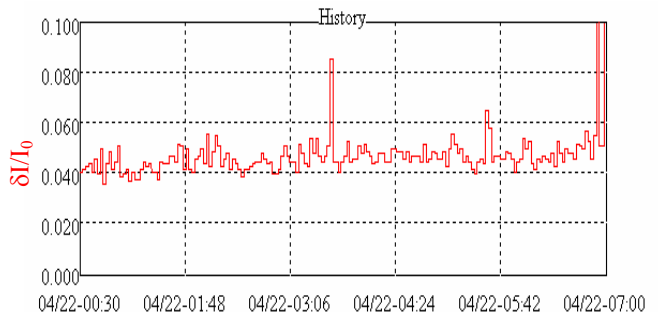


Figure 5. Fluctuation of Photon instability detected by a 50- μm pinhole detector during top-up injection.

maintained to be better than 0.06% in most time of top-up injection period.

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 °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 °C/hour due to very limited cooling capability. Due to the thermal effect, 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.

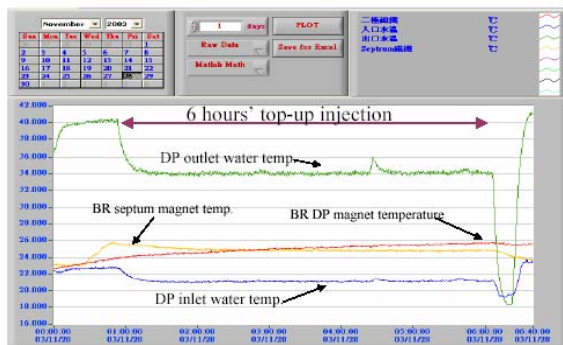


Figure 6. The temperature readings of dipole magnet and septum core under intermittence operation mode of injector at TLS.

RAIDIOLOGICAL CONSIDERATIONS

It is the first priority to keep the experimental area as a non-radiation controlled working environment. Archived information about the radiation dose rate was analysed in detail, between user's decay mode and top-up injection mode. One of typical example is shown in Fig. 7, where the radiation dose rate increases by a very small amount along the bending magnet beam line. The increased amount in Fig. 7 and the accumulated dosage during top-up injection is well under manageable range. However, it is necessary to increase the exclusion zone along the shielding wall of some of insertion sections due to the small chamber and higher vacuum pressure at these sections.

Special care was put on the down stream of first bending magnet right after the injection section. A permanent magnet will be installed at the entrance of the photon beamline to deflect the escaped electrons

downward to shielding wall, which can prevent high energy electrons get into the users' beamline.

The thickness of shielding wall will be re-enforced along the storage ring especially at the injection section. The exclusion zone of some beamlines will extend outward and real time interlock monitor will be installed to keep the radiation dosage as low as acceptable. Additional radiation safety interlock system will be implement to abort the injection, if injection efficiency lower than or injection period higher than specified value.

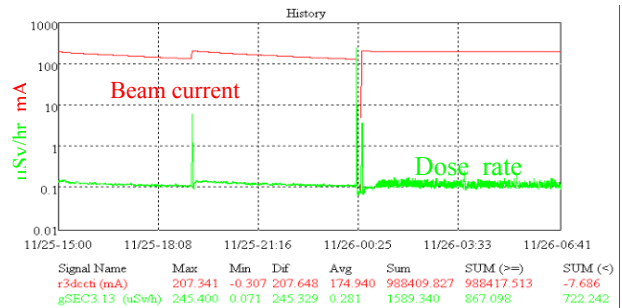


Figure 7. The radiation dose rate along the shielding wall of bending magnet during decay mode and top-up injection.

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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