PROGRESS TOWARDS IMPLEMENTATION OF TOP-UP AT THE AUSTRALIAN SYNCHROTRON

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Abstract

The Australian Synchrotron Light Source has enjoyed several years of stable operations with a high degree of availability. It is now time to move towards top-up operations to improve the stability and integrated flux of the photon beam. This paper describes the steps that have been taken and what remains to be done in order to implement top-up injection as the normal operation mode.

INTRODUCTION

Top-up is a mode of operation where the injection system is continually kept ready to inject a pulse into the storage ring. With top-up it is possible to keep the stored current stable to within less than a percent. The main advantage of running in this mode is that it keeps a constant heat load on the optical elements of the beamlines. The main disadvantage is that the injection system elements will be on for long periods of time reducing their remaining lifetime at a much greater rate than fill-on-fill operations.

A working group was formed with the radiation safety officer, representatives from the Accelerator Science and Operations group, engineering, controls, beamlines, and the state government radiation regulator. The goal of this group is to get agreement from all interested parties that any risks with injecting beam into the storage ring with beamline shutters open are acceptable within the defined constraints identified by the group without restrictions to personnel on the technical floor.

Assumptions

The basic assumptions that determined the starting point for the working group decisions were:

- It is acceptable to have shutters opened with stored beam regardless of beam-loss scenario.
- Injection with shutters open can only occur if there is stored beam in the ring.
- The parameters of the injected beam can be kept within defined limits with interlocks prior to the storage ring.
- Modelling results will be complimented by measurements.
- Model geometry based on measurements.

The exact definitions of these assumptions, especially the stored beam and injected beam parameters, are being developed based on observations and the details of the implementation of interlocks which is ongoing.

INJECTION SYSTEM PERFORMANCE

The injection system was specified to be compatible with top-up operation. Many top-up test runs with shutters closed have been performed over the last few years. This has given us the experience needed to identify the systems that need to be improved in order to optimize the advantages of implementing top-up. All of the systems except for the pulsed septa and kickers respond repeatably to first triggers or any trigger frequency up to the maximum whole system frequency of 1 Hz. The system can deliver single buckets with very low charge up to 75 bucket trains with several nC. This allows flexibility in determining the injection charge and frequency. The default for the ongoing studies is to inject a 75 bucket train with approximately 0.2 mA and inject when the current drops below 200 mA. A set of beam scrapers is use to reduce the lifetime enough so that the shots come every few minutes. Figure 1 shows the current during a 2 hour period of one of these runs.

Figure 1: Current during a top-up run.

As can be seen, there is still quite a variation in the captured current per shot. This is primarily driven by the drifting of the pulsed magnets which are run in open loop and are susceptible to temperature variations.

TRACKING STUDY

The first step in the process of implementing top-up is to ensure that the likelihood of sending energetic electrons down the beamline tubes is negligible. A tracking study was performed to determine this. The first step is to fill the available horizontal phase space at the storage ring end of the booster to storage ring transfer line with particles. These particles are then tracked through the storage ring. The second step is to fill the available horizontal phase space of the beamline front end exit outside the shielding tunnel wall and track these particles back to the storage ring. Any overlap of these two sets of particles would indicate a possibility of electrons travelling down the beamline. Figure 2 shows the layout of the end of the transfer line with a pre-septum and two thin septa along with the first sector of the storage ring. The two thin septa have 10 mm channels which restrict the possible extent of the particles.

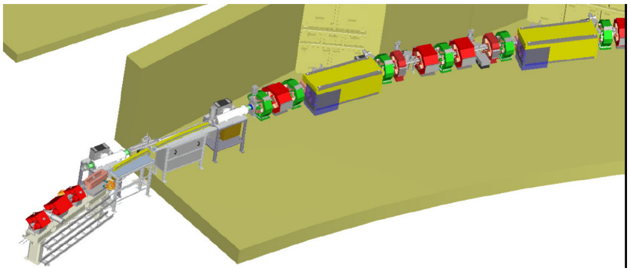

Figure 2: Layout of the transfer line and sector 1.

Figure 3 shows the possible phase space at the end of the transfer line.

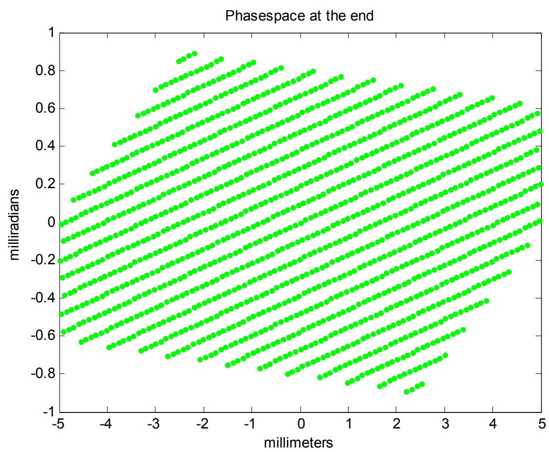

Figure 3: Electron distribution in horizontal phase space at the end of the transfer line.

The tracking study showed that there were no possibilities to get the two phase spaces to overlap. An example of the closest distance found, which occurs near the first dipole port, can be seen in Figure 4.

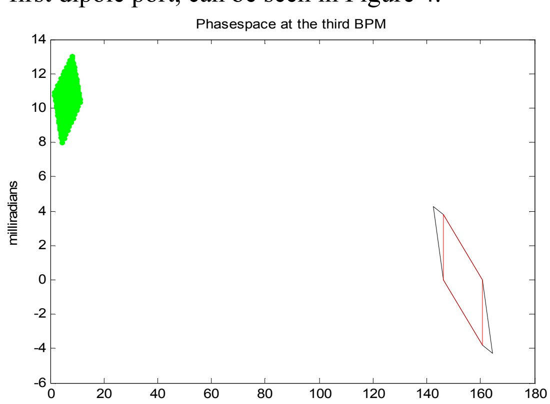

Figure 4: Distance between tracked injected particles and backward tracked beamline aperture.

The results of the tracking study were positive enough for the working group to decide to recommend that studies with open shutters could be performed.

Additional tracking studies in the vertical plane have allowed us to identify the best position for an aperture to restrict the vertical size of the injected beam in order to avoid having the in-vacuum undulator gaps determining the injection efficiency.

RADIATION MEASUREMENTS

The next step is to perform top-up runs during machine studies time and perform radiation measurements around the facility, with special attention being given to the area around the beamline first optical enclosures.

The regular area monitoring that is in place is used to find any unexplained increases in radiation levels around the facility while the top-up testing with open shutters is being conducted. Other portable detectors have been used to measure at specific locations outside of the enclosures. A typical placement of the detectors can be seen in Figure 5.

Figure 5: Photon radiation monitor next to the first optical enclosure.

For insertion device beamlines the gaps were set to the standard gaps used during injection, which for the in-vacuum devices is 10 mm and for the wiggler the nominal user beam gap. A white-beam slit just inside the enclosure was closed making the baseline measurement consist of mainly back-scattered x-rays. The measurement sequence is to inject to 200 mA with shutters closed and record a period of beam decay, open the shutters and close the insertion device gap and record another period of beam decay, then start top-up and record another period keeping the current at 200 mA. A typical set of measurements showing the stored current, insertion device gap, and shutter status along with the photon and neutron levels can be seen in Figures 6 and 7.

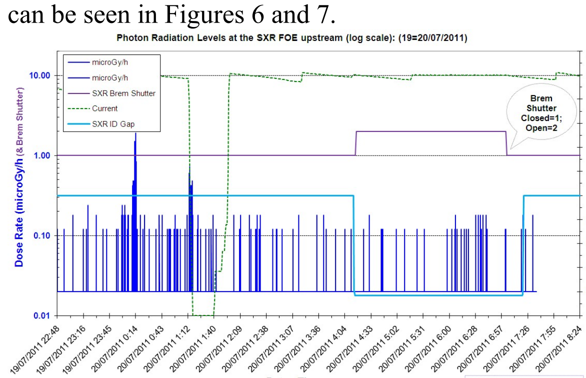

Figure 6: Photon radiation levels during a typical test run.

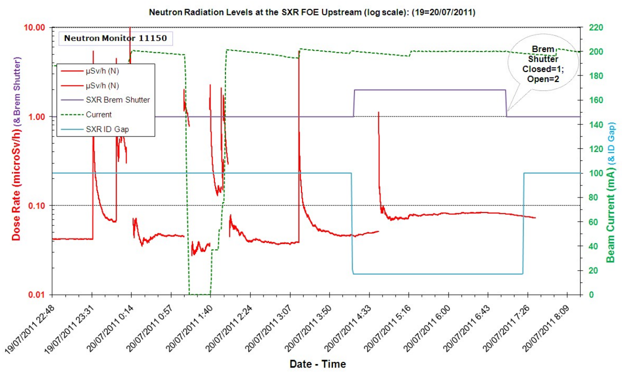

Figure 7: Neutron radiation levels during a typical test run.

The results of the measurements have been consistently indicating that there are no increased levels around the first optical enclosures associated with injecting with the front-end shutters opened. The normal area monitoring results confirm this. There are monitors placed above the injection point which are used as an indication of how well the injection process is going. Figures 8 and 9 show the results from these monitors during the period that included the top-up run shown in Figures 6 and 7. The increase there is showing the increased spikes from the top-up shots at a slightly lower level as expected.

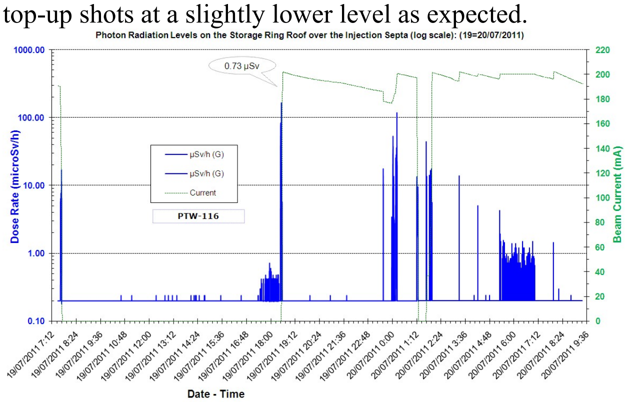

Figure 8: Photon radiation levels above the injection point including a top-up test.

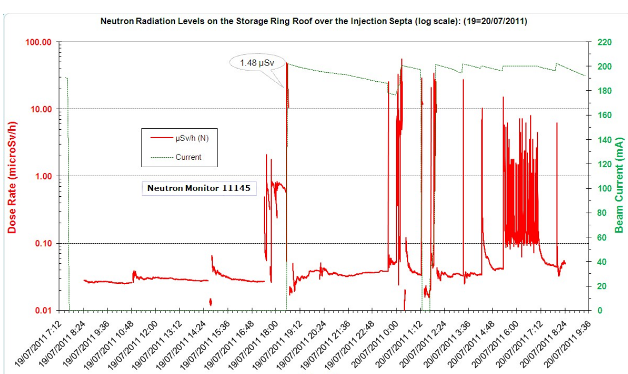

Figure 9: Neutron radiation levels above the injection point including a top-up test.

TRANSFER LINE UPGRADES

There are upgrades to the transfer lines that have been implemented or planned. The downstream end of the transfer line has been upgraded with an additional two screens with cameras as well as an in-flange fast current transformer. Ultimately the measure of the injection efficiency that may be used as an interlock will come from the difference in the charge passing this transformer and the increase in the stored current since there will be an aperture in the transfer line closer to the booster which will restrict the vertical beam size. There will also be 2 stripline detectors installed in the transfer line to monitor position stability and injected charge.

REMAINING WORK

While a lot of progress has been made, there is much that has to be done before running top-up during user runs. A major component of this work is to implement the interlocks that determine whether or not it is safe to perform top-up injections. The interlock that inhibits injection if there is no stored beam will be one of the key systems. It has been decided that besides the stored beam current being above a certain threshold, stored beam will also be interpreted as requiring that the multipole magnet currents are within certain limits to ensure that the ring is not in some alternative optics mode. The same magnet current interlock system will be used to make sure that the energy of the injected beam is within the specified limits.

While some tests have been done with the beamlines looking at the beam while the injection elements are firing have been done, there is much more time needed to run top-up tests with the beamline personnel attempting to take data as users would in order to identify what needs to be done to identify what needs to be done to optimize the advantages of implementing top-up.

CONCLUSION

Progress is being made in the move to top-up operations for regular user beam runs in 2012. The issue from the accelerator systems point of view have been identified and work is underway to optimize the injection process and implement the interlocks that ensure the state of the storage ring is within the limits defined to allow injection with shutters opened. Some preliminary studies have been conducted together with the beamlines while injecting with opened shutters and the initial results are positive. There is still much more work to be done in this regard and the move to injecting fill-on-fill with open shutters will be made as soon as possible to allow for more experience with data collection while the injection system is running.

ACKNOWLEDGEMENT

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