

# TOP-UP MODE OPERATION AT SRRC

T. S. Ueng, K. T. Hsu, Jenny Chen, C. S. Chen, K. K. Lin, SRRC, Hsinchu 30077, Taiwan

## *Abstract*

Top-up mode injection is under studying in the newly upgraded 1.5 GeV Taiwan Light Source at SRRC. Some of the control software and hardware are modified in order to achieve a one-button machine operation. The electron beam can be injected automatically from the injector into the storage ring to fill the stored beam to a preset high current limit whenever it decreases to a preset lower limit. Several effects, such as the injection efficiency, the stability of the stored electron beam orbit and the radiation safety issues were studied, the solutions for their improvements were also investigated.

## 1 INTRODUCTION

The injection system of SRRC storage ring was upgraded from 1.3 GeV to 1.5 GeV recently by changing the magnet power supply system and extraction system. The power supplies of the booster to storage ring transfer line have also been changed. At the same time a major upgrade of its control system has been done. The electrons produced by the electron gun are accelerated to 140 KeV, then, accelerated by a 50 MeV Linac and 1.5 GeV booster synchrotron. The extracted electron beam is then guided through a transfer line and fed into the storage ring. During the routine operation a 200 mA electron beam is accumulated and let it decay to around 100 mA, which takes about 8 hours. The users will perform their experiments during this period. It is known that the heat loads from the injection process and during the current decay affect the storage ring components and the beam line optics components. The beam line users may need complicated calibrations for the acquired data or need to wait for the optics reaching the thermal equilibrium before performing the experiments. Recently, a new operation mode, top-up mode injection, is under studying at several facilities[1] hoping to solve this type of problems and also to improve the performance of the storage ring. At SRRC, a continued study is also underway following a previous study[2] at 1.3 GeV to explore the feasibility of this mode of operation.

## 2 THE INJECTION CONCERN

Since the SRRC injector is dedicated to the storage ring electron beam injection, the injector can be available for the top-up mode injection all the time if necessary. Accompanying the 1.5 GeV upgrade of the SRRC booster synchrotron, some of the hardware and software of the control system have been modified during the past couple

of months for testing the top-up mode injection operation. This includes the upgrade of fast timing system of the booster and the pulsed magnets, and the improvement of the bucket addressing method. It allows a more precise timing trigger and stable beam current in the injector during the operation. Some related concerns affecting the present testing of top-up mode injection are described as following.

### 2.1 Injection efficiency

The relative injection efficiency is quiet low from the booster synchrotron to the storage ring at this stage. Also, the time structure of current in the booster synchrotron is fluctuated due to the instability of the Linac klystron modulator voltage and some hardware components. The electrons per bunch can not be controlled accurately. At present, the single bunch current at the booster has only about 0.2 mA. If the single bunch injection is chosen for the top-up mode injection, a long injection time will be required. It requires reliable and durable pulse magnet components[3]. Since the beam disturbance during the injection process may limit its usage, the usable beam time will be reduced. For the multi-bunch injection mode, the beam current in the booster can reach to more than 3.5 mA. Thus, only the multi-bunch injection was tested for the top-up mode injection operation recently.

### 2.2 Beam bunch pattern

A constant beam bunch pattern with little bunch current variation provides the stability for the stored beam and that after different injections. Because the variation of beam current in the preinjector system, the bunch pattern in the booster synchrotron varies also. It is difficult in filling the beam in the storage ring with a constant bunch pattern. The present approach is to fill the beam in the storage ring with few mA each step, then fill it in the next step with a shifted bunch position. It continues until the target current is obtained. The purpose is to preserve the beam bunch pattern in the storage ring.

### 2.3 Storage ring lattice

After the upgrade of SRRC booster synchrotron, the lattice of the booster and the matching lattice of the storage ring have not been studied thoroughly. In order to meet the stability requirement of photon beam demanded by the beam line users, a user lattice is reloaded after storing the electron beam. The user lattice of the storage ring for the user beam time is only slightly different from the injection lattice in the setting of a quadrupole strength. But, this user lattice can not be used to inject the electron

beam to the storage ring efficiently. Thus, we adopted the injection lattice for the top-up mode injection during the test runs.

### 3 RESULTS AND DISCUSSION

During the past couple of months, the top-up mode injection has been performed several times at the SRRC storage ring. Generally, the current in the booster synchrotron could vary and has more than 10% difference for the different injection cycles. In Fig. 1, one hour of the typical result of the test run is plotted. In the figure the data points were sampled every 100 msec in order to examine the information in each injection cycle. During the experiment, the high limit of the beam current in the storage ring was set to 200.0 mA, and the low limit was set to 199.5 mA. In Fig. 1a, it shows that the current was sometimes injected to slightly higher than 200.0 mA. This is due to the multi-bunch injection method used. At the final injection step during each injection cycle it might inject more than the necessary amount of current. As the current reached the lower limits the electron beam would be re-injected right away. In Fig. 1b, the currents at booster are shown when the injection process occurred. It shows that the injection process took about 2.5 seconds each injection cycle. In some of the early test runs the current would sometimes went down to 199.4 mA before the re-injection process started due to the mismatch of the waveform of injection kickers. After the correction of troubled kicker, the re-injection process ran greatly during the recent tests. In the case the booster had higher current the injection time would be even shorter. As for the decay time for the 0.5 mA current, it took about 130 seconds. In Fig. 1c, the data corresponding to one of the horizontal beam position monitors are shown. It shows qualitatively the beam disturbance during the injection process.

The execution of top-up mode injection can be roughly divided into two types. One is to inject the electrons to a pre-set high current value and, then, to inject frequently to supplement the decayed current to maintain its high current. Another is the so-called refill mode top-up injection. It is to inject the electrons to a pre-set high current limit and allow it to decay to a lower current value. Then, the injection will repeat automatically again. In principle these two approaches are the same from the viewpoints of design of control methodology. The critical point for selecting which method to use should depend on the performance of accelerator and the benefits to the beam line users. For the present SRRC storage ring, due to the multi-bunch injection method used, the current stability is hard to be within 0.1%, thus the frequently injection mode may not be practical. But, for the refill mode top-up injection, it might provide some benefits to the beam line users. If a decay of 5 mA currents (from 200 mA decays to 195 mA) is chosen, it will allow a 20 minutes of stable photon beam to use, and with only about 20 seconds of re-injection time. Or, one can set a lower

current limit to allow a longer user beam time. During this mode of operation, trigger signals are needed to provide to the users for them to configure their data acquisition equipment to start the data acquisition when the beam injection is complete and stop the data acquisition if the beam injection is about to occur. This is to avoid the highly unstable beam during the beam injection process.

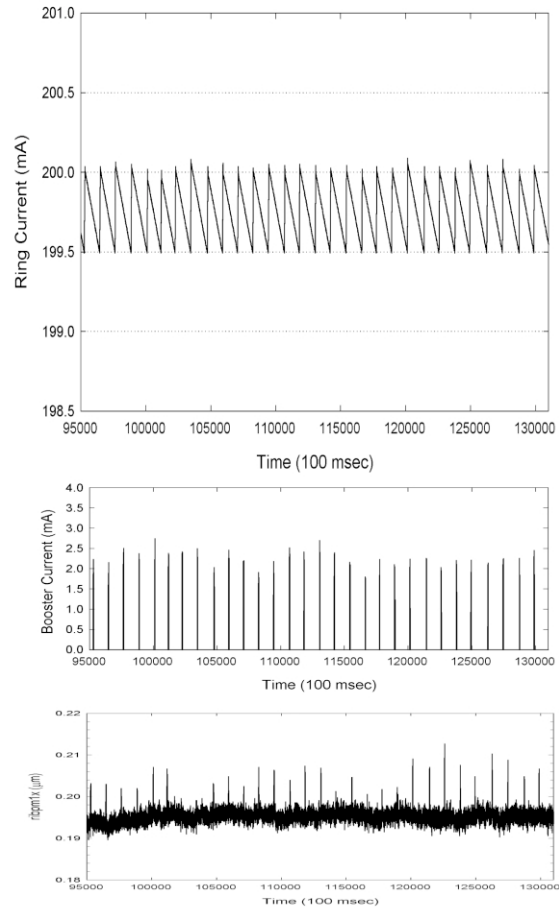


Figure 1: The typical result of top-up mode operation. (a) The beam current measured in the storage ring; (b) the beam current in the booster synchrotron during the injection process; (c) the orbit disturbance during the injection seen by the horizontal beam position monitor.

### 4 THE RADIATION SAFETY ISSUE

In the routine beam injection to the storage ring the photon shutters of the beam lines are closed for the safety reason. During the top-up mode injection, the electron beam injection will occur at short time interval. If the beam disturbance during the injection is small, the beam line user will be able to use the photon beam during the injection. Thus, the photon shutter in the photon beam line will be opened during the injection. In the case the beam

disturbance prohibits the users to run their experiments, the users might not leave the beam line during the few seconds of injection period and the photon shutter might not be closed. If the bending magnet or the quadrupole after the straight section is short, it will let electron beam exits through a photon beam line. In order to prevent this to happen, the beam injection process will be stopped automatically if any malfunction is happened to the magnet system or any other accelerator hardware during the injection.

Besides, a radiation monitoring system should be used to monitor the radiation level at some specific points. If the radiation level is higher than some level, the beam injection should be stopped also. During the beam injection the radiation level is usually much higher in some areas. We have used the present radiation monitor system to estimate the radiation level. The radiation dosage at one point of the control room, which normally has radiation level higher than the working area was shown to have only 3 to 5 times of the background dosage during many of our test runs. It is a result of the short injection period, few seconds. For the beam line user area, the radiation level also did not show any safety problem when the top-up injection was operated normally.

## 5 CONCLUSION

At present, it still has a long way to make the top-up mode injection as a routine operation at SRRRC. Many improvements on the accelerator hardware and software are necessary to make it feasible.

The reliabilities of the pulsed power subsystems, such as pulse magnets, microwave system and some electronics for the electron gun, are very important to the success of the top-up mode injection. During the refill mode operation, the time interval between the subsequent injection is much longer. It is not necessary to put these components in the operation mode. A modification in the

timing control sequence is being made to allow these components to operate only during the beam injection.

During the test runs, it showed that the matching of waveforms and the timing of triggers of the four storage ring injection kickers are critical to the precise injection of the electron beam. An improvement on this injection kicker system is planned for the next year.

The present storage ring lattice for the users gives a tune very closed to the resonance point and is not suitable for injection. Thus, a lattice solely for the injection is used. Since this injection lattice can not give a target orbit demanded by the users, to find a new lattice that allows an easy injection and at the same time satisfies the user shift orbit requirement is needed for this mode of operation. At that time, the single bunch injection may also be studied for the top-up mode injection.

Finally, for the personnel safety more radiation monitors would be installed at some user area to monitor the radiation level. They will also be served as a reference to determine the condition for the beam injection.

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