IMPROVEMENTS TO THE INJECTION EFFICIENCY AT THE TAIWAN LIGHT SOURCE

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Abstract

The Taiwan light source began top-up operation in October 2005 with an initial beam current of 200 mA. This was subsequently raised to 300 mA. In the early phase of top-up operation, the injection efficiency varied markably under different machine operating conditions. A procedure to optimize and maintain the injection efficiency is presented. Future improvements and the prospects for a 400 mA top-up operation are discussed.

INTRODUCTION

On Oct. 12, 2005, the storage ring at the Taiwan Light Source changed from decay mode of operation to top-up mode operation. There are significant differences between these two modes of operation [1]. The Booster and Injection septum and kickers have to be operational at 24 h full time.

In the decay mode, the malfunction of the Booster or the Injection components may cause delay in the storage ring operation. The difference of 30 s or 3 min. injection time, due to injection efficiency variation, plays little role in the overall storage ring performance. Furthermore, once storage ring has accumulated to an operational current, there is time to diagnose and fix problems associated with the injection chain.

In the top-up operation, malfunction of injection components may cause beam loss and disrupt user's experiments. Booster stability and injection efficiency become important issues in the top-up mode operation.

At the TLS, the injection time is 1.8 s in every minute. Maintaining stable storage current require a stable current in the Booster as well as a stable injection efficiency. This paper discusses the procedure to improve and maintain injection efficiency at the TLS.

THE BOOSTER EXTRACTION AND THE STORAGE RING INJECTION SCHEME

The booster has a three bumpers system that used to get the shortest possible closed orbit bump. The bumper 2 plays as a useful tuning knob when booster tunes were changed [2].

A 69.774 m long transfer line deliveries the booster beam in parallel to the trajectory of stored beam. A 0.9 m long injection septum with 10 degree deflection angle is attached to the SR vacuum chamber. The layout of injection section and trajectories of the injected beam and the stored beam is shown in Fig. 1.

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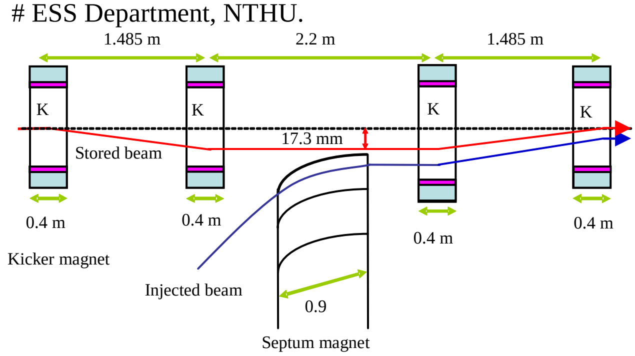

Figure 1: Trajectories of the injected and the stored beams.

ESTIMATION OF INJECTION EFFICIENCY

The circumferences of the Booster and the storage ring are 72 m and 120 m respectively. The revolution periods are 240 ns and 400 ns respectively. The Booster operates at 10 Hz and 2 mA. In general, every two Booster pulses, the storage ring accumulate about 1 mA storage current. Thus the overall injection efficiency is about 1/2.4, or 41.6%. This number is used as a reference for our injection tuning study.

ADJUSTMENT OF INJECTION PARAMETERS

The injection efficiency depends critically on electron beam orbit in the transfer line, orbit bump in the storage ring and the beam optics. A few key components in the TLS are the bumper 2, the septum, and the element R1QDT6 is a trim quadrupole locates at the sixth quadrupole (defocusing quadrupole) of the first section. A schematic layout of one superperiod of storage ring is shown in Fig. 2.

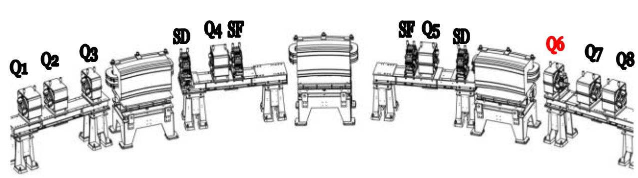

Figure 2: One superperiod of the TLS storage ring. R1QDT6 refers to a trim defocus quadrupole located at the sixth quadrupole of the first section.

The booster has 3 bumpers. Their usage is to create a local orbit bump in order to minimize kicker field for beam extraction. Changing the bumper 2 can effectively adjust the initial condition for the beam orbit in the transfer line. Fig. 3 shows a typical bump orbit, and an indicator of the bumper 2 location.

The septum at the injection straight section in the storage ring plays an important role to maintain the injection efficiency. Changing the septum voltage can effectively adjust the injecting trajectory of injected beam. Fig. 4 shows the measured injection efficiency in terms of the septum voltage.

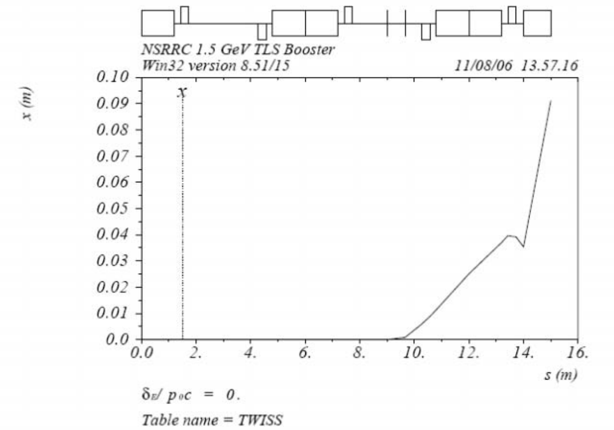

Figure 3: A typical bump orbit at the exit of the extraction septum.

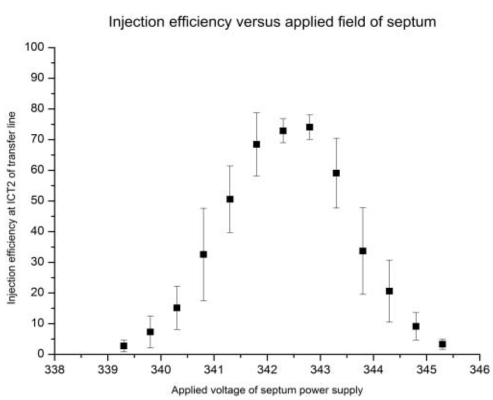

Figure 4: The measured efficiency as a function of the septum voltage.

The difference arises essentially from the compensation of other injection components and heating of the septum. At the top-up mode operation, the setting of the septum is constant. Its value will change only when there is a change in the injection components. Change of injection status occurs when thermal equilibrium is altered. This happens at the intermediate state between the changes from the decay mode to the top-up mode.

The element R1QDT6 is a trim quadrupole located at the Q6 (defocusing quadrupole) of the first section. This quadrupole can change the injection beam optics. We use the locality of the R1QDT6 to adjust the betatron tunes and the injection efficiency.

Fig. 5 shows the injection efficiency in term of the available tuning range of R1QDT6, which is effectively adjust the betatron tunes for different condition of insertion device. The gaps of insertion devices have to change for fulfilling the user’s experiments during the top-up operation.

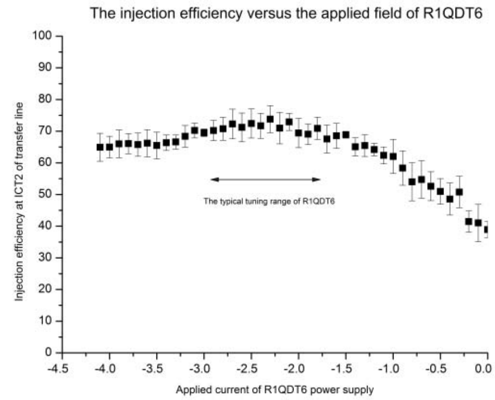

Figure 5: The injection efficiency as a function of R1QDT6 current.

INJECTION EFFICIENCY AND PRESENT STATUS

The injection efficiency can be determined by 4 DCCT's located at the entrance of the transport line (ICT1), the middle of the vertical bend section in the transport line (ICT2), the 3rd section of the storage ring (R3DCCT), and the current transformer (B10DCCT) in the Booster ring.

In this report, we measured the transmission efficiencies from the Booster to ICT1, from the ICT2 to the storage ring, and the injection efficiency from the Booster to the storage ring. At present, the transmission efficiencies from the Booster to ICT1 is about 70%, and from ICT2 to the storage ring is about 60%. The average injection efficiency from the Booster to the storage ring is about 34%. Thus we find that the transmission efficiency is 81%.

Since the DCCTs at ICT1 and ICT2 are single pass devices, these devices are not as precise as the DCCTs in the Booster and the storage ring. The optimization procedure is based essentially on the injection efficiency from the Booster to the storage ring. Generally, the circulating current in the Booster can vary from 1 mA to 3 mA, and the number of top-up injections can vary from 4 to 1 times respectively.

IMPROVING INJECTION EFFICIENCY AND PROSPECTS FOR THE FUTURE

Since 2005, we find two major factors in improving the injection efficiency. These two major factors are (1) the transmission efficiency of the transfer line and the tuning of the sextupoles strength of storage ring and (2) digital transverse feedback system in suppressing the transverse instability [3]. Because of the transverse feedback system, the betatron motion has a larger range of operational ν_x and ν_y.

The trend chart of injection efficiency of top-up operation from October 2005 up to now is shown in Fig. 6.

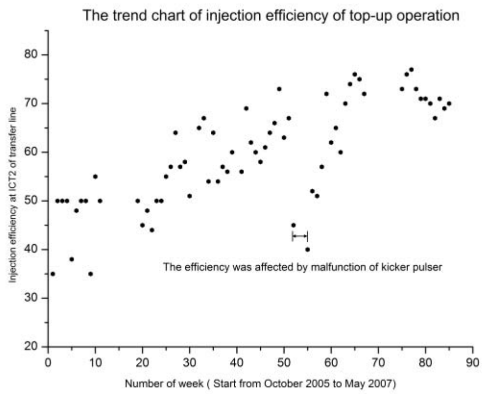

Figure 6: The trend in injection efficiency during top-up operation in the period from October 2005 to May 2007.

Based on the measured efficiency of ICT1, ICT2, and total efficiency, we have developed an optimization procedure to improve the injection efficiency for the top-up operation. First, the booster extraction bumpers and kicker are finely tuned to maximize the ICT1 reading. Notice that the transmission efficiency of the booster to storage ring transfer line can be quantitatively obtained from the ratio of ICT2 and ICT1 readings. After careful tuning, a 90% overall transmission efficiency of the transfer line can be maintained in routine top-up operation. Next, information concerning the beam accumulation rate of the storage ring and ICT2 reading provides guideline for injection septum adjustment. Third, a tuning knob marked R1QDT6 is utilized in case of required such that the betatron tunes can match the working condition of transverse feedback system.

In the near future, we will focus our effort on (1) Improving the transmission efficiency from the Booster to the ICT1, and (2) improving the transmission efficiency from the ICT2 to the storage ring. The initial goal is to optimize the Booster orbit bumpers and septum in order to achieve a transmission efficiency of 80%.

Once this achieved, we will carry out similar optimization of components to achieve a transmission efficiency of 85% from the ICT2 to the Storage Ring with 95% transmission efficiency of transfer line. Thus we can achieve an injection efficiency of 65% from the Booster to the Storage Ring. With this improvement, we will be able to achieve 400 mA top-up operation in the storage ring.

REFERENCES

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[2] TLS booster design handbook.

[3] K.H. Hu et al., Commissioning of the Digital Transverse Bunch-by-Bunch Feedback System for the TLS, EPAC 2006, (2006).

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