STATUS OF TOP-UP OPERATION IN UVSOR-II

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Abstract

Many efforts to realize multi-bunch top-up operation of UVSOR-II have been made. Until the end of FY2009, problem of transverse beam oscillation at injection timing has been solved by distributing injection timing signals to all beam-line and by stopping data acquisition during the injection. From summer of FY2010, all user runs will be done with the multi-bunch top-up operation. Developments on single bunch injection and single-bunch top-up operation have been done and we succeeded in single-bunch top-up operation in July 2009. The single-bunch top-up operation has been used for user experiments and experiments on advanced light source development such as Free Electron Laser (FEL), coherent harmonic generation and coherent synchrotron radiation.

INTRODUCTION

Top-up or top-off operation is now common technique for keeping the stored beam current in a storage ring and contributes to increase the average flux of generated synchrotron radiation. Many 3rd generation synchrotron light sources introduced the top-up operation to supply photon beams with constant flux.

UVSOR-II is a low emittance, 750 MeV synchrotron light source. Low emittance and low energy synchrotron light sources naturally suffered from short electron lifetime due to strong Touschek effect. Thus realization of top-up operation is strongly required. And many efforts have been made to introduce the top-up operation to user experiments.

In this paper, history and present status of top-up operation in UVSOR-II, single-bunch top-up operation and top-up operation of UVSOR-II SR-FEL are reported.

UVSOR-II ACCELERATORS

UVSOR-II consists of a 15-MeV linear accelerator, a 750 MeV booster synchrotron and a 750 MeV low emittance storage ring. The schematic diagram of the accelerators is shown in Fig. 1. The focusing magnets of the storage ring, which were ordinal combination of quadrupoles and sextupoles, were replaced with combined function ones to obtain longer straight sections. And then the ring lattice was changed from normal double bend achromatic cell to extended double bend achromatic one with distributed dispersion function for smaller transverse emittance [1, 2]. Consequently, the emittance was reduced from 160 to 27 nm [3]. The storage ring equips two RF cavities, fundamental 90.1 MHz one and 3rd harmonic 270 MHz one. The 3rd harmonic one is routinely used for suppressing the coupled bunch instability and controlling the longitudinal electron bunch shape [4]. In normal multi-bunch operation it is used to lengthen the bunch length for longer beam lifetime. The typical parameters of the UVSOR-II storage ring are listed in table 1.

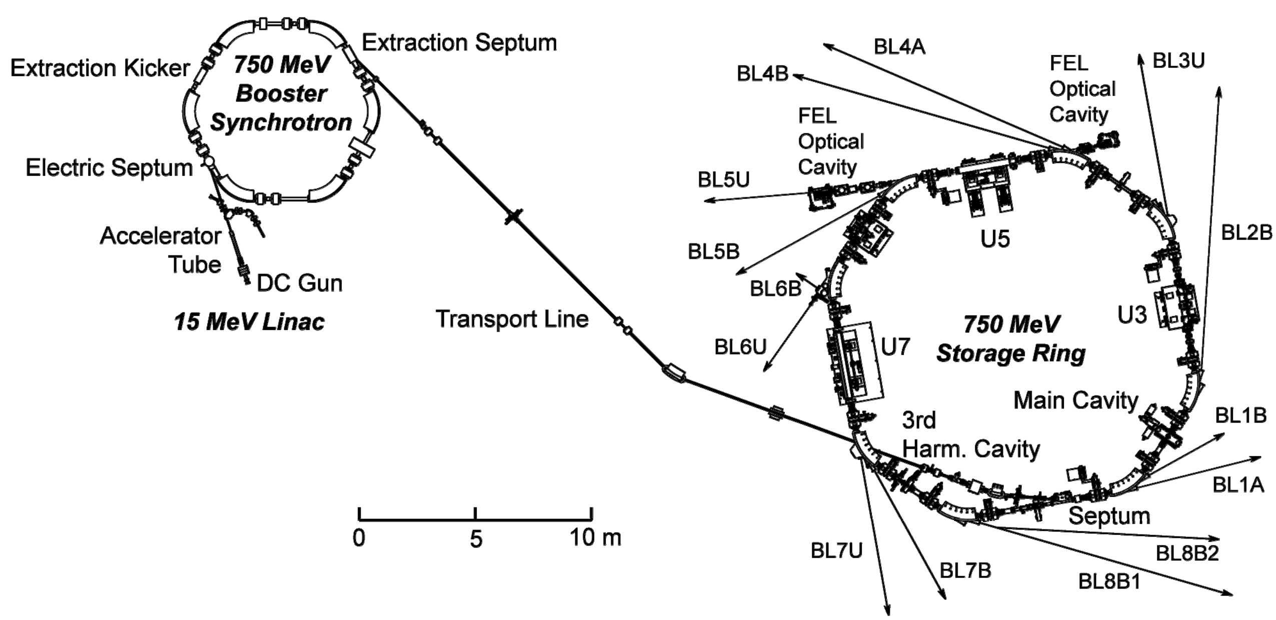

Figure 1: UVSOR-II accelerators in 2009.

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Table 1: Main parameters of the UVSOR-II storage ring

Energy	750 MeV
Maximum Stored Current	500 mA (multi-bunch) 100 mA (single-bunch)
Natural Emittance	27 nm-rad
Circumference	53.2 m
RF frequency	90.1 MHz
Harmonic Number	16
Bending Radius	2.2 m
Lattice	Extended DBA × 4
Straight Section	(4 m × 4) + (1.5 m × 4)
RF Voltage	100 kV
Betatron Tune	Hor. : 3.75, Vert. : 3.20
Momentum Compaction	0.028
Natural Chromaticity	Hor. : -8.1, Vert. : -7.3
Energy Spread	4.2×10^{-4}
Natural Bunch Length	108 ps

HISTORY OF TOP-UP OPERATION

To enable the top-up operation, reinforcement of radiation shields around the ring were done, from 2003 to 2006. The magnet power supplies for the booster synchrotron and beam transport line were upgraded in 2006 and 2007, respectively. The maximum beam energy can be injected to the storage ring was increased from 600 MeV to 750 MeV in order to enable full energy injection. And after some minor upgrades, we got permission for the top-up operation from the Japanese government.

Since October 2008, trials of top-up operation have been done from Thursday night to Friday morning during 12 hours in every user operation week. During the test operation, we succeeded in keeping the stored beam current around 300 mA. In the Fig. 2, time trend of the top-up operation is shown. The electron beam is injected for about 10 second every one minute with the repetition rate of 1 Hz. When the injection efficiency is kept at the

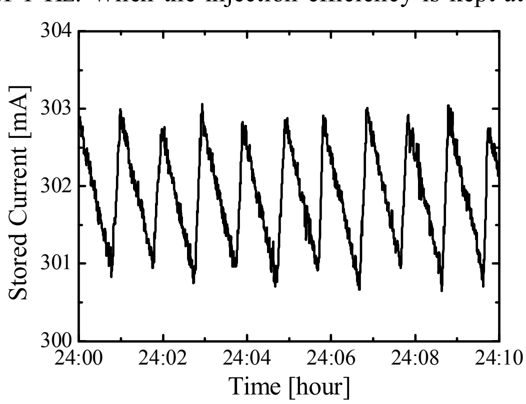

Figure 2: Time trend of beam current during a top-up operation.

normal level, the stored beam current fluctuation is less than 1 % as one can see in Fig. 2.

As the result of trial operations, one serious problem which was instantaneous orbit movement at the injection time was found. Three pulsed kickers and one septum magnet are used for beam injection and some beam-lines are located inside of the injection bump. Thus the effect is inevitable. However, even in the other beam-lines, the effect was observed because of the leakage of the bump orbit. The transverse beam movement was measured at the outside of injection bump by a turn-by-turn BPM system [5] and results are shown in Fig. 3. There are many considerable reasons of bump leakage such as insufficient deflection angle of kickers, sextupole magnets in the bump orbit, mismatch of the kicker exciting current and misalignment of the kicker etc. We decided to provide injection timing signal for the data acquisition system at the beam-lines to stop the data acquisition during the injection, around 10 second per one minute.

In last January, all beam-lines got ready for the top-up operation and we started to extend the top-up operation to daily user operation. In last February, 40-hour top-up operation was accomplished. And from next user operation started from July 2010, top-up operation will be the normal operation mode of the storage ring.

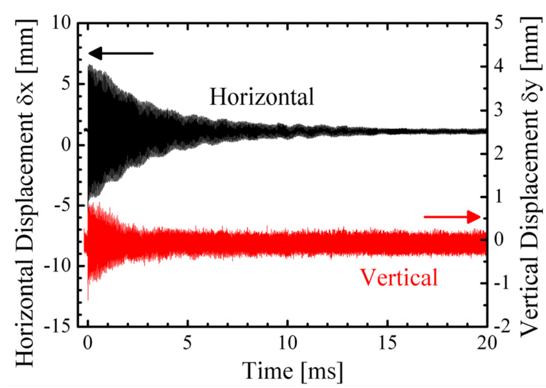

Figure 3: Beam orbit movement just after the injection measured at the entrance of the U5 in Fig. 1, outside of the injection bump.

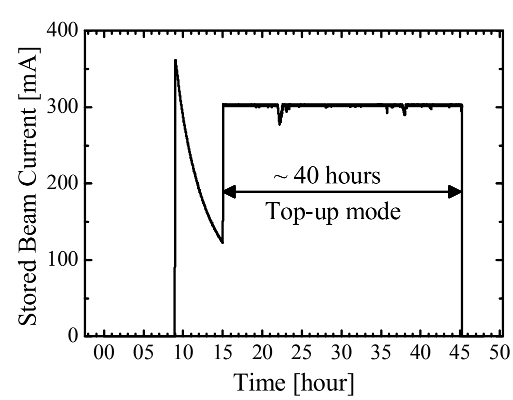

Figure 4: The 40-hour top-up operation in 4-5, Feb., 2010.

SINGLE BUNCH TOP-UP OPERATION

As a parallel work of the top-up operation in multi-bunch mode, single bunch injection and single bunch top-up operation were prepared, because the Touschek effect is more significant at single bunch mode and benefits of the top-up operation are quite large for the single bunch mode. Ordinary, the single bunch filling mode has been achieved by 4-bunch injection and 3-bunch damp by an RF knock-out in the storage ring [6]. During the top-up operation, maximum injection charge is limited for radiation safety. When the top-up operation was done with such the knock-out scheme, the limit could be easily exceeded and also radiation dose in the experiment hall got high. Therefore single bunch injection from the booster synchrotron is strongly required for single bunch top-up operation.

Since the acceleration frequency of the booster synchrotron and storage ring were 90.1 MHz, single bunch acceleration in the booster and single bunch injection to the storage ring can be accomplished if the linac can provide short macro-pulse beam whose duration is less than 10 ns. For that purpose, the DC gun of UVSOR-II injector equips two grid pulsers, one is for long pulse (~ 1.5 μs) and the other is for short pulse (~ 5 ns). In June 2009, we succeeded in the short macro-pulse generation at the linac, single bunch acceleration in the booster and single bunch injection to the storage ring. Soon after the demonstration, single-bunch top-up operation was introduced as normal operation mode during the single-bunch user operation, which is held two weeks in a year. Figure 5 shows the time trend of the single bunch top-up operation. During the single bunch operation, stored beam current was kept around 50 mA and the spurious bunch was dumped by the RF knock-out for keeping the bunch purity sufficiently high for user experiments.

The single bunch top-up operation is not only good for user operation but also good for experiments of coherent radiation generation such as FEL, CHG and CSR. Before the accomplishment of the single bunch injection, the experiment requires really often beam injection and the stored current always decreased. Such situation is not good for systematic measurements. Now we can make those experiments with constant beam current for several hours and the single-bunch top-up operation contributes many new results.

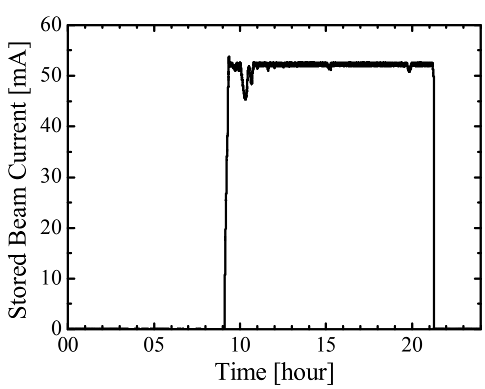

Figure 5: Single-bunch top-up operation in 9th, Sep. 2009.

STORAGE RING FEL LASING WITH 2-BUNCH TOP-UP OPERATION

The storage ring FEL (SR-FEL) has been suffered from the time varying nature of the stored beam current, i.e. time varying heat load on the cavity mirror and time varying laser gain. Owing to the single bunch injection, the UVSOR-II SR-FEL user experiments can be done with constant current for several hours. First top-up operation of the UVSOR-II SR-FEL with the lasing wavelength of 215 nm was carried out in last July. As shown in Fig. 6, the stored beam current was kept constant around 130 mA for one and half hour. And as the consequence, the FEL average power was kept constant around 110 mW.

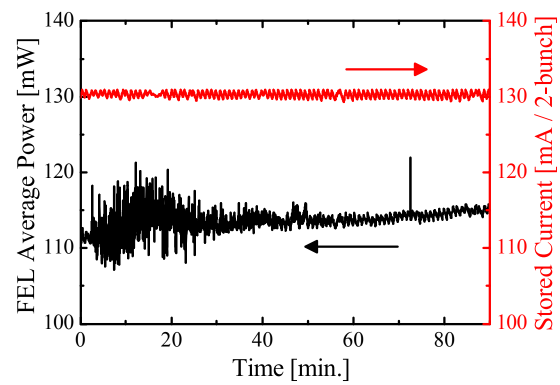

Figure 6: Time trend of the FEL average power and stored beam current.

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