STATUS OF UVSOR-III

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Abstract

UVSOR-III is the 750 MeV synchrotron light source. In 2012, three new components were installed in the storage ring. First one is combined function bending magnets to reduce the emittance from 27.4 nm-rad to 16.9 nm-rad. These magnets can produce dipole, quadrupole and sextupole fields. Second one is an in-vacuum undulator. It was installed at 1.4 m straight section, which is the last free space reserved for insertion devices. As a result, the storage ring is now equipped with six undulators. Last one is a newly designed pulse sextupole magnet. This is beneficial to the user experiments in the top-up operation mode. The commissioning was started in June 2012 and the users operation was started in August 2012. Since then, we started to call the ring UVSOR-III.

The in-vacuum undulator was successfully commissioned. The test operation of the pulse sextupole magnet was successful although some improvement on the injection efficiency is necessary before introducing it to the users operation. The ring is routinely operated in the top-up injection mode with beam current of 300 mA.

INTRODUCTION

UVSOR is a low energy and compact synchrotron light source. The electron energy is 750 MeV and its circumference is 53.2 m. Its relatively low electron energy is suitable to produce synchrotron radiation in the longer wavelength region, from VUV to soft X-rays.

The first light was observed in 1983. To meet the increasing demands for brighter light, an upgrade project was performed in 2003. In this upgrade, by modifying the magnetic lattice, the emittance was reduced from 160 nm-rad to 27 nm-rad and four 1.4 m short straight sections were created [1, 2]. Since this upgrade, we started to call the ring UVSOR-II.

In the middle of 2000's, further upgrades were proposed and have been performed. In the first stage, the top-up injection scheme was introduced. For this upgrade, the magnet power supplies of the booster synchrotron and the beam transport line were replaced. The radiation shielding was reinforced. The top-up injection scheme was successfully introduced to the users operation in 2008.

In the second stage of the upgrade, the injection point was changed to obtain a 4-m long straight section. It was carried out in 2010. A new optical klystron type undulator was installed at the straight section in 2011, which has been used for coherent light source developments.

In the third stage of the upgrade, three new accelerator components were installed. The first one is the combined function bending magnets which are beneficial to reduce the emittance to about 17 nm-rad. It is also so beneficial that eight defocussing quadrupole magnets have become possible to be removed to create additional spaces in future. Second one is an in-vacuum undulator. It was installed at 1.4 m long short straight section, which is the last free space reserved for undulators. It would provide soft X-rays for a scanning transmission X-ray microscope (STXM) beam-line. As a result, UVSOR-III is now equipped with six undulators. The third one is a pulsed sextupole magnet for injection. This is beneficial to supress the orbit displacement during the injection.

The reconstruction in the third stage was carried out in 2012, from April to June. Figure 1 shows the layout of the ring after the upgrade in 2012.

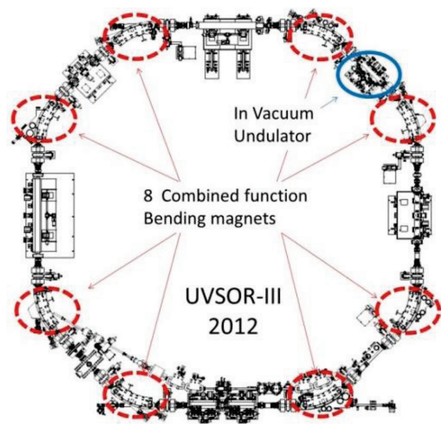

Figure 1: Layout of UVSOR-III.

MAGNETIC LATTICE OF UVSOR

The original UVSOR (UVSOR-I) lattice consisted of four double-bend achromat cells. For UVSOR-II, the triplets of the quadrupole magnets between the two dipole magnets were replaced with a pair of doublets, to create 1.4-m short straight sections. To reduce the emittance, the horizontal betatron phase advance of the cells was increased and, in addition, the dispersion function was distributed to all straight sections [3]. To create as much space for the straight sections as possible, the sextupole field was integrated in the quadrupole magnets.

The lattice of UVSOR-III is basically the same as that of UVSOR-II. However, to further reduce the emittance, the dipole magnets were replaced with combined function magnets. They have a taper-shaped pole face to produce a horizontal defocusing quadrupole field as well as a dipole field. In addition, the magnets produce sextupole fields by the shaped pole ends. The magnet parameters are summarized in Table 2. The lattice functions and main parameters of UVSOR-II and -III are summarized in Fig. 2 and Table 1. The main parameters of the dipole magnets are shown in Table 2. When introducing the

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combined function magnets, the damping partition numbers were changed and the horizontal emittance was reduced. In addition, the ring can be operated without one family of the defocusing quadrupole magnets. In future, they would be removed when more spaces are required in the ring.

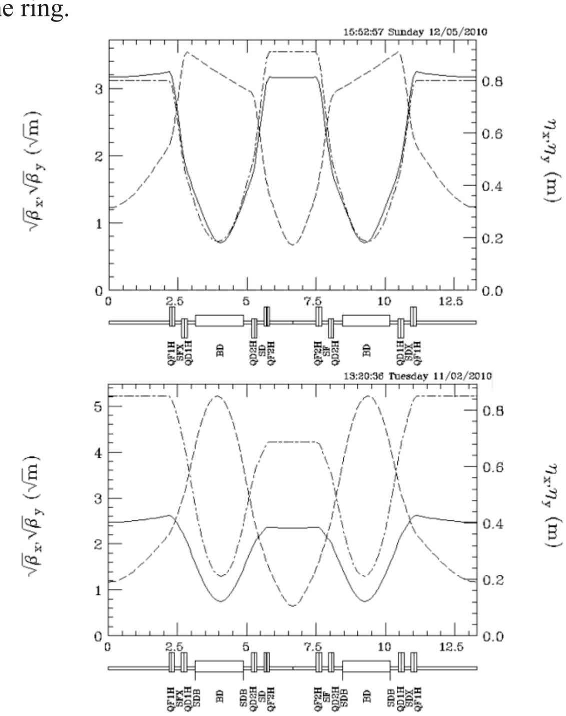

Figure 2: Optics of UVSOR-II (up), and III (down). The betatron functions in the horizontal and vertical plane (solid and dashed line) and the dispersion function (chain line).

Table 1: Main Parameters of UVSOR-II and III

Parameter	II	III
Operation Energy	750 MeV	750 MeV
Injection Energy	600 MeV	750 MeV
Average Beam Current	~200 mA	300 mA
Circumference	53.2 m	53.2 m
No. of Superperiods	4	4
Straight Section for I.D.	4 m × 3 1.5 m × 2	4 m × 4 1.5 m × 2
Emittance	27.4 nm-rad	16.9 nm-rad
Energy Spread	4.2×10^{-4}	5.4×10^{-4}
Betatron Tunes	(3.75, 3.20)	(3.60, 3.20)

Table 2: Main Parameters of Dipole Magnets

Parameter	II	III
Bending radius	2.2 m	2.2 m
Magnetic length	1.728 m	1.728 m
Pole gap at the centre	48.0 mm	55.2 mm
Bending angle	45°	45°
Field Index (n)	0	3.36
Quadrupole field (K1)	0 m^{-1}	-1.2 m^{-1}
Sextupole field(K2)	0 m^{-2}	-2.43×2 m^{-2}

IN-VACUUM UNDULATOR FOR STXM BEAMLINE

A new in-vacuum undulator for the scanning transmission soft X-ray microscope (STXM) beam-line (BL4U) was constructed in April 2012 [3]. The magnetic period length is 38 mm and the pole length is about 1 m. Figure 3 shows the undulator for STXM. This is sixth undulator in this ring. A schematic image of the beam-line is shown in Fig. 4. The construction and commissioning of the beam-line is on going. In June 2013, the user experiment will be started.

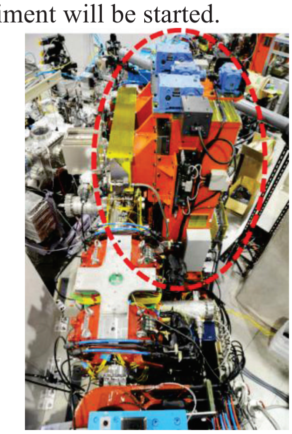

Figure3: New in-vacuum undulator for BL4U STXM beam-line.

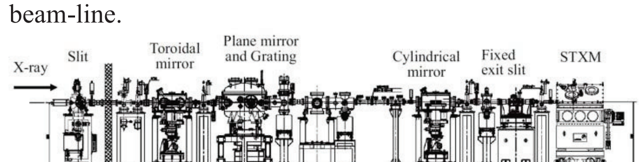

Figure4: Schematic imageof the optical system of BL4U.

PULSE SEXTUPOLE MAGNET INJECTION

A novel injection scheme using a pulsed multipole magnet was developed and successfully demonstrated in KEK [4, 5]. We introduced this injection scheme with pulsed sextupole magnet (PSM) to UVSOR-III. By using such a pulsed multipole magnet, instead of the ordinary kicker magnets, it is expected to supress the orbit displacement during the injection. This is particularly important for UVSOR-III, because the existing kicker magnets cannot create a closed bump orbit. In addition, for a small storage ring like UVSOR-III, it is beneficial to save space if the injection were possible with only one pulsed magnet instead of three or four kicker magnets.

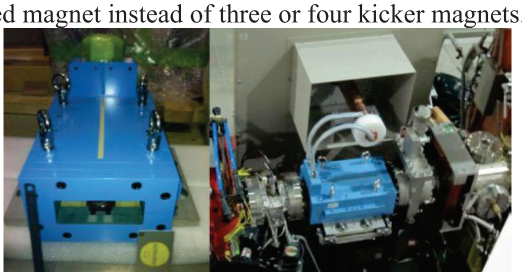

Figure 5: Photo of the pulse sextupole magnet.

Test experiments of the beam injection with PSM have been performed. After optimization of horizontal and vertical tune of UVSOR-III storage ring, the maximum injection efficiency of 23% was achieved. It was also comfirmed that the electron beam up to 300mA could be accumulated by this scheme. It was also observed that the horizontal beam movement during the injection was drastically suppressed with PSM injection as comparing with the normal injection scheme with the kicker magnets. For further improvement of injection efficiency, we are going to increase the excitation current and to optimize the location of the PSM in the ring.

COMMISSIONING OF UVSOR III

The commissioning of UVSOR-III was started in the middle of June, 2012. After removing a few hardware problems, the electron beam was successfully stored until the end of June. We found that the injection efficiency was more sensitive to the betatron tunes than before the reconstruction. The reason of this is still under investigation. Until the end of July, we had operated the storage ring with high beam current for vacuum conditioning. Finally, we started the users operation from the beginning of August. However, during the users beam time, we observed sudden beam losses by a few milli-amperes or a few tens of milli-ampere. Although its frequency is getting lower, we still observe them. Presumably this may due to the dust trapping phenomena. As described above, during this shut down, we broke the vacuum and left them for a few weeks. This might cause this.

For the commissioning of UVSOR-III, a turn by turn beam positions monitor (BPM) system was designed and constructed [6]. The signals from the pick-up electrodes of the BPM's were sent to a digital oscilloscope through a signal switching system constructed by a co-axial relays remotely controlled. It was proved that the system was quit powerful during the commissioning. We could get useful information, such as the betatron tunes, the energy mismatching between the beam transport line and the storage ring and so on, before the beam storage.

From the end of 2011, pressure rise in the vacuum system at the main RF cavity had been observed during the operation. In April 2012, ceramic window of the input coupler was renewed. However, the condition was not changed. In April 2013, we remove the cavity from the ring and check inside of the cavity. The cavity is demountable with flanges. Demountable positions are shown in Fig.6. There were contaminations like oil at the demountable flange B. After removing the contamination, the cavity performance was dramatically changed. Now the cavity can be operated without aggravation of vacuum. The contamination is under investigation.

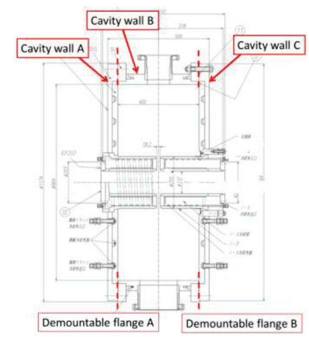

Figure 6: Main cavity of the ring.

SUMMARY

The upgrade project to UVSOR-III is completed. The users operation was successfully started. However the beam injection efficiency is currently around 65 %, it should be improved to around 80 % as UVSOR-II. The beam lifetime of UVSOR-II and III were around 3 hours and 1.5 hours at the beam current of 300 mA, respectively. It is expected that the Touschek effect of the UVSOR-III is stronger than that of UVSOR-II. It can be overcome by the top-up operation.

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