# 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 ones are an in-vacuum undulator and a beam line. It was installed at 1.4 m straight section, which is the last section reserved for insertion devices. As a result, UVSOR-III is now equipped with six undulators. It would provide soft X-rays for a scanning transmission X-ray microscope (STXM) beam-line. Last one is a newly designed pulse sextupole magnet at the injection point. This is beneficial to the user experiments in the top-up operation mode. Fine machine tuning is in progress.

## 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 longer wavelength region, from VUV to soft X-rays.

The first light was generated in 1983. To meet the increasing demands for brighter light, an upgrade project was performed in 2003. 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]. The upgraded light source was renamed UVSOR-II.

After this first major upgrade, further upgrades were proposed and have been performed. The first one is introduction of the top-up injection scheme. Top-up operation was started from 2008.

The second stage of the major upgrade is to move the injection point to obtain a 4-m long straight section. It was done 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 2012, the third stage upgrade which includes 3 components was done. The first one is the replacement of the bending magnets with combined function ones to reduce the emittance to about 17 nm-rad. Second one is an in-vacuum undulator was installed at 1.4 m long short straight section which is the last section 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 an installation pulsed sextupole magnet to prevent the oscillation by the injection. After these upgrade, the ring was renamed UVSOR-III. Fig.1 shows the layout of the ring before and after the upgrade in 2012.

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# He was transferred to KEK in April 2013.

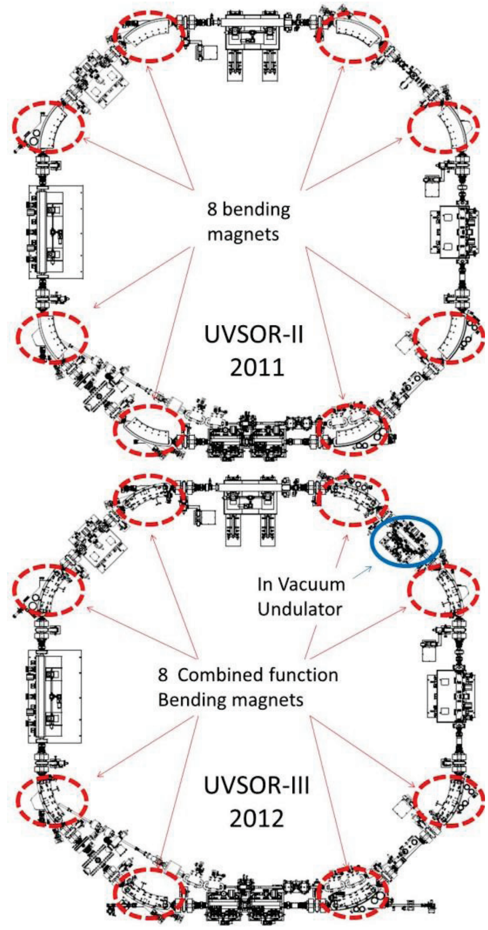


Figure 1: Layout of UVSOR-II (up) and UVSOR-III (down).

## 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 a short 1.4-m long straight section. 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 create a horizontal defocusing quadrupole field as well as a dipole field. These bending magnets parameters are summarized in Table 1. The lattice functions and main parameters of UVSOR-I, 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 combined function magnets, the damping partition numbers are changed and the horizontal emittance is reduced. In addition, the ring can be operated without one family of the defocusing quadrupole magnets. In future, these will be removed when more spaces are required in the ring.

Table 1: Main parameters of dipole magnets

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

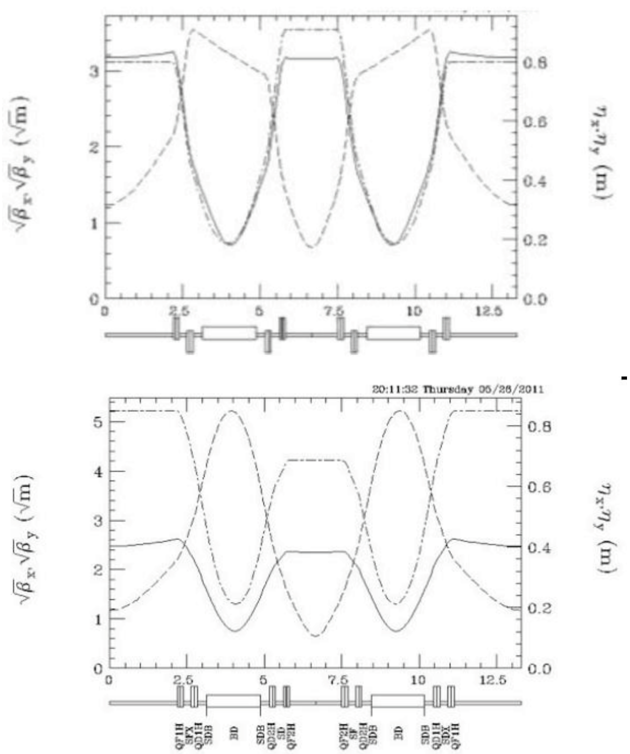


Figure 2: Optics of UVSOR-II (up), and III (down). The betatron functions in the horizontal and vertical plane (solid and dashed line) and the dispersion function (chain line).

Table 2: Main parameters of UVSOR-II and III

| | 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 |
| **Number of Superperiods** | 4 | 4 |
| **Straight Section for I.D.** | 4 m × 3<br>1.5 m × 2 | 4 m × 4<br>1.5 m × 2 |
| **Emittance** | 27.4 nm-rad | 16.9 nm-rad |
| **Energy Spread** | $4.2 \times 10^{-4}$ | $5.4 \times 10^{-4}$ |
| **Betatron Tunes** | (3.75, 3.20) | (3.60, 3.20) |

## IN-VACUUM UNDULATOR FORSTXM 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. Fig.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 was started from April 2012. In June 2013, the user experiment will be started.

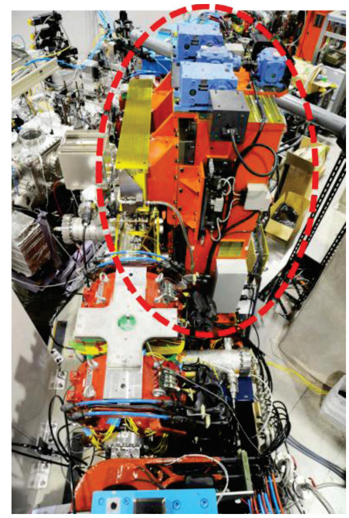

Figure 3: New in-vacuum undulator for BL4U STXM beam-line.

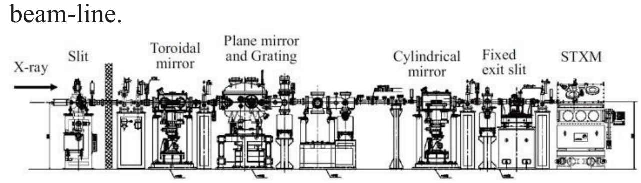


Figure 4: Schematic imageof the optical system of BL4U.

## PULSE SEXTUPOLE MAGNET INJECTION

A new injection scheme called as pulsed multipole injection has been developed in KEK [4, 5]. We introduced this scheme with pulsed sextupole magnet (PSM) to UVSOR for increasing the efficiency of user experiments. Fig. 5 shows the photo of PSM.

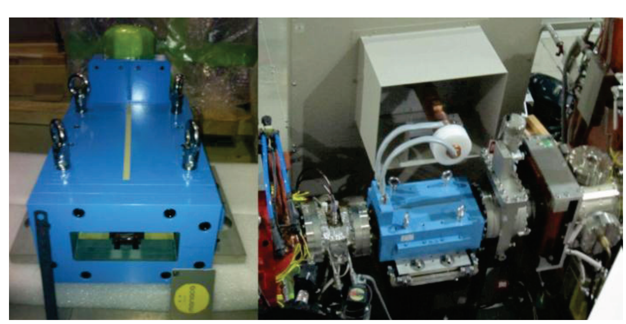

Figure 5: Photo of the pulse sextupole magnet.




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Test experiments of electron beam injection with PSM have been performed. After optimization of horizontal and vertical tune of UVSOR-III storage ring, the maximum injection efficiency increased to 23% at 300mA operation. The horizontal beam movement was drastically suppressed with PSM injection.

For further improvement of injection efficiency, the maximum excitation current will be increased and place of PSM will be moved.

## COMMISSIONING OF UVSOR III

The commissioning of UVSOR-III was started in the middle of June. After removing a few hardware problems, finally electron beam was storage on middle of June. We found that the injection efficiency strongly depends on the machine parameters such as betatron tunes. 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. During this shut down, we broke the vacuum system and left them for a few weeks. This might cause this.

Turn by turn beam positions monitor (BPM) system was designed and constructed, which is very useful for the commissioning of the storage ring [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, the degree of vacuum at the main RF cavity had increased in the operation. In April 2012, ceramic window of the input coupler was renewed, because the operation voltage nearly reached capacity of the RF source. Since the cavity performance was not changed, we remove the cavity from the ring and check inside of the cavity in April 2013. 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 has been analysed for presuming the intrusion reasons.

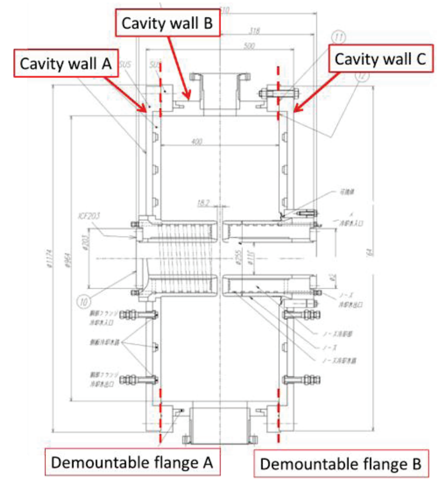


Figure 6: main cavity of the ring.

## SUMMARY

The upgrade project to UVSOR-III is almost complete and commissioning of the synchrotron was completed until June 2012. The storage of the electron beam was successful. However the beam injection efficiency is currently around 65 %, it should be improved to around 80 % as UVSOR-II. The vacuum conditioning and beam-line conditioning was completed in July 2012. The operation for beam-line users was started from August 2012. The beam lifetime of UVSOR-II and III were around 3 hours and 1.5 hours at the beam current of 300 mA. 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.

## ACKNOWLEDGEMENT

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