STATUS OF UVSOR-II

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Abstract

In 2003, UVSOR, a 2nd generation synchrotron light source of 750 MeV, has been successfully upgraded to UVSOR-II, which has small emittance of 27 nm-rad and 6 straight sections available for insertion devices. All the reconstruction works were completed within three months, from April to June, 2003. In July, the commissioning was started. In September, the users operation was started. The vacuum is gradually improved along with the increase of the integrated beam current. The beam lifetime has come to be dominated by Touschek effect. To improve the lifetime, an upgrade of the RF cavity is planned. Two new in-vacuum undulators were successfully commissioned. In December, 2003, we have succeeded in oscillating the free electron laser again on UVSOR-II.

INTRODUCTION

Since the first beam in 1983, UVSOR had been operated for about 20 years as a national VUV light source in Japan [1]. The UVSOR accelerator complex consists of a 15 MeV linac, a 600 MeV booster-synchrotron and a 750 MeV storage ring. The circumference of the ring was 53.2 m. The magnetic lattice was double-bend achromatic and four-fold symmetric with four straight sections, three of which were available for insertion devices. Two undulators and one super-conducting wiggler were in operation. Many of the accelerator components including the insertion devices had been used for many years and it was getting harder to maintain their good conditions.

In 2000, we proposed an upgrade plan, in which the emittance would be reduced by a factor of 6 and the number of straight sections would be doubled [2]. Some old accelerator components including the insertion devices would be replaced. Fortunately, this plan was soon approved and funded. We started with constructing a prototype of multi-pole magnets. Also we started constructing an in-vacuum undulator. In the fiscal year 2002, all the accelerator components, such as magnets, beam ducts and pumping system, another in-vacuum undulator and so on, were constructed. In 2003, the facility was shutdown for three months and the accelerators and the beam-lines were reconstructed. In July, the commissioning of the upgraded UVSOR, UVSOR-II, was started.

DESIGN AND CONSTRUCTION OF UVSOR-II

The design of the UVSOR-II was described elsewhere [2]. The lattice modification, which is illustrated in Fig. 1, is most essential. The original lattice was double-bend achromatic. One short straight section is created between two bending magnets in each cell. The horizontal betatron phase advance is increased. The momentum dispersion is distributed over the ring, including the long straight sections. As the result, the ring has totally eight straight sections, six of which can be used for insertion devices, and its emittance is reduced by a factor of 6. The design goal of the emittance is 27 nm-rad, which is in the world-smallest level among the low energy light sources below 1 GeV.

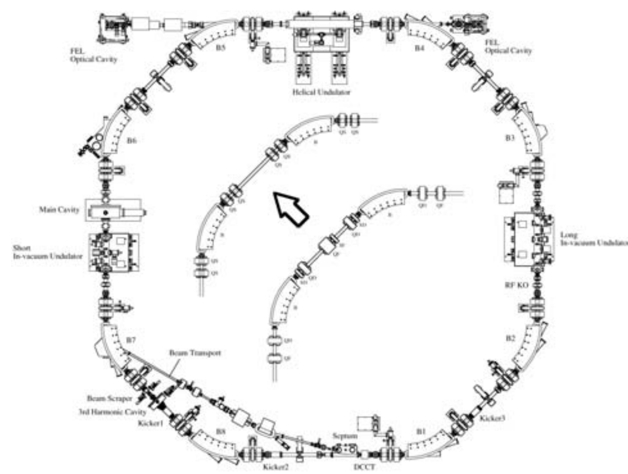

FIGURE 1: Configuration of UVSOR-II. The lattice modification is also illustrated. Three undulators are already installed. Three short straight sections are reserved for future undulators.

TABLE 1. Parameters of UVSOR-I and II

	UVSOR-I	UVSOR-II
Electron Energy	750 MeV	750 MeV
Circumference	53.2 m	53.2 m
Number of Super-periods	4	4
Straight Sections	3m x 4	4m x 4,1.5m x 4
Emittance	165 nm-rad	27.4 nm-rad
Energy Spread	$4.2x10^{-4}$	$4.2x10^{-4}$
Betatron Tunes	(3.16, 1.44)	(3.75, 3.20)
Natural Chromaticity	(-3.4, -2.5)	(-8.1, -7.3)
Momentum Compaction	0.026	0.028
XY Coupling (presumed)	10%	10%

All the accelerator components for UVSOR-II were constructed during the fiscal year 2002. The operation of the original UVSOR (UVSOR-I) was terminated in the end of March, 2003. In April, all the magnets including their beam pipes were replaced, except for the bending magnets. New focussing magnets are combined-function (quadrupole / sextupole). Additional windings on the pole and the pole face of a normal quadrupole magnet produce sextupoles field. The new beam pipes are made of SUS, which have racetrack cross section with diameters of 110mm in horizontal and 38mm in vertical. They are pumped by TSP and SIP. All the magnet power supplies were replaced with new IGBT switching power supplies. Their control system utilizing VAX mini-computers and CAMAC interface was replaced with new system based on a personal computer and programmable logic controllers, both of which are connected to a local area network.

In parallel with the reconstruction of the magnetic lattice described above, replacement of the electron gun of the injector, installation of an in-vacuum undulator, rearrangement of the beam diagnostic system, replacements of two beam ducts for bending magnets, were carried out. All the reconstruction works were completed until the end of June. All the vacuum chambers were baked in the first week of July.

COMMISSIONING OF UVSOR-II

The commissioning of the injector was started in the first week of July, in parallel with the baking of the storage ring. It was observed that the intensity of the electron beam accelerated in the booster synchrotron was increased by a factor of 2 or 3, comparing with that before the upgrade. It is considered to be due to the better beam quality of the new electron gun.

The commissioning of the storage ring was started in the second week of July. After removing a few hardware problems, finally we could store the electron beam on 14th of July. The maximum beam current reached 500 mA after one week. We started the commissioning with a high emittance optics which had the beam parameters very similar to that of UVSOR-I. Until the end of July, we succeeded in operating with the low emittance optics. The optical functions are shown in Fig. 2. The beam profiles observed at a bending magnet for both optics are shown in Fig. 3. A beam size measurement system utilizing interferometer is under preparation.

In July and August, we continued high current operation for vacuum conditioning, in parallel with the tuning of the SR beam-lines. The beam lifetime is being improved as shown in Fig. 4 as the vacuum is being improved. It can be seen that the improvement has become slower. This indicates that Touschek effect has come to be dominant.

In the first week of September, we started the users operation with UVSOR-II. The filling beam current is 350 mA. The beam is injected every 6 hours.

At present, the beam emittance in the users operation is about 60 nm-rad, which is larger than the design goal 27 nm-rad. We have found no problem in the operation at 27 nm-rad, except for the lifetime. However, for many of the users, the flux is more important than the brilliance. Thus, we decided to re-start the users operation with modest emittance until the lifetime problem is solved.

To improve the lifetime, we are increasing the RF accelerating voltage from 46 kV to 75 kV gradually. The replacement of the input coupler in 2002 made this possible. As the next step, we are planning to replace the cavity in 2005 to be capable of producing 150 kV. This will greatly improve the lifetime as shown in Fig. 5.

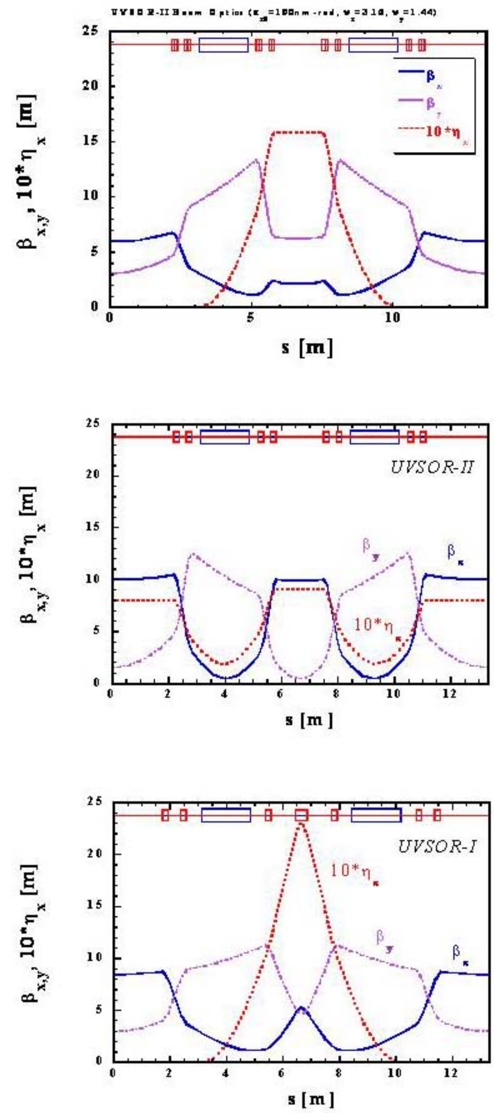

FIGURE 2: Optical functions of UVSOR-I (lower) and UVSOR-II in low emittance mode (middle) and in commissioning mode (upper). The beam parameters of the commissioning mode is similar to those of UVSOR-I.

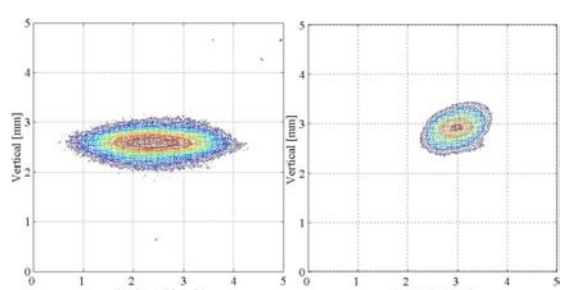

FIGURE 3: Beam profiles in the high emittance optics (left) and in the low emittance optics (right).

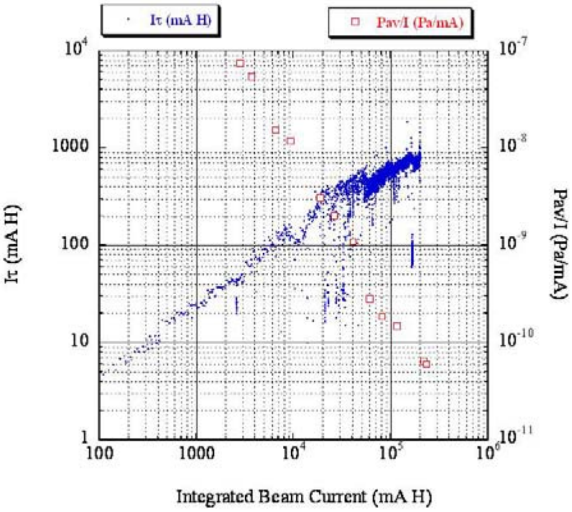

FIGURE 4: Improvement of the beam lifetime during the first 6 months. Improvement of the vacuum is also shown.

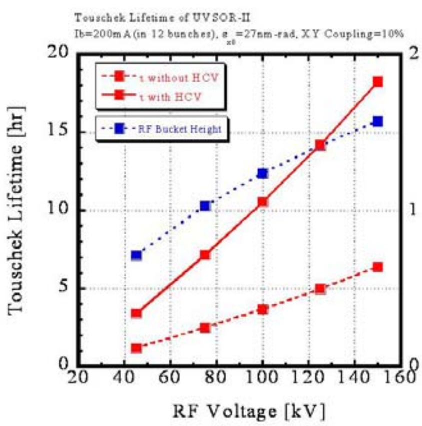

FIGURE 5: Touschek Lifetime estimated as a function of RF accelerating voltage. The RF bucket height is also shown. The operating voltage was 46 kV for UVSOR-I. It was increased to 55 kV and being increased to 75 kV. The cavity will be replaced in 2005 with the one capable of 150 kV.

COMMISSIONING OF UNDULATORS

UVSOR-II has three undulators. Two of them are in-vacuum type. They were constructed as a part of the UVSOR-II project. The beam optics of UVSOR-II fits these devices, since it has small vertical betatron function as shown in Fig. 2. The minimum gap allowed for these devices was confirmed to be 15 mm, as shown in Fig. 6. These two devices were installed at the longer straight sections where the vertical betatron function is about 1.5 m. The shorter straight sections have smaller value of 0.5 m. If we install in-vacuum undulators at these sections in future, the minimum gap of about 10 mm will be allowed.

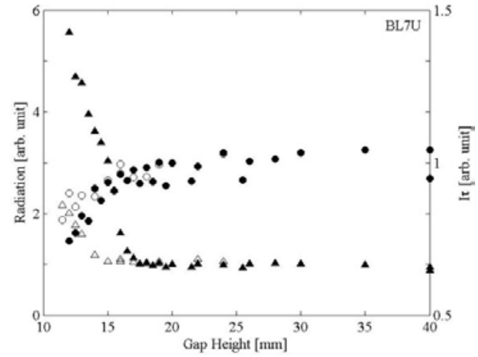

FIGURE 6: Aperture survey of the in-vacuum undulator for BL7U. The beam lifetime and the radiation level are illustrated versus magnetic pole gap. The white circles represents the lifetime, the white triangles radiation level measured at the beam-line. The black circles and triangles are those measured for the beam optics with larger (about factor of two) vertical betatron function.

SUMMARY

We have succeeded in converting the old UVSOR-I to an undulator-based light source, UVSOR-II. All the reconstruction works were completed in three months. The commissioning was completed in two months. The vacuum is being steadily improved. The beam lifetime has come to be dominated by Touschek effect. To improve the lifetime, we are planning to replace the RF cavity in spring 2005.

We have three short (about 1.5m) straight sections, hopefully occupied by short undulators in near future. We have already re-started the study on the free electron laser [4]. In December 2003, we succeeded in the first FEL oscillation on UVSOR-II. The wave length was in visible region. The low-emittance of UVSOR-II will enable us to oscillate the FEL in shorter wave length, hopefully below 200 nm.

REFERENCES

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