Present Status of UVSOR-II

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Abstract. A 750 MeV synchrotron light source, UVSOR-II, is routinely operated for users with emittance of 27 nm-rad, which is the world smallest among the operational synchrotron light sources of relatively low energy below 1 GeV. Eight bending magnets and three undulators provide synchrotron light to totally 13 beam-lines. Two of the undulators are of in-vacuum type and another is of variable polarization type. A high performance monochromator for the beam-line, BL3U, and a high-resolution photoelectron energy analyzer for the end station at BL5U have been successfully installed, both of which utilize undulator radiation. The IR beam-line, BL6B has been upgraded by introducing a so-called magic mirror as the first mirrors and the world-highest intensity has been successfully achieved. Fourth undulator of variable polarization type and its beam-line are under construction. The energy upgrade of the injector is in progress, to realize the top-up operation within a few years. The wavelength of the free electron laser has come into the deep UV region, thanks to the low emittance of the ring. Some users' experiments are in progress. A Ti:Sa laser for the laser-bunch slicing experiments was installed. Intense coherent terahertz radiation produced by the laser e-beam interaction has been successfully detected.

Keywords: emittance, storage ring, undulator, beam-line, monochromator.
PACS: 07.85.Qe

INTRODUCTION

The first light on UVSOR was in 1983. Since then, this 750 MeV synchrotron light source has been providing synchrotron radiation in a wide wavelength range from far-infrared to soft X-rays. After the successful 15 year operation, it had come to be noticed that the facility must have been upgraded to survive for the next one decade as a national facility among the newly constructed 3rd generation light sources. In 2000, a new magnetic lattice was proposed which would have much smaller emittance and more straight sections available for insertion devices [1]. To realize this lattice, all the quadrupole and sextupole magnets and their beam pipes must have been replaced. Replacements of the insertion devices and some old components of the injector were included in the upgrade plan. Fortunately, this plan was soon approved and funded. In 2003, the reconstruction of the accelerators was carried out. It took about three months to complete the reconstruction works and took about two months for the commissioning including the vacuum conditioning [2]. An old undulator and an old super-conducting wiggler were replaced with two in-vacuum undulators during the upgrade [3]. Even after this upgrade, the accelerators and the beam-lines have been being upgraded continuously. Recent progress will be described in this paper. Latest results from the researches on the light source developments will be also described.

STATUS OF ACCELERATORS

The UVSOR-II accelerator complex is composed of a 15 MeV linear accelerator, a 600 MeV booster synchrotron and a 750 MeV electron storage ring. The ring is routinely operated for users with a small emittance of 27 nm-rad, which is the world smallest among the operational synchrotron light sources of relatively low energy below 1 GeV. The main machine parameters are summarized in Table 1. The ring is equipped with three undulators as shown in Table 2. Two of them are of in-vacuum type and one is of variably polarized type. The latter is used not only to provide normal SR to a beam-line but also to drive free electron laser. Another new undulator of variably polarized type is under construction. This undulator will be installed in October, 2006. The configuration of the ring after the installation of the new undulator is shown in Fig. 1.

CP879, *Synchrotron Radiation Instrumentation: Ninth International Conference,*
edited by Jae-Young Choi and Seungyu Rah

Following the major upgrade in 2003, the main RF accelerating cavity of the storage ring has been replaced in 2005 [4]. The new cavity can provide three times higher accelerating voltage than before, which was necessary to keep the lifetime long against the strong Touschek effect. The control system which was constructed in 90's based on mini-computers and CAMAC interfaces has been replaced part by part with new system based on personal computers. In 2006, the replacement has been completed.

The accelerator complex is operated for about 40 weeks in a year. Weekly, the machine is operated for users experiments from Tuesday to Friday and for machine studies on Monday. Daily, the machine is operated for 12 hours, from 9 a.m. to 9 p.m. The beam injection interval is 6 hours. UVSOR-II is normally operated under multi-bunch mode with partial filling. The single bunch operation is also conducted about two weeks per year. Initial beam currents stored under multi-bunch and single-bunch modes are 350 mA and 100 mA, respectively.

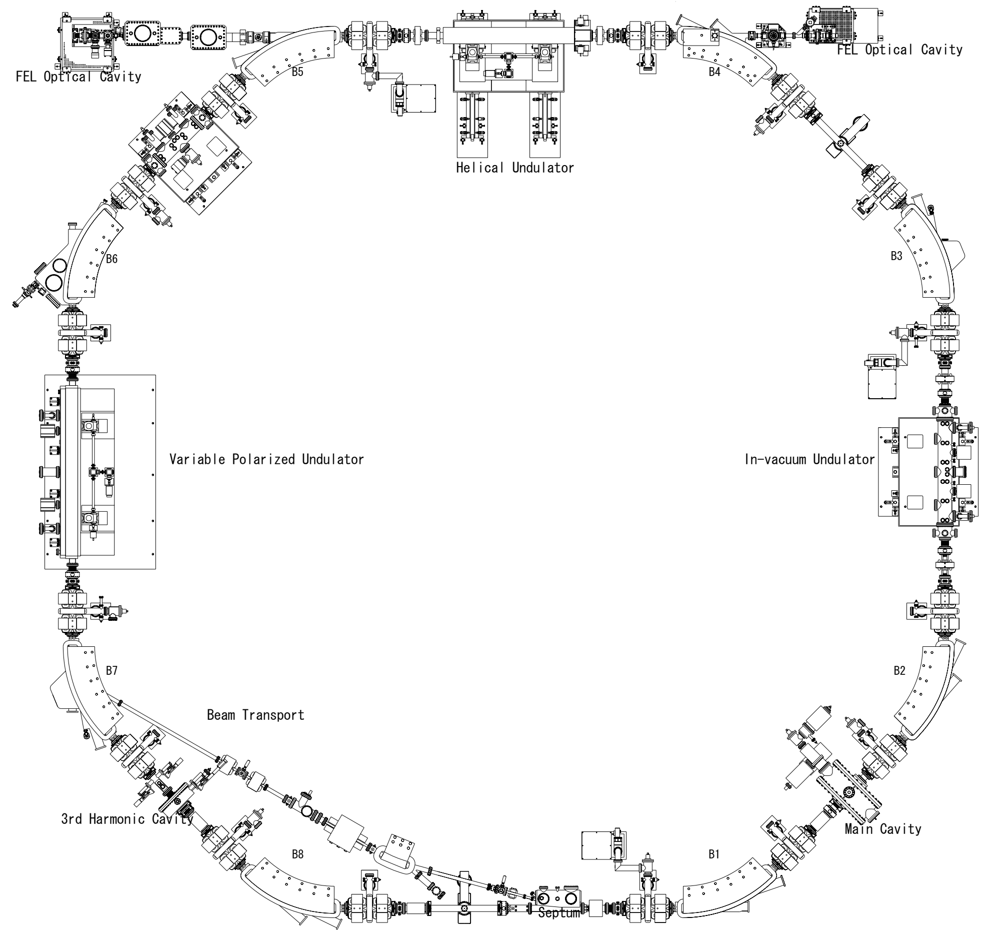

FIGURE 1. Configuration of UVSOR-II Storage Ring. The undulator between B6 and B7 will be installed in October 2006.

TABLE 1. Main Parameters of UVSOR-II

Parameters	Values
Electron Energy	750 MeV
Circumference	53.2 m
Straight Sections	4 m x 4, 1.5 m x 4
Bending Radius	2.2 m
Natural Emittance	27.4 nm-rad
Natural Energy Spread	4.2×10^{-4}
Natural Bunch Length	160 psec
RF Frequency	90 MHz
RF Voltage	100 kV
Filling Beam Current (Multi-bunch Mode)	350 mA
(Single-bunch Mode)	100 mA

TABLE 2. Insertion Devices of UVSOR-II

Insertion Devices	Parameters	
BL3U In-vacuum Undulator	Number of Periods	50
	Period Length	38 mm
	Pole Length	1.9 m
	Max. Deflection Parameters	2.0
	Polarization	Linear
BL5U Variably Polarized Undulator	Number of Periods	21
	Period Length	110 mm
	Pole Length	2.35 m
	Max. Deflection Parameters	4.6 (Helical)
		8.5 (Linear)
	Polarization	Linear/Helical
BL6U In-vacuum Undulator(1)	Number of periods	26
	Period Length	36 mm
	Pole Length	0.94 m
	Max. Deflection Parameter	2.8
	Polarization	Linear
BL7U Variably Polarized Undulator(2)	Number of periods	38
	Period Length	76 mm
	Pole Length	2.95 m
	Max. Deflection Parameter	5.4 (Horizontal)
		3.6 (Vertical)
		3.0 (Helical)
	Polarization	Horizontal/Vertical/Helical

Note) (1) This undulator is now at the straight section between B6 and B7 and will be moved to the section between B5 and B6 in summer 2006. (2) This undulator is under construction and will be installed in summer 2006.

LIGHT SOURCE DEVELOPMENTS

The free electron laser (FEL) at UVSOR has a long history. By introducing a helical optical klystron in 1990's, the laser wavelength of 239 nm was achieved, which was once the world shortest [5]. After the upgrade of the accelerators in 2003, the FEL has come into a new phase. Thanks to the smaller emittance and the shorter bunch length of UVSOR-II, the FEL gain in the deep UV region has been greatly improved. Now the FEL can be oscillated at 215 nm with the output power exceeding 100 mW. Some users' experiments are in progress by using the deep UV FEL.

Laser bunch slicing is a method to produce density structures on electron pulses by using an ultra-short laser [6]. At UVSOR-II, a Ti:Sa laser which could be synchronized with the electron pulses was commissioned in 2005. The laser pulses could be introduced to the ring by utilizing a part of the optical system for the FEL without any modification on the accelerator. The undulator for the FEL can be tuned to the wavelength of the Ti:Sa laser (800nm). This enables the energy exchange between the laser field and the electron beam, which is essential to this technology. We have successfully observed an intense terahertz radiation which indicated the occurrence of the laser e-beam interaction [7]. The intensity per pulse of the terahertz radiation is 10^5 times higher than that of the normal synchrotron radiation in the same wavelength region.

Even after the replacement of the RF cavity, the typical lifetime in users' operation is 6 hours at 200 mA and the beam is injected every 6 hours. To solve this problem completely, we are going to introduce the top-up injection scheme. The energy of the booster synchrotron, which is currently 600 MeV, will be increased to the full energy, 750 MeV, in summer 2006 by replacing the 20 year old magnet power supply. Some parts of the beam transport system will also be replaced. The top-up operation will be introduced to the users operation within a few years.

STATUS OF BEAM-LINES

Eight bending magnets and three undulators provide synchrotron light to totally 13 beam-lines, at present. The bending magnet with its radius of 2.2 m provides SR, whose critical energy is 425 eV. The undulators cover the energy range from UV to soft X-rays. The 13 beam-lines can be classified into two categories. Nine of them are so-called "Open beam-lines", which are open to scientists of universities and research institutes belonging to the government, public organizations, private enterprises and those of foreign countries. The rest of the 4 beam lines are so-called "In-house beam-lines", which are dedicated to the use of the research groups within Institute for Molecular Science.

We have 1 soft X-rays (SX) station equipped with a double-crystal monochromator, 7 EUV and SX stations with a grazing incidence monochromator, 3 VUV stations with a normal incidence monochromator (1 VUV station BL7U with an undulator is under construction), 1 infrared station equipped with FT interferometers, 1 non-monochromatized stations for the irradiation of white-light. A high performance monochromator for BL3U [8] and a high-resolution photoelectron energy analyzer for the end station at BL5U [9] have been successfully installed, both of which utilize undulator radiation. The IR beam-line, BL6B has been upgraded to be capable of providing powerful far-infrared radiation [10]. This was realized by introducing a so-called magic mirror as the first mirrors. The world-highest intensity has been achieved in the wavelength range from sub-milli to near IR region.

The new beam line, which will utilize the variably polarized light provided by the new undulator, is under construction at BL7U [11]. The commissioning will start in October, 2006.

TABLE 3. List of Beam-lines

Beam Lines	Light Source	Monochromator/Spectrometer	Energy Range	Experiments
1A	bending	Double-Crystal	600 eV – 4 keV	Solid (Absorption)
1B	bending	1m Seya-Namioka	1.9 – 40 eV	Solid (Reflection/Absorption)
2B	bending	18m Spherical Grating	20 – 200 eV	Gas (Photoionization/Photodissociation)
3U	undulator	Varied-Line-Spacing Plane Grating (Monk-Gillieson)	40 – 600 eV	Gas, Liquid, Solid (Photoelectron/Photon Emission)
4A1	bending	Multi-Layered Mirror	50 – 95 eV	Irradiation
4A2	bending	None		Irradiation
4B	bending	Varied-Line-Spacing Plane Grating (Monk-Gillieson)	80 – 800 eV	Gas (Photoionization/Photodissociation), Solid (Photoemission/Absorption)
5U	undulator	Spherical Grating (SGM-TRAIN)	5 – 250 eV	Solid (Photoemission)
5B	bending	Plane Grating	5 – 600 eV	Calibration, Solid (Absorption)
6U(1)	undulator	(under consideration)	40 – 600 eV	(Surface Science)
6B	bending	Martin-Puplett FT-FIR, Michelson FT-IR	0.25 meV – 2.5 eV	Solid (Reflection/Absorption)
7U(2)	undulator	10m Wadsworth	6 - 40 eV	Solid (Photoemission)
7B	bending	3m Normal Incidence	1.2 – 30 eV	Solid (Reflection/Absorption)
8B1	bending	15m Constant Deviation Grazing Incidence	30 – 600 eV	Gas, Solid (Absorption)
8B2	bending	Plane Grating	1.9 – 150 eV	Solid (Photoemission)

Note) (1) The undulator is now at the straight section between B6 and B7 and will be moved to the section between B5 and B6 in summer 2006. (2) This undulator and the beam-line is under construction and will be installed in summer 2006.

ACKNOWLEDGMENTS

The authors wish to give thanks to all the staff members of the UVSOR facility, for their efforts on the operation and maintenance of the facility.

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