STATUS OF UVSOR-II AND LIGHT SOURCE DEVELOPMENTS

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Abstract

UVSOR-II, a 750 MeV synchrotron light source of 53 m circumference, is now routinely operated with low emittance of 27 nm-rad and with four undulators.We have started top-up test operation since October, 2008 by utilizing a part of users beam time. The beam current is kept at 300 mA for 12 hours as injecting electrons with 1 Hz repetition for 10 seconds every one minute.

A new 5 year project has been started in 2008 for light source development which includes a resonator type free electron laser, coherent harmonic generation and coherent synchrotron radiation. A new 4-m straight section will be created by moving the injection point to another short straight section in 2010. New undulators will be introduced and dedicated VUV and THz beam lines will be constructed. The existing femto-second laser system is being upgraded.

STATUS OF ACCELERATORS

The first beam of UVSOR was in 1983. Since then, this machine has been operated as one of the major synchrotron light sources in Japan [1]. Its relatively low electron energy is suitable to produce synchrotron radiation in longer wavelength region, from VUV to THz. In 2003, after 20 year operation, the storage ring had a major upgrade [2], including a modification of the magnetic lattice [3]. After this upgrade, we have started to call the ring, UVSOR-II. The UVSOR-II has a small emittance of 27 nm-rad and six straight sections are available for insertion devices, four of them are already occupied by undulators and two are reserved for future insertion devices. The main parameters of the ring are summarized in Table 1.

After the upgrade in 2003, because of the relatively low beam energy and the small emittance, the Touschek effect severely limits the beam lifetime. Although the effect is suppressed by a 3rd harmonic cavity [4] and also by the upgrade of main accelerating cavity [5], the beam lifetime is still short as compared with high energy light sources. We have to inject electron beam every six hours. To solve the lifetime problem eternally, the top-up operation has been prepared. The energy of the booster and the beam transport line were upgraded from 600 MeV to 750 MeV. We had to replace only the magnet power supplies of the bending magnets and quadrupole magnets of the booster and that of the bending magnets of the beam transport line. Fortunately, all other devices are compatible with the full energy operation. To keep the peak electric power for the synchrotron same as before the upgrade, the repetition rate was reduced from 3 Hz to 1Hz, with which the injection rate is still high enough for the daily operation. The main parameters of the injector is shown in Tbale 2 We have, in the user's run, started operating the machine with full energy injection from July 2007.

From October 2008, we have started the top-up test operation, that has been opened to users for checking the effects on their experiments. An injector trigger control system has been constructed, which delivers the trigger signal to the linac, the booster and the pulse magnets. The system delivers the trigger signal with 1 Hz repetition for 10 seconds every one minutes. The system observes the stored beam current on the storage ring and, if it exceeds a certain value (300 mA at present), within the 10 seconds, it stops to deliver the signal. The test operation has been performed on every Thursday night from 9 pm to 9 am. Figure 1 shows an example of the beam current history on Thursday. We have succeeded in keeping the beam current constant for 12 hours. Small dips during the top-up mode were caused by decrease of the injection efficiency. The fluctuation of the stored beam current is less than 1% when injection efficiency is kept at the normal level. Current problems on the top-up operation are to keep the injection efficiency steady for many hours without tuning the injector frequency and to suppress the instantaneous orbit movement at every injection. The former is important because the machine is operated by only a few operators. The latter is important for users. Indeed, at some beam-line some effects on the experiments have been noticed. In near term, we are going to deliver an injection timing signal to the beam-lines to start and stop the date acquisitions. In long term, we have to introduce more sophisticated injection scheme.

UVSOR has four insertion devices, all of which are undulators. An optical-klystron type undulator of variable polarization [6] is providing VUV radiation to a photon spectroscopy beam-line and is parasitically used for driving a resonator type free electron laser and for other coherent light source technologies described below. Two in-vacuum type undulators [7] are providing VUV and soft X-ray radiation. An APPLLE-II type undulator is provid-

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ing VUV radiation of various polarization [8]. For all the undulators, the closed orbit distortion and the betatron tune shift are compensated by feed-forward systems [9]. We have noticed a non-linear effect of the APPLE-II undulator which shortens the beam lifetime. A sophisticated correction scheme is under consideration.

A future plan, in which the ring would be further upgraded, is under consideration. By replacing the bending magnets which have been used for about 25 years with combined function ones, the emittance may be further reduced by a factor of two. In addition, by moving the injection point, a new straight section of four meter long would become available for an insertion device. The latter will be realized in a new project on coherent light source development, which will be described below.

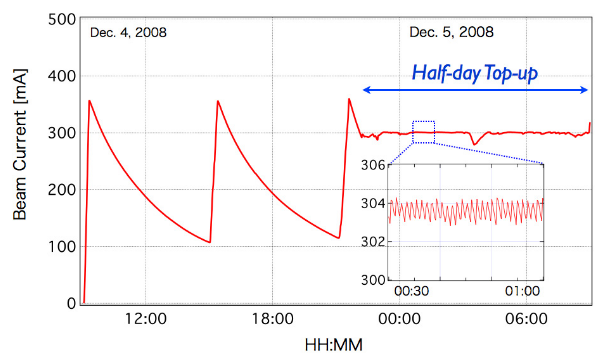

Figure 1: The typical history of the beam current.

Table 1: Main Parameters of the Ring

UVSOR-II Storage Ring

Electron Energy	750 MeV
Circumference	53.2 m
Natural Emittance	27 nm-rad
Natural Energy Spread	4.2×10^{-4}
RF Frequency	90.1 MHz
Harmonic Number	16
Bending Radius	2.2 m
Straight Sections	4 m×4, 1.5 m×4
RF Voltage	100 kV
Betatron Tunes (horizontal, vertical)	(3.75, 3.20)
Momentum Compaction	0.028
Natural Bunch Length	108 ps
Filling Beam Current	350 mA (multi-bunch mode) 100 mA (single-bunch mode)

Table 2: Main Parameters of the Injector.

Linac

Energy	15 MeV
Length	2.5 m
Frequency	2856 MHz
Accelerating RF Field	$2\pi/3$ Traveling Wave
Klystron Power	1.8 MW
Energy Spread	~1.6 MeV
Repetition Rate	2.6Hz

Booster

Energy	750 MeV
Injection Energy	15 MeV
Beam Current	32 mA (uniform filling)
Circumference	26.6 m
RF Frequency	90.1 MHz
Harmonic Number	8
Bending Radius	1.8 m
Lattice	FODO×8
Betatron Tune (Horizontal, Vertical)	(2.25, 1.25)
Momentum Compaction	0.138
Repetition Rate	1 Hz (750 MeV)

RECENT LIGHT SOURCE DEVELOPMENTS

After the upgrade of the magnetic lattice in 2003 and of the main RF cavity in 2005, the performance of the resonator-type free electron laser (FEL) was greatly improved [10]. Utilizing excellent properties such as the high average power, the wide spectral range from 800 nm to around 200 nm, the natural synchronization with the SR and variable polarization, several users experiments are in progress [11]. In FY2007, we have succeeded oscillation at 199.4 nm. [12] In FY 2008, we have developping a feedback system to stabilize the optical cavity. The feedback system continuously controls cavity mirror alignment as monitoring the output laser power. The rapid derease of the output power just after the start of the oscillation was successfully suppressed as shown in Fig.2. Some basic researches on the free electron laser dynamics has been successfully in progress, in collaboration with French team [13]. In this year, we are constructing a VUV diagnostic system and mirrors for lasing FEL at around 190 nm.

A 2.5-mJ 1-kHz Ti:sapphire laser system was installed which could be synchronized with the RF acceleration of the ring. The laser beam is transported through the optical ports for the FEL. The undulator for the FEL, which can be tuned to the laser wavelength, 800 nm, is used as the modulator. It was successfully demonstrated to produce intense coherent synchrotron radiation (CSR) in the terahertz region with variations on spectral property [14]. In particular, for the first time, we have succeeded in producing

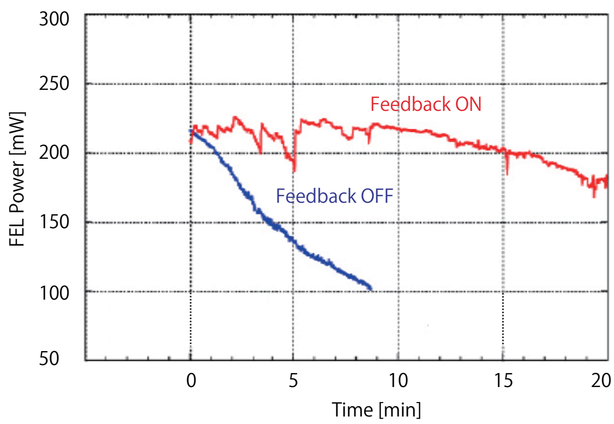

Figure 2: 230-nm FEL power variation before and after introducing the feedback system.

monochromatic CSR in the bending magnet.

The laser system has been also used for coherent harmonic generation (CHG) experiment in collaboration with French Group. The CHG has possibility to produce coherent radiation with short wavelength where cavity mirrors for the FEL are not available. Following the successful production of coherent third harmonics [15], CHG in helical configuration was successfully demonstrated for the first time [16]. Some basic researches on CHG are on going [17].

The light source developments described above has been performed by utilizing the existing FEL system and an infrared beam-line for public use. To develop these technologies further and also to start their applications, a new research project has been started. A new 4m straight section will be created by moving the injection point to another short straight section in 2010. At the new straight section, two undulators and dispersion section in between will be introduced. Dedicated VUV and THz beam-lines will be constructed. The laser system is being upgraded to increase the pulse energy up to 50mJ.

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