RECENT DEVELOPMENTS AT UVSOR-II

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Abstract

UVSOR-II, a 750 MeV synchrotron light source of 53m circumference, is now routinely operated with low emittance of 27 nm-rad and with four undulators, two in-vacuum ones and two variably polarized ones. The injector and the beam transport line have been upgraded to be compatible with full energy injection, preparing for the top up operation in near future.

Research works on the beam dynamics are in progress, such as ion-trapping or Touschek scattering. A resonator type free electron laser is successfully operational in very wide range, from visible to deep UV, with high average power exceeding 1 W. A femto-second laser system was introduced and the laser transport line was constructed by utilizing a part of the FEL system. Intense coherent terahertz radiation was successfully produced by the laser-electron interaction. Coherent harmonic generation was also demonstrated by using the same laser system.

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 Terahertz. 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, which is smaller by a factor of 6 than before, and totally eight straight sections, which is twice larger. Six of the 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.

The ring is operated for about 40 weeks a year, 5 days a week and 12 hours a day. The beam injection is twice a day, at 9am and 3 pm. The filling beam current is 350 mA in multi-bunch mode and 100 mA in single bunch mode.

After the upgrade in 2003, the ring is routinely operated with the small emittance of 27 nm-rad. To suppress the strong Touschek effect due to the low emittance and to the low electron energy, a 3rd harmonic cavity is routinely used [4]. It is also effective to suppress the longitudinal coupled bunch instabilities. The main accelerating cavity, which was constructed more than 20 years ago, has been replaced [5]. By this replacement, the RF accelerating voltage was greatly improved by a factor of 3. This was also effective to improve the lifetime.

To solve the lifetime problem eternally, we are preparing for the top-up operation. UVSOR-II has a 600 MeV booster synchrotron whose energy was slightly lower than the operating energy of the storage ring, 750 MeV. We confirmed by a simulation that the booster magnets were compatible with the 750 MeV acceleration. In 2006, we have replaced the magnet power supply, which was constructed 25 years ago. Soon after, we have succeeded in accelerating electrons up to 750 MeV. In 2007, the bending magnet power supply of the beam transport line has been replaced to be compatible with the 750 MeV injection. Other devices, such as the injection magnets in the ring, are capable of the full energy injection. The full energy injection is under testing and will be realized soon. Then, we will start testing the top-up operation.

Table 1: Main Parameters of the Ring

Parameters	Values
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	4m x4, 1.5m x4
RF Voltage	100 kV
Betatron Tunes	(~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)

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INSERTION DEVICES

UVSOR had three insertion devices until 2001, one superconducting wiggler and two undulators. During the upgrade project in 2003, the wiggler and one of the undulators were removed. Another undulator remained operational, which is a helical optical-klystron-type undulator used for providing VUV radiation to a beam line and also parasitically used for driving a resonator type free electron laser [6]. Two new in-vacuum type undulators were constructed and were successfully commissioned [7], which provide VUV radiation of relatively short wavelength. In 2006, an APPLLE-II type undulator was constructed and installed, which will provides VUV radiation of various polarization [8]. At present, this relatively small ring has four undulators and has two short straight sections reserved for future undulators.

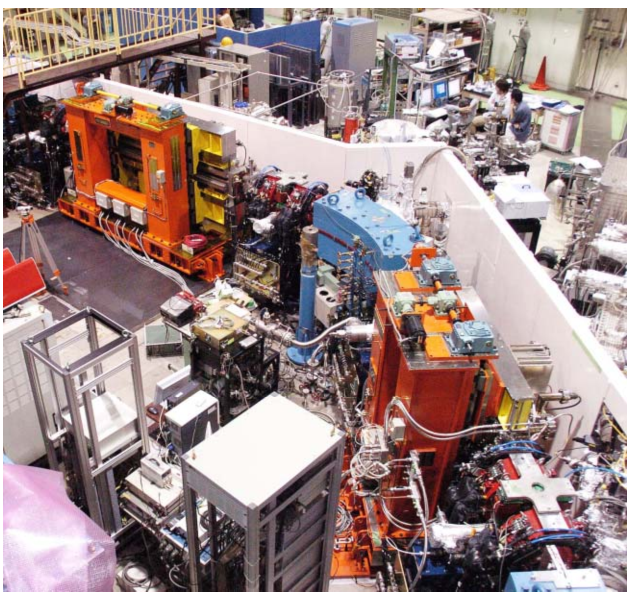

Figure 1: A part of the storage ring: Two of four undulators, in-vacuum one (near) and variably polarized one (far), can be seen.

RECENT BEAM DYNAMICS STUDIES

Ion Trapping

It is observed at UVSOR-II that the betatron tunes changes with the beam current, which cannot be explained by the effect of the chamber wall impedance. The tune shift depended on the vacuum condition. The phenomenon was interpreted by the changes of the numbers of trapped ions [9].

Touschek Effect

The low beam energy and the low beam emittance of UVSOR-II make Touschek effect the dominant process of the beam decay. It is known that one electron of the Touschek scatted electron pair can trapped by the following RF bucket. By utilizing this phenomenon, a method to measure Touschek lifetime separately from the other process such as gas scattering was proposed and demonstrated [10].

Coherent THz Bursts

When we operate UVSOR-II in single bunch mode with high beam current such as 100 mA, very intense bursts of the synchrotron radiation was observed in terahertz region [11]. The observation was made at an infrared beam line [12], by using a liquid-He-cooled bolometer. There existed a threshold current for this phenomenon, which was around 70 mA but depended on the operating condition such as the RF voltage. The temporal structure of the bursts varies with the beam current. The bursts appear quasi-periodically at the lower beam current and chaotically at higher.

RECENT LIGHT SOURCE DEVELOPMENTS

Free Electron Laser

The free electron laser (FEL) at UVSOR-II has a long history and is still developing. After the upgrade of the magnetic lattice in 2003 and of the main RF cavity in 2005, the performance of the FEL was greatly improved. It has come to be possible to oscillate in the deep UV region with a high power exceeding 1W [13, 14]. By utilizing the excellent properties such as the high power, the wide spectral range from 800 nm to 215 nm, the natural synchronization with the SR and variable polarization, several users experiments have been done or are in progress [15, 16, 17]. In addition, the stable oscillation of the UVSOR-II FEL makes some basic researches on the free electron laser dynamics possible [18, 19].

Terahertz Coherent Synchrotron Radiation

A laser bunch slicing system has been constructed at UVSOR-II, as shown in Fig. 2. A Ti-sapphire laser was installed which could be synchronized with the RF acceleration of the ring. The repetition rate is 1 kHz and the pulse energy is 2.5 mJ. The laser beam was transported through the optical ports for the FEL. The undulator for the FEL, which can be tuned to the laser wavelength, 800 nm, was used as the modulator.

We have started the bunch slicing experiment with observing coherent terahertz synchrotron radiation at the infrared beam line which is located at the second bending magnet downstream of the undulator. It was successfully demonstrated to control the spectra of the CSR by changing the laser pulse width or laser pulse shape [20, 21, 22].

Coherent Harmonic Generation

The laser bunch slicing system can be used for coherent harmonic generation experiment. The injected laser pulse interacts with the electron bunch in the undulator. As the bunch proceeding in the optical klystron type undulator, a density modulation of the laser wavelength is created. If

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the density modulation has higher order frequency component, coherent harmonics of the injected laser is generated. As injecting the 800 nm laser, the coherent third harmonic radiation of 266 nm was successfully observed at the optical monitor station downstream of the undulator [23]. It is interesting that the coherent harmonic radiation and the coherent terahertz radiation are generated simultaneously.

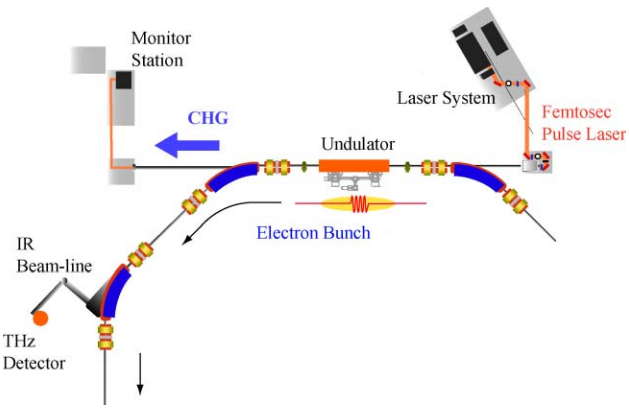

Figure 2: Experimental setup for the source development studies based on laser

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