PRESENT STATUS OF UVSOR-II

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Abstract

After the successful twenty year operation, in 2003, the UVSOR storage ring, a 750 MeV synchrotron light source, was upgraded to UVSOR-II which has small emittance of 27 nm-rad and 6 straight sections available for insertion devices. Three undulators are in operation and one is under construction. To suppress the strong Touschek effect, a new RF cavity was constructed and successfully commissioned in 2005. Upgrades on the injector and the radiation shields are in progress, preparing for top-up operation in near future.

The smaller emittance of UVSOR-II gives a higher gain of the existing free electron laser in the deep UV region. A high power lazing around 215 nm with average output power exceeding 200 mW was successfully demonstrated. Some users experiments have started. A Ti:Sa laser which can be synchronized with the RF acceleration of UVSOR-II was introduced in 2005. A laser bunch slicing experiment and a coherent harmonic generation experiment has started. Some early results have been obtained.

INTRODUCTION

The UVSOR electron storage ring was constructed early in 1980's. The first beam was in 1983. Since then, the ring has been providing synchrotron radiation (SR) in the infrared, VUV and soft X-ray region to about 16 beam-lines, half of which are opened to the nation-wide users and those from foreign countries. After the successful 20 year operation, it had come to be noticed that some major upgrade was indispensable to survive in the next decade as a national facility among new third generation light sources and small facilities in universities.

In 2000, a new magnetic lattice was designed [1], which would give smaller emittance and more straight sections. The upgrade project was soon approved and, in 2003, the accelerator was reconstructed [2]. After three month shut down for the reconstruction works and two months for the commissioning and the vacuum conditioning, users operation was successfully restarted. Since then, we call our machine UVSOR-II.

The free electron laser (FEL) at UVSOR-II has a long history. The first lazing was early in 1990's. By introducing a helical optical klystron in the middle of 90's, they have succeeded in lazing at 239 nm [3]. This was once the world shortest record and has been the shortest record of UVSOR-FEL until recently. However, after the upgrade of the accelerator in 2003, it has come to be possible to oscillate at shorter wavelength with high output power, thanks to the smaller emittance and the higher peak current of the electron beam.

In 2005, an ultra-short pulse laser was installed, which can be synchronized with the electron bunches circulating in the ring. By utilizing this, a laser bunch slicing experiment [4] and a coherent harmonic generation experiment [5] has started.

In this paper, recent status of the UVSOR-II storage ring and its injector will be described. Recent progress of the research activities on light source developments will be also described.

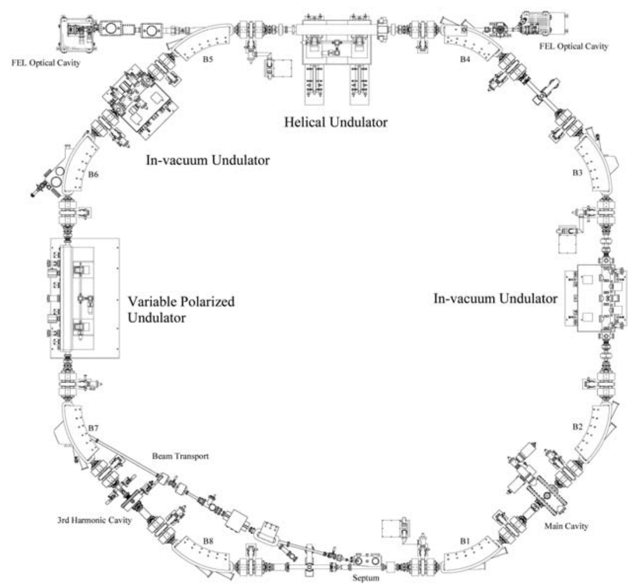

Figure 1: Configuration of the UVSOR-II storage ring after the installation of fourth undulator in October 2006.

Table 1: Main Parameters of UVSOR-II

Electron Energy	750 MeV
Circumference	53.2 m
Straight Sections	4m x 4, 1.5m x 4
Natural Emittance	27 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	350 mA*

Note: *In multi-bunch operation for SR users.

PRESENT STATUS OF ACCELERATORS

Operation Status

The UVSOR accelerators are operated for about 40 weeks in a year. A few weeks are dedicated for machine studies and others are for SR experiments. Weekly, it is operated from Monday to Friday. Mondays are dedicated

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for machine studies. Daily, it is operated from 9 a.m. to 9 p.m. In users runs, the injection is twice a day, at 9 a.m. and 3 p.m. We can store 500 mA in multi-bunch mode, however, the lifetime is so short and the electron beam is not so stable. In users operation, the filling beam current is 350 mA in multi-bunch mode and 100 mA in single bunch mode. Single bunch users run is performed for a few weeks every year, for timing experiments.

The beam lifetime of UVSOR-II is short, normally 6 hours at 200 mA. Because of the relatively lower electron energy and of the small emittance, Touschek effect severely limits the lifetime. To remove this problem completely, we are preparing for top-up injection, as described later.

Magnetic Lattice

The present lattice has small emittance of 27 nm-rad, with finite dispersion at all straight sections. The ring has totally eight straight sections, six of which are available for insertion devices. The vertical betatron function at the straight sections is small as shown in Figure 2, which is suitable for narrow gap undulators.

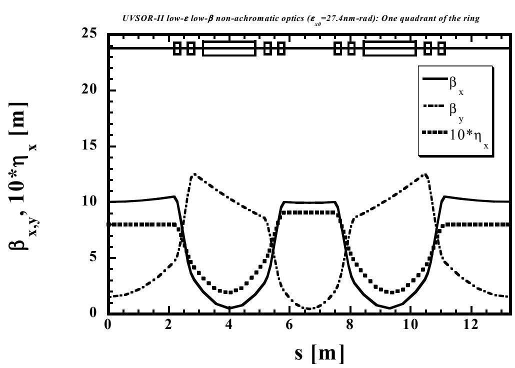

Figure 2: Beam Optics of UVSOR-II for Users Operation.

RF System

The UVSOR-II storage ring has two RF cavities, one is 90 MHz main accelerating cavity and another is the third harmonic cavity. The main cavity had been used for about 20 years and, in 2005, it was replaced with new cavity [6]. With the same RF power source, a 20 kW solid-state amplifier, the new cavity can produce about three times higher accelerating voltage than before, which is indispensable to suppress strong Touschek effect. The third harmonic cavity is routinely used to increase the bunch length and also to stabilize longitudinal instabilities [7]. The former is also to suppress the Touschek effect.

Insertion Devices

During the major upgrade of the accelerator in 2003, we replaced a super-conducting wiggler and an old undulator with two in-vacuum undulators [8]. In adding to these two new devices, a variably polarized undulator, which is used both for the SR experiments and the FEL researches, is in operation. An APPLE-II type undulator of 3 m long is under construction as the fourth undulator and will be installed in October, 2006. We still have two short straight sections reserved for future undulators.

Injector

The injector of UVSOR-II is composed of a 15 MeV linear accelerator and a 600 MeV booster synchrotron. During the upgrade in 2003, the electron gun and the pulse modulator of the linear accelerator were replaced. The injection efficiency to the booster synchrotron was increased by a factor of three, which is presumed to be due to the smaller emittance and/or the smaller energy spread of the electron beam.

The top-up operation, in which electron beam is injected intermittently and the stored beam current is kept almost constant, has now come to be a standard technology in modern synchrotron light sources [9]. This is a very promising technology to remove the lifetime problem eternally. To realize the top-up injection at UVSOR-II, first, we must replace the 20 year old power supply, which limits the maximum beam energy of the booster synchrotron at 600 MeV, which is lower than the energy of the storage ring, 750 MeV. The new power supply is currently under construction and will be installed in July, 2006. Some power supplies in the beam transport system will be replaced in March, 2007. Then, we will start full energy injection. We will check the injection efficiency, the radiation shielding and so on. We are going to introduce the top-up injection to the users operation within one or two years.

Control System

The control system of the accelerators, which was constructed early in 1990's, was based on the VAX mini-computers and the CAMAC interfaces [10]. Although the system was quit stable, it had come to be very difficult to maintain the computers. As the old accelerator components being replaced in the upgrade project, the control system has been replaced with a new system based on personal computers and programmable logic controllers which are connected each other by a local area network.

SOURCE DEVELOPMENTS

Free Electron Laser

The free electron laser at UVSOR-II utilizes an optical klystron type helical undulator [11], which is normally used to provide circular polarized undulator radiation to a beam-line. An optical cavity was constructed not to interfere with the beam line. A mirror is inserted to extract the SR to the beam line and it is removed during the FEL experiment.

The FEL can provide high power coherent light exceeding 1 W in visible wavelength region [12]. However, the shortest wavelength had remained at 239 nm for many years, because of the low quality of the electron beam. The major upgrade of the accelerator in 2003 has changed the performance of the FEL drastically. The smaller emittance and the higher peak current of the electron beam have made it possible to oscillate in the deep UV region with high output power [13]. Currently, the shortest wavelength is 215 nm with the average power exceeding 200 mW. Some users experiments which utilize this high power laser in deep UV region have started. Lazing in the shorter wavelength around 200 nm is promising, which will be tried in near future. The basic parameters of the FEL are listed in Table 2.

Table 2: Main Parameters of FEL

Wave Length	215 – 800 nm
Average Power	~200 mW @ 215 nm ~1.2 W @ 570 nm
Repetition Rate	11.25 MHz
Pulse Width	~10 psec
Line Width ($\delta\lambda/\lambda$)	$\sim 10^{-4}$

Laser Bunch Slicing

The laser bunch slicing is a technology to cut out a part of an electron bunch, proposed to produce femto-second SR pulses and/or intense coherent radiation in the terahertz region [14]. This technology was successfully demonstrated in a few synchrotron light sources [15, 16].

In this scheme, a femto-second laser pulse is injected to a storage ring and interacts with an electron bunch in an undulator which is tuned to the laser wavelength. As the laser pulse is shorter than the electron bunch, a small part of the bunch suffers energy modulation. As the bunch is proceeding in the ring, the modulated part is separated from the bunch and finally ultra-short fragments of the electrons and an ultra-short dip on the bunch are created.

In case of UVSOR-II, the undulator used for the FEL can be tuned to the visible wavelength. In 2006, a Ti:Sa laser was installed which can be synchronized to the RF acceleration of the ring. The repetition rate, the pulse energy and the nominal pulse width of the laser are 1 kHz, 2.5 mJ and 130 fsec, respectively. This pulse energy is large enough to produce energy modulation comparable to or exceeding the RF bucket height of the ring, which is around 1 %. The laser transport line could be constructed by utilizing the optical cavity of the FEL without any modification of the accelerator.

We have already succeeded in observing coherent terahertz emission at an infrared beam line [17], located downstream of the undulator section. The details of the experiments are described in a separated paper [4]. The Ti:Sa laser is also used for a coherent harmonic generation experiment, which is also presented separately [5].

SUMMARY

- The UVSOR storage ring was successfully upgraded in 2003 and was renamed UVSOR-II, which has the world smallest emittance of 27 nm-rad among the operational synchrotron light sources of electron energy lower than 1 GeV.
- Three undulators are in operation and the fourth will be installed in October 2006. Two short sections are reserved for future undulators.
- The injector is being upgraded to be capable of providing full energy electron beam, preparing for top-up injection in near future.
- The free electron laser has come to be operational in the deep UV region with high output power exceeding a few hundred mW. Some users experiments have started.
- A laser bunch slicing experiment has started in 2005. Intense coherent radiation in the terahertz region has been observed successfully.
- Research activities on beam physics or accelerator technology are also very active [18].

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