PRESENT STATUS AND UPGRADE PLAN ON COHERENT LIGHT SOURCE DEVELOPMENTS AT UVSOR-II

M. Adachi*, M. Katoh, H. Zen, Y. Taira, J. Yamazaki, K. Hayashi, S. Kimura, Institute for Molecular Science, National Institutes of Natural Sciences, Okazaki, 444-8585, Japan
T. Tanikawa, School of Physical Sciences, The Graduate School of Advanced Studies (SOKENDAI), Okazaki, 444-8585, Japan
M. Hosaka, N. Yamamoto, Y. Takashima, Graduate School of Engineering, Nagoya University, Nagoya, 464-8603 Japan
T. Takahashi, Research Reactor Institute, Kyoto University, Osaka, 590-0494 Japan

Abstract

We have been intensively developing coherent light sources utilizing electron bunches in the storage ring, UVSOR-II, by adding some external components to the ring. We have succeeded to generate free electron laser (FEL) in visible to DUV range, coherent synchrotron radiation (CSR) in THz range and coherent harmonic generation (CHG) in VUV range have been extensively studied under international collaborations. Recently, some achievements are obtained such as FEL lasing with top-up injection mode and turn-by-turn CSR generation. Based on these results, a 5-year new research project on the coherent light source developments has been started from FY2008. A part of the injection beam transport line and a part of the storage ring were reconstructed to produce a straight section dedicated for the light source development. New laser system, undulators and beamlines are under construction.

UPGRADE FOR COHERENT LIGHT SOURCE DEVELOPMENTS

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 [2]. After this upgrade, we have started to call the ring, UVSOR-II. The UVSOR-II has a small emittance of 27 nm-rad.

UVSOR has four 4-m long straight sections. Three of them have been already occupied with three insertion devices, all of which are undulators. One of them, named U5, is an optical-klystron type undulator of variable polarization [3] is providing VUV radiation to a photo-electron spectroscopy beam-line and is parasitically used for driving a resonator type free electron laser [4] and for other coherent light source technologies described below. And another straight section was used for injection.

The previous coherent light source developments has been performed by utilizing the existing FEL system and an infrared beam-line for public use. In order to develop these technologies further and also to explore their applications, a 5-year new research project has been started. The project builds up with creation of new straight section, construction of new undulator optimized for the coherent light sources [5] and construction of beamlines dedicated for the coherent light sources [6].

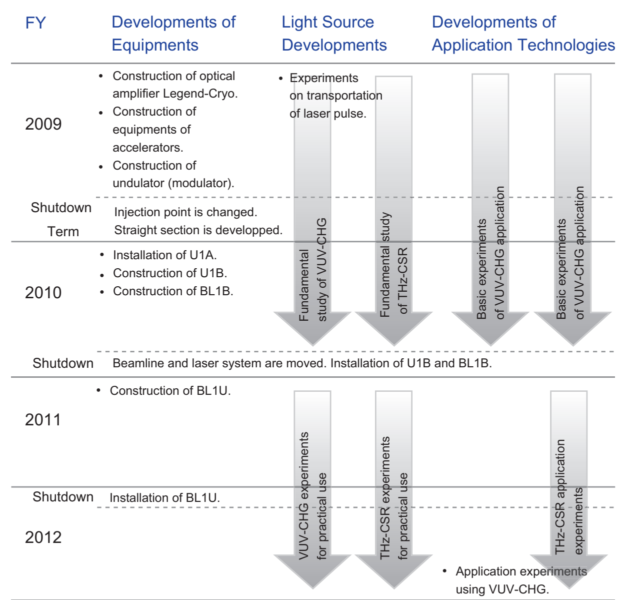

Figure 1: A part of the time schedule of the five-year project. The project have been started from FY2008.

The time schedule of the project is shown in Fig. 1. At the present, in a shutdown term from March 2010 to June 2010, we have finished the first major upgrade of the accelerators: the main RF cavity and some equipments are moved and re-arranged, the injection point is changed and new 4-m long straight section has been created. The beam commissioning for the upgraded accelerator with the new injection point will be started soon afterward. At FY2010, we will finish constructing the whole of new undulator U1 and the dedicated beamline BL1B. At the end of FY2010, we will install U1 and BL1B. The other dedicated beamline BL1U will be constructed at FY2011 and install at FY2012.

* adachi@ims.ac.jp

Figures 2 and 3 show the previous and future upgraded accelerator, respectively.

At FY2008, we install a new amplifier Hidra-50/ COHERENT which has ability to generate 50 mJ/pulse at repetition rate of 10 Hz. At the end of FY2009, the other amplifier Legend-Cryo/ COHERENT (10-mJ/pulse at 10-Hz) was installed into the laser system. The Legend-Cryo is in start-up process. At present, the storage ring has been equipped with external laser sources as shown in Table 1.

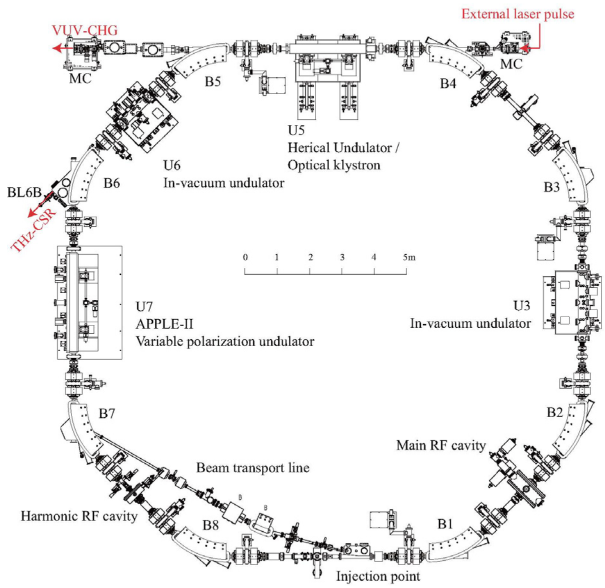

Figure 2: Configuration of the UVSOR-II (before the reconstruction). MC indicates the chamber of the FEL resonator mirror.

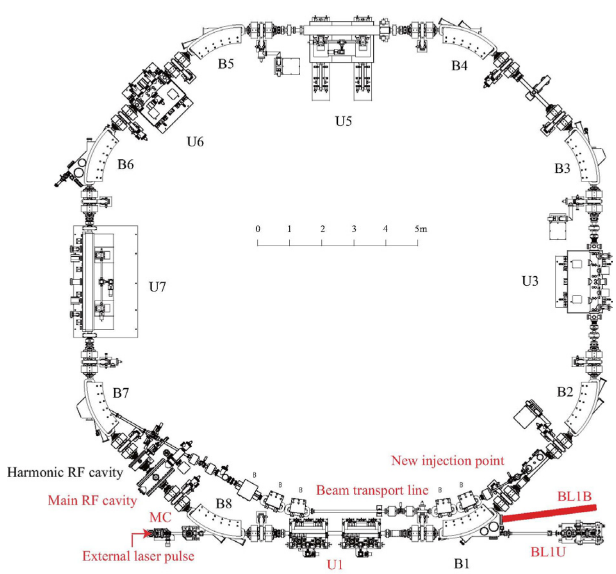

Figure 3: Configuration of the UVSOR-II$^+$ (after the reconstruction). The injection point have been already changed.

Table 1: Specifications of Laser Amplifiers

	Legend	Hidra	Legend -Cryo
Repetition rate	1 kHz	10 Hz	1 kHz
Max. pulse energy	2.5 mJ	50 mJ	10 mJ
Center wavelength	800 nm	800 nm	800 nm
Min. pulse duration	130 fs	130 fs	130 fs

RECENT PROGRESS IN 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 [7]. Utilizing excellent properties such as the high average power, the wide spectral range from 800 nm to 199.4 nm [9], the natural synchronization with the SR and variable polarization, several users experiments are in progress [8]. At FY 2008, we have developed 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 [6] and we have achieved FEL lasing with top-up operation [4]. Some basic researches on the free electron laser dynamics has been successfully in progress, in collaboration with French group [10].

The Ti:sapphire laser system was synchronized with the RF acceleration of the ring. The laser beam is transported through the optical ports for the FEL. The undulator U5, which can be tuned to the laser wavelength of 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 [11]. In particular, for the first time, we have succeeded in producing monochromatic CSR in the bending magnet. For enhancing power of the CSR, we have also succeeded in turn-by-turn generation of CSR with a low alpha (1/2 and 1/3) operation mode [12]. Recently, we have installed an optical fiber as shown in Fig. 4, which realizes stable transportation of the short laser pulse from oscillator MIRA to the bamline BL6B. We succeeded to measure THz-CSR electric field with an electro-optic sampling method by utilizing this transported laser pulse as the probe pulse [13].

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 [14], CHG in helical configuration was successfully demonstrated for the first time [15]. Some basic researches on CHG are on going [16]. At FY2009, we installed VUV spectrometer measurement system to the FEL cavity line, which realizes measurement of CHG spectra in the region from 50 nm to

300 nm [17].

Adding to the above coherent light sources, we have performed gamma ray pulse generation in MeV region via laser Compton scattering [18].

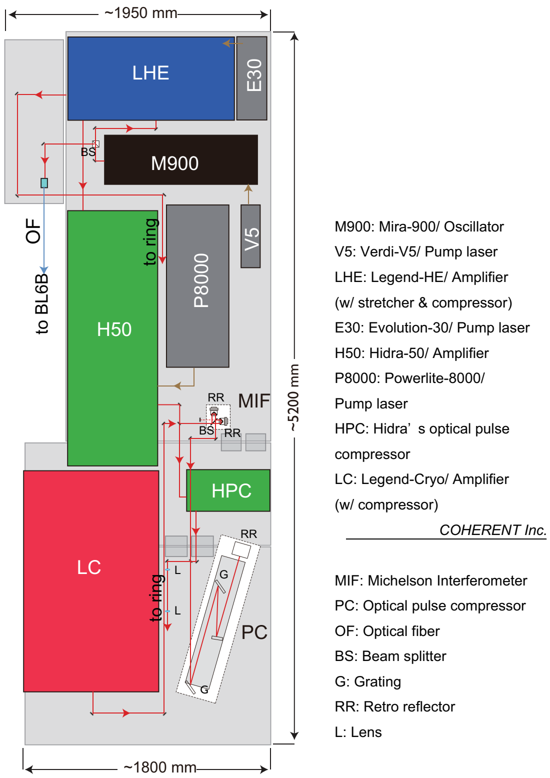

Figure 4: A schematic drawing of the laser system.

ACKNOWLEDGEMENT

We would like to give thanks to all the staff members of the UVSOR facility. A part of this work was supported by Grant-in-aid for Scientific Research from JSPS and Quantum Beam Technology Program by JSPS/MEXT. Some parts of the researches on the light source developments are collaboration works with Drs. M. Shimada, T. Hara, A. Mochihashi, M. E. Couprie, M. Labat, G. Lambert, S. Bielawski, C. Szwaj, C. Evain, P. Marc partly supported by International Collaboration Program of IMS and by the Invitation Fellowship Program of JSPS.

REFERENCES

[1] M. Katoh et al., "Present Status of UVSOR-II", AIP Conf. Proc. 879 (2007), 192-195.

[2] M. Katoh et al., "Construction and Commissioning of UVSOR-II", AIP Conf. Proc. 879 (2007), 49-52; M. Katoh et al., "New Lattice for UVSOR", NIM A 467-468 (2001), 68-71.

[3] S. Kimura et al., "Design of a helical undulator for UVSOR", J. Electron Spectrosc. Relat. Phonom., 80 (1996) 437-440.

[4] H. Zen et al., "STATUS OF TOP-UP OPERATION IN UVSOR-II', in these proceedings.

[5] T. Tanikawa et al., "STATUS OF VUV-CHG AT UVSOR-II', Proc. FEL2009, (2009, Liverpool, UK).

[6] M. Adachi et al., "STATUS OF UVSOR-II AND LIGHT SOURCE DEVELOPMENTS', Proc. of PAC2009 (2009, Vancouver, Canada).

[7] M. Hosaka et al., "Upgrade of the UVSOR storage ring FEL", NIM A 528 (2004), 291-295; M. Hosaka et al., "High Power Deep UV Lasing on the UVSOR-II Storage Ring FEL", Proc. FEL2006 (2006, Berlin), 368-370.

[8] T. Gejo et al., "The investigation of excited states of Xe atoms and dimmers by synchronization of FEL and SR pulses at UVSOR", NIM A 528 (2004), 627-631; M. Hosaka et al., "Status and Prospects of User Application of the UVSOR Storage Ring Free Electron Laser", AIP Conf. Proc. 705 (2004) 61-64; T. Nakagawa et al., "Measurements of threshold photoemission magnetic dichroism using ultraviolet lasers and a photoelastic modulator", Rev. Sci. Instr. 78 (2007), 023907; T. Ogawa e al., "Asymmetric Synthesis and Decomposition of Amino Acids by Circularly Polarized Light from Free Electron Laser', Origins of Life and Evolution of Biospheres (2009) in press.

[9] M. Hosaka et al., "Lasing below 200 nm at the UVSOR-II FEL", UVSOR Activity Report 35 (2008) 40.

[10] S. Bielawski et al., "Feedback Control of Dynamical Instabilities in Classical Lasers and FELs", Proc. 27th FEL Conf. (2005), 391-397; M. Labat et al., "Longitudinal and transverse heating of a relativistic electron bunch induced by a storage ring free electron laser", PRSTAB 9, 100701 (2007).

[11] M. Shimada et al., "Coherent Terahertz Radiation at UVSOR-II", Jpn. J. Appl. Phys. 46, No. 12 (2007), 7939-7944; S. Bielawski et al., "Tunable narrowband terahertz emission from mastered laser-electron beam interaction", Nature Phys. 4 (2008), 390-393.

[12] M. Shimada et al., "OBSERVATION OF TRANSVERSE-LONGITUDINAL COUPLING EFFECT AT UVSOR-II', in these proceedings. M. Shimada et al., "Transverse-Longitudinal Coupling Effect in Laser Bunching Slicing", Phys. Lev. Lett. 103 (2009), 144802.

[13] I. Katayama et al., "Feedback Control of Dynamical Instabilities in Classical Lasers and FELs", UVSOR Activity Report 37 (2010) in press.

[14] M. Labat et al., "Coherent harmonic generation on UVSOR-II storage ring", Eur. Phys. J. D. e2007-00177-6 (2007).

[15] M. Labat et al., "Optimazation of a Seeded Free-Electron Laser with Helical Undulators', Phys. Rev. Lett. 101 (2008) 164803.

[16] M. Labat et al., "Observation of Synchrotron Sidebands in a Storage-Ring-Based Seeded Free-Electron Laser', Phys. Rev. Lett. 102 (2009) 014801.

[17] T. Tanikawa et al., "Spectral Measurement of VUV CHG at UVSOR-II', in these proceedings.

[18] Y. Taira et al., "Generation of Ultra-Short Gamma-ray Pulses by Laser Compton Scattering in an Electron Storage Ring', in these proceedings; Y. Taira et al., "Feasibility Study of Ultra-short Gamma Ray Pulse Generation by Laser Compton Scattering in an Electron Storage Ring', Nucl. Instrum. Meth. A in press.