PRESENT STATUS AND FUTURE PROSPECTS OF PROJECT ON UTILIZING COHERENT LIGHT SOURCES FOR USER EXPERIMENTS AT UVSOR-II

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Abstract

From fiscal year 2008, a 5-year new research project named as Quantum Beam Technology Program has been started. The project aims at utilizing coherent synchrotron radiation (CSR) and coherent harmonic generation (CHG) for user experiments, and includes introduction of new driving laser system, dedicated undulators and beamlines. Present status of preparation and future prospects of the project are described in this paper.

INTRODUCTION

At UVSOR facility, coherent light sources such as free electron laser (FEL) [1-5], CSR [6-8] and CHG [9-13] have been intensively studied. We succeeded in generating broadband CSR by laser bunch slicing [6] and monochromatic CSR through FEL interaction between electron bunch and periodically amplitude modulated laser [7]. In addition, CHG at 3rd harmonics of Ti:Sapphire laser has been observed [9]. After those successful experiments, a 5-year new research project named as Quantum Beam Technology Program has been started from fiscal year 2008. The project aims at utilizing those coherent light sources for user experiments.

There are some interesting phenomena due to the excitation of mid-IR and THz sources such as the vibration in conductivity of manganite excited by a mid-IR pulse laser [14], and picosecond carrier dynamics in indium antimonide (InSb) in the THz region after a THz pumping [15]. However, there was no direct observation of the time-dependent electronic structure after THz pumping so far.

For direct investigation of electronic structure, photoemission spectroscopy (PES) is a powerful experimental method because the occupied electronic structure as well as the density of states can be directly observed.

Then we selected target of the project as measuring the temporal evolution of electronic structure after THz pumping by utilizing THz-CSR and CHG as pumping source and probe light for PES, respectively.

OVERVIEW OF PROJECT

In UVSOR-II, CSR in THz region and CHG in VUV region are available at same time. In our project, we are planning to perform the THz pump – PES probe spectroscopy using the quasi-monochromatic THz-CSR as an excitation source and the CHG as a probing light. This spectroscopy possibly enables us to measure temporal evolution of electronic structure after the resonant excitation of vibration modes and energy gaps. In experiment, CHG with 6th harmonics of Ti:Sapphire laser (~ 9 eV, VUV-CHG) will be used because the CHG is used for light source for PES.

The schematic drawing of the designed THz pump – PES probe spectroscopy system is shown in Fig. 1. The amplitude modulated Ti:Sapphire laser pulse (1 kHz, 10 mJ/pulse) is injected to an optical klystron in UVSOR-II storage ring. Then a periodic energy modulation in electron bunch is created at the modulator through FEL interaction between the injected laser and electron bunch.

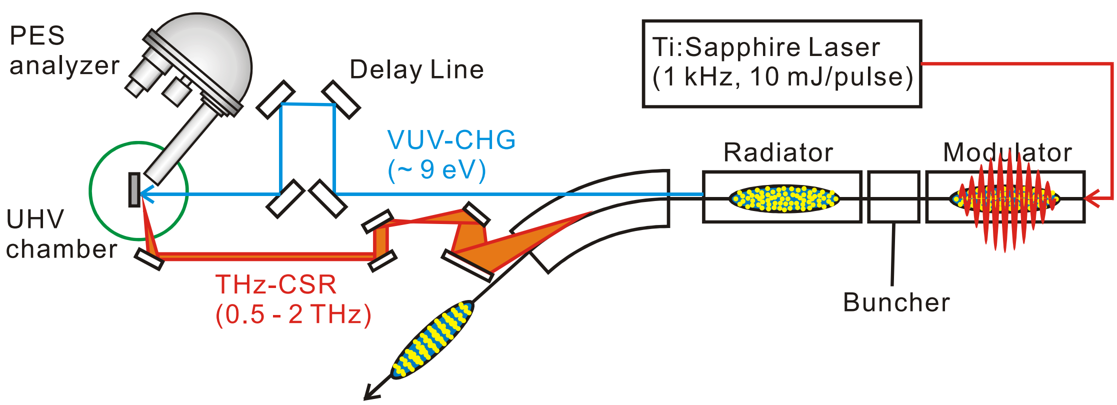

Figure 1: Schematic drawing of THz pump – PES probe spectroscopy system.

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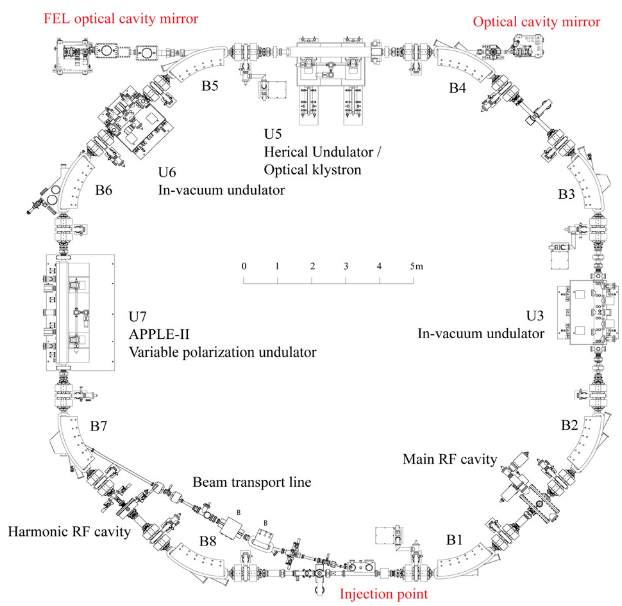
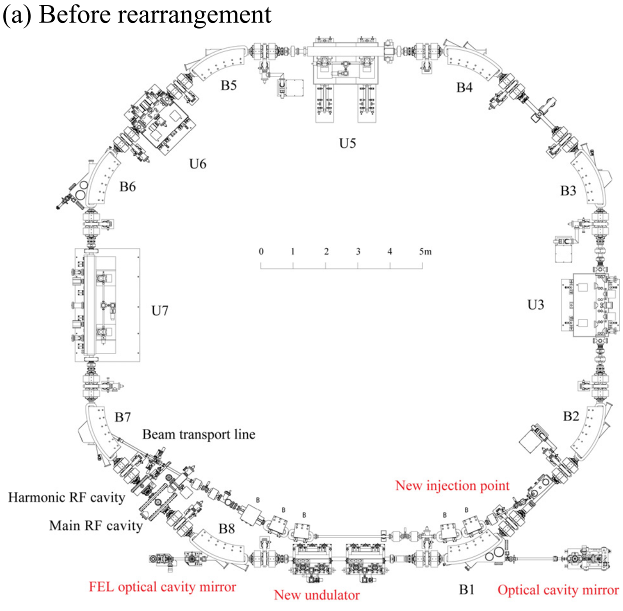
After passing through the buncher, micro-bunches at 800-nm (laser wavelength) are created. The micro-bunched electron bunch generates VUV-CHG at the radiator. After that, when electron bunch passing through first bending magnet, large density modulation with the period of amplitude modulation of injected laser is created in the electron bunch. Then quasi-monochromatic CSR is generated from the electron bunch in the bending magnet. Since those coherent lights are emitted from same electron bunch, there is no time jitter between them. Since both THz-CSR and VUV-CHG are monochromatic lights, no monochromator for both lights are required. Those lights are directed to the same position on a sample in an ultra-high vacuum chamber with photoelectron analyzer (VG-Scienta SES100).



(a) Before rearrangement



(b) After rearrangement

Figure 2: Arrangement of storage ring components before and after rearrangement.

PRESENT STATUS OF PREPARATION

Rearrangement of Components

A part of storage ring components are rearranged for creating long straight section for this project. As shown in Fig. 2, main RF cavity and injection point were moved to have vacant long straight section. Those rearrangements are finished until summer in 2010. And after rearrangement, we succeeded in injection and operation of the storage ring.

The laser system which has been used for CSR and CHG experiment has been moved from near the upstream FEL optical cavity in Fig. 2 (a) to near the downstream FEL optical cavity in Fig. 2 (b) in this spring. At the same time, the upstream FEL cavity mirror also has been moved.

Optical Klystron

In this spring, one of the undulator for optical klystron (modulator) has been installed. The main parameter of the modulator is shown in Table 1. Because this optical klystron will also be used for oscillator FEL experiment, we decided to use Apple-II undulator for both modulator and radiator. The longest resonant wavelength of this undulator is about 880 nm with 600 MeV electron beam. The parameter of the other undulator (radiator) is same as modulator and fabrication of radiator has been finished. The radiator will be installed during shutdown time of UVSOR facility, next September. We started to design electromagnetic buncher magnet. The structure of designed buncher is same with three pole wiggler. In this fiscal year, the buncher will also be installed.

Table 1: Main Parameters of Modulator

Structure	Apple-II
Number of Periods	11
Period Length	88 mm
Minimum Gap	24 mm
Maximum K-value	7.31 (Linear Polarization)

Laser System

In UVSOR-II, Ti:Sapphire laser system consists of a mode-locked oscillator (COHERENT Mira) and a regenerative amplifier (COHERENT Legend) has been installed before starting this project. Then the maximum average power and repetition rate are 2.5 W and 1 kHz. In fiscal year 2008, high peak power amplifier (COHERENT Hidra-50) has been installed to investigate the effect of high peak power laser injection. Higher average power and higher repetition rate are more suitable for practical applications. To enhance those of CSR and CHG, high average power (10 W) and same repetition rate (1 kHz) regenerative amplifier (COHERENT Legend-Cryo) has been installed in UVSOR-II at the end of fiscal year 2009. The specifications of those three

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amplifiers are listed in Table 2. Now those are available for application experiments.

Table 2: Specification of Laser Amplifiers

	Legend	Hidra-50	Legend-Cryo
Repetition Rate	1 kHz	10 Hz	1 kHz
Max. Pulse Energy	2.5 mJ	50 mJ	10 mJ
Centre Wavelength	800 nm	800 nm	800 nm
Min. Pulse Duration	130 fs	130 fs	130 fs

THz Beamline

A THz beamline dedicated for THz pump – PES probe experiments has been designed. To collect THz-CSR in the wide acceptance angle, a three dimensional "magic mirror" that has been successfully installed at BL43IR, SPring-8 [16] and BL6B, UVSOR-II [17] is employed. Figure 3 shows the form factor of electron bunch with bunch slicing as a function of the horizontal emission angle from the straight section. The form factor corresponds to the efficiency of the evolution of CSR. THz-CSR below 3 THz (~ 100 cm^{-1}) is generated from 10 degree. Above 20 degree, the intensity of THz-CSR below 2 THz (~ 67 cm^{-1}) is rapidly increased. In addition, according to the geometrical condition, the first mirror can be put at 34 degree in maximum. Therefore the magic mirror acceptance angle of THz-CSR was chosen to be 17.5-34 degree (288 mrad) in horizontal direction. The vertical angle was set to ±40 mrad for collecting the widely expanded THz-CSR.

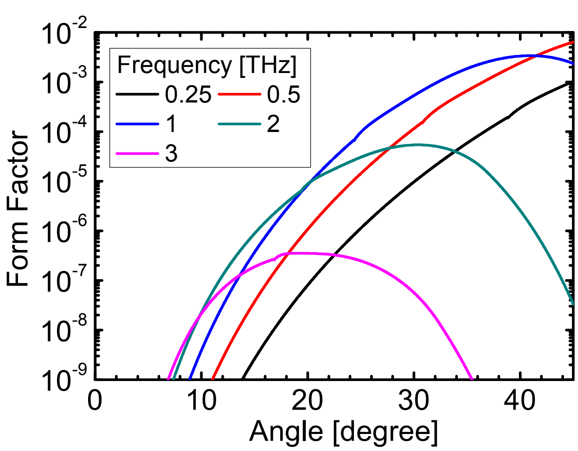

Figure 3: The form factor of electron bunch with bunch slicing at various THz frequencies as a function of the horizontal angle of the bending magnet from the straight section.

A new vacuum chamber for the bending magnet and the slotted magic mirror has been installed in this spring. The magic mirror and second flat mirror have been also installed at the same time. Now a transport line is under construction. In the beamline, a Martin-Puplett-type Fourier transform interferometer will be installed to check the spectral feature of THz-CSR. The installation of all components of THz beamline will be finished before December 2011.

FUTURE PROSPECTS

Preparation of almost all components will be finished within this fiscal year. In next fiscal year, the THz pump – PES probe spectroscopic experiments will be started. We hope this new tool based on coherent light sources enables us to elucidate the low-energy electronic structure that is the origin of the physical properties of solids.

SUMMARY

At UVSOR-II, now developments for user application of CSR and CHG are being carried on. Target of the application is measuring the temporal evolution of electronic structure of solids after THz pumping. For that purpose, rearrangement of storage ring components and creation of vacant long straight section has been done successfully. The modulator of optical klystron has been installed in the straight section and radiator will be installed soon. The buncher is now under designing. High peak power and high average power laser system has been installed. Designing work of THz beamline has been accomplished and the three dimensional magic mirror and the second flat mirror has been installed. Installation of all components of THz beamline will be finished before December 2011. Almost all preparation will be finished within this fiscal year. In next fiscal year, the THz pump – PES probe spectroscopy beamline based on cohrent light sources will open.

ACKNOWLEDGEMENT

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