STATUS OF VUV CHG AT UVSOR-II

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Abstract

At the UVSOR-II electron storage ring, coherent light source developments based on laser seeding techniques are in progress. In the previous results, generation of deep UV (UltraViolet) CHs (Coherent Harmonics) of variable polarization by using a femto-second laser has been achieved.

Based on the successful results, a new five year research project has been started, which includes construction of dedicated undulator system and beam lines. New undulator system is now under designing. A VUV (Vacuum UltraViolet) spectrometer has been constructed and is under testing. In a preliminary experiment, the spectra of CHs in the VUV region were successfully observed, which were extending up to 8th harmonic.

INTRODUCTION

At the UVSOR-II, studies of a cavity FEL (Free Electron Laser) have been worked for many years [1,2,3]. By utilizing a part of the FEL system, studies on CSR (Coherent Synchrotron Radiation) in terahertz range and CHG (Coherent Harmonic Generation) in deep UV range by using a femto-second laser system have been worked in these years. In the studies of CSR, not only intense terahertz synchrotron radiation but also tunable monochromatic terahertz radiation by a laser modulation technique has been generated successfully [4,5]. In the studies of CHG, deep UV CHs with circular polarization by a laser seeding technique with an OK (Optical Klystron) have been generated successfully [6,7].

In the present configuration, the FEL, CSR and CHG experiments have been performed by sharing synchrotron radiation beam lines opened for users. Moreover, the OK is not the optimum one for CHG because the magnet parameters of the modulator, the buncher and the radiator, cannot be varied independently.

A five-year project for upgrading the coherent light sources at UVSOR-II was started in 2008. A new undulator system is under designing, which will be inserted into a long straight section created by moving the injection point to another straight section. The Ti: Sapphire laser system is being upgraded. A VUV spectrometer for the diagnostics of the cavity FEL and the CHs has been constructed and is being tested.

In this paper, we report some results on the design of new undulator for VUV CHG. Then, we describe the design and the construction of new VUV spectrum measurement system. We also show some preliminary results on the spectral measurements.

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DESIGN OF NEW UNDULATOR SYSTEM

A new undulator system for coherent light generation will consist of three independent components, a modulator, a buncher and a radiator. In addition, this undulator system will adopte APPLE-II configuration which can generate coherent radiation with variable polarization. The length of the straight section available for the undulator system is about 3 m. We are considering a movable radiator which enables two type of arrangements; one is FEL configuration in which the radiator is aligned in straight and another is CHG configuration in which the radiator is tilted and that enables separation of CHs from the seed light.

Figure 1 shows the fundamental radiation wavelength as a function of the period length. The RADIA [8], a calculation code of 3-D magnetic field, was used for its design. The requirement from the beam clearance sets the minimum pole gap 24 mm. The magnet period length was determined to satisfy the following conditions; to be tuned at 800 nm for the 600 MeV of electron beam energy in the planar mode, to be tuned at 400 nm for 750 MeV in the planar mode and to be tuned at 300 nm for 750 MeV in the helical mode for the FEL, CSR and CHG experiment in the deep UV region. As the result, 84 mm of the period length was selected. The number of periods is 12 and the magnetic length will be about 1 m.

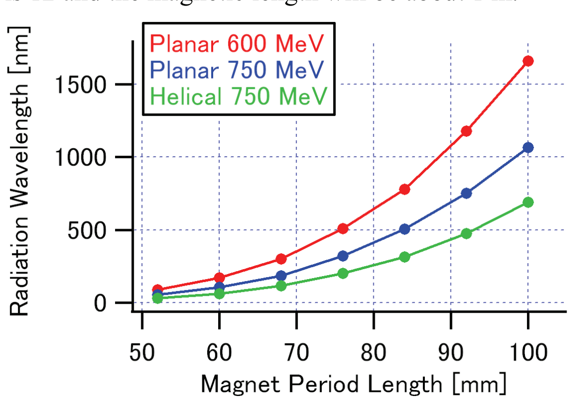

Figure 1: Calculated magnet period length vs. radiation wavelength in the modulator of the new undulator system.

DESIGN AND CONSTRUCTION OF VUV SPECTROMETER AND PREFOCUSING MIRROR SYSTEM

At the UVSOR-II, the CHG and FEL experiments have been performed by utilizing the existing FEL cavity. The FEL and CHs light are extracted through a quartz window downstream of the FEL cavity. A spectrometer for visible and deep UV light (C5094, Hamamatsu Photonics) has been employed to measure the spectrum of CHs and FEL. The light in the VUV region couldn't be measured due to the absorption of the window. In order to measure CHs in VUV range, a new VUV spectrum measurement system has been constructed.

Figure 2 and 3 illustrates configuration of the new VUV spectrum measurement system, which is directly connected to the FEL cavity. The VUV spectrometer (VMK-200-UHV, Vacuum & Optical Instruments) has a wavelength range of 50 ~ 300 nm which is limited by a concave replica grating (2400 grooves/mm, Pt coated, 4.5 of F number). The spectrometer is Seya-Namioka configuration of 64 degree of input-output angle and is compatible with an ultra-high vacuum environment. An electron multiplier tube (R5150MOD, Hamamatsu Photonics) is used as the photo detector, whose wavelength range is below 200 nm. The first dynode is BeO and the maximum gain is 10^9.

A prefocusing mirror system consists of a linear transfer apparatus with two optics holders and a steering mirror for injection to the VUV spectrometer. One of the two optics holders is attached with an aluminum flat mirror of 45 degree reflection to steer the emitted light from OK to the light diagnostic section shown in figure 4. The other optics holder is to attach a band-pass filter or a thin metallic filter. When the linear transfer apparatus is not inserted, the light is introduced to the VUV spectrometer by the steering mirror made of aluminum. This will be replaced with a SiC mirror in near future to suppress the fundamental of the intense Ti: Sapphire laser.

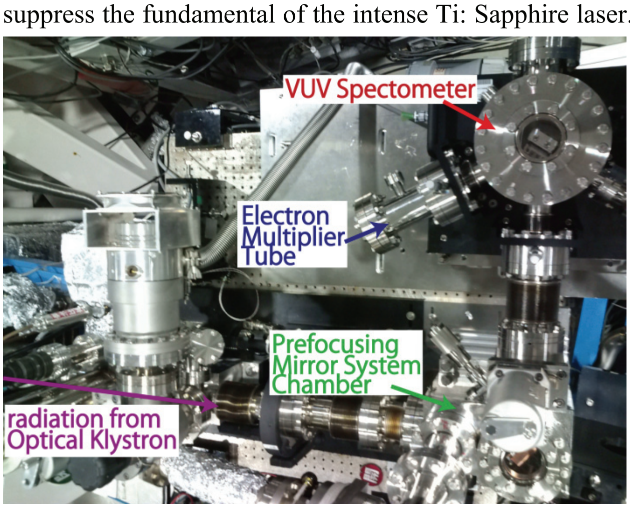

Figure 2: VUV spectrum measurement system downstream of the FEL cavity.

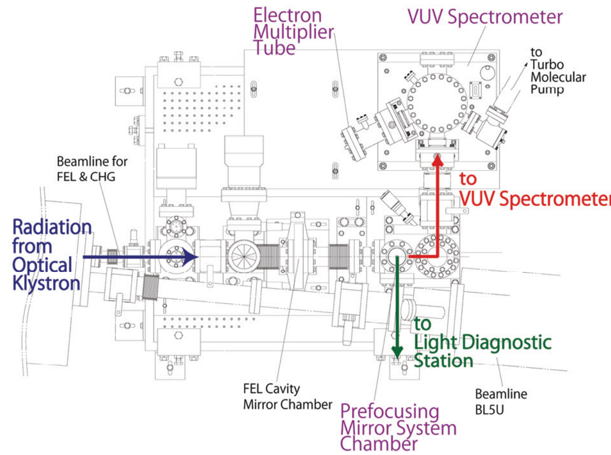

Figure 3: Layout of VUV spectrometer and prefocusing mirror system.

SPECTRUM MEASUREMT OF VUV CHG

Experimental Setup

Figure 4 illustrates the experimental setup of the CHG spectrum measurement. Femto-second Ti: Sapphire laser pulses generated by a mode-locked oscillator with external RF synchronism (Mira, COHERENT) and a regenerative amplifier (Legend, COHERENT) are injected with 1 kHz repetition rate from the upstream side of FEL cavity via a sapphire window with an antireflection coat. A focusing lens (f=5000 mm) made of BK7 is settled upstream of the sapphire window and the laser is focused in the modulator part of OK with a waist size of 0.43 mm.

The CHs generated by the interaction between the laser pulse and the electron beam are propagated to the light diagnostics section settled downstream of the FEL cavity or to the VUV spectrum measurement system.

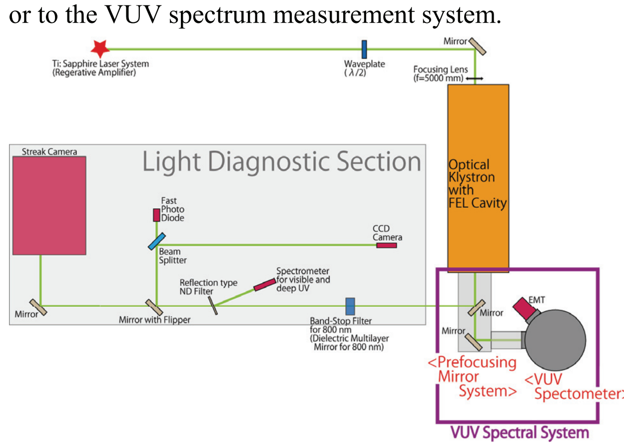

Figure 4: Schematic drawing of the experimental setup in CHG spectrum measurement experiment.

Experimental Parameters

Table 1 shows parameters of the electron beam, the OK and Ti: Sapphire laser in this experiment.

Table 1: Experimental Parameters

< Electron Beam >	
Beam Energy	600 MeV
Beam Current	~ 30 mA
Natural Bunch Length	87 ps
Natural Emittance	17.5 nm-rad
Energy Spread	3.4×10^{-4}
Revolution Frequency	5.64 MHz
Operation Mode	Single Bunch
<Optical Klystron>	
Period Length	110 mm
Number of Periods	9 + 9
K Value	6.32
<Ti: Sapphire Laser>	
Wavelength	801 nm
Bandwidth	11 nm
Pulse Energy	2.05 mJ
Pulse Duration	442 fs (chirped condition)
Repetition Rate	1 kHz

Experimental Methods

In the first step, the seed light, Ti: Sapphire laser pulse, is aligned to the electron beam spatially and temporally. The spatial alignment is carried out looking at the overlapping the SE (Spontaneous Emission) from the OK and the laser through the entire OK by using a position-movable CCD camera illustrated in figure 4. Next, the temporal alignment between the seed laser pulse and the electron beam is performed roughly by overlapping the SE pulse and the laser pulse by using a fast photo diode. Then, it is performed precisely by using a streak camera (C5680, Hamamatsu Photonics).

After the temporal-spatial overlap is achieved, the emission from OK is guided to the VUV spectrum measurement system. A light-pass alignment of the VUV spectrometer and the detector is performed by steering the 0-th order emission from the spectrometer, using the mirror in the prefocusing mirror system. Next, the grating in the spectrometer is set to the target wavelength and input-output horizontal slits of spectrometer are made narrower to 0.15 mm. Then, the output signal from the detector is measured by an oscilloscope triggered by the 1 kHz laser trigger signal. The acquired data are averaged 1280 times. After the acquirement, the grating is rotated by a 0.25 nm step. The procedure is iterated to sweep the spectral range desired to observe.

Experimental Results

In the first step, the SE from the OK was measured. The result is shown in Figure 5. In this figure, the reflectivity, the diffraction efficiency of optics and the quantum efficiency of detector are not corrected. It was confirmed that the spectra between 50 and 200 nm (5~15th harmonics) were clearly measured as expected from the specification. In the next step, CHs were measured. The CHs up to 8th order (100 nm) could be observed. In Figure 6 the spectra of the 5th harmonic of SE and CH are shown. The data clearly demonstrate that the bandwidth of CH was much narrower than that of SE.

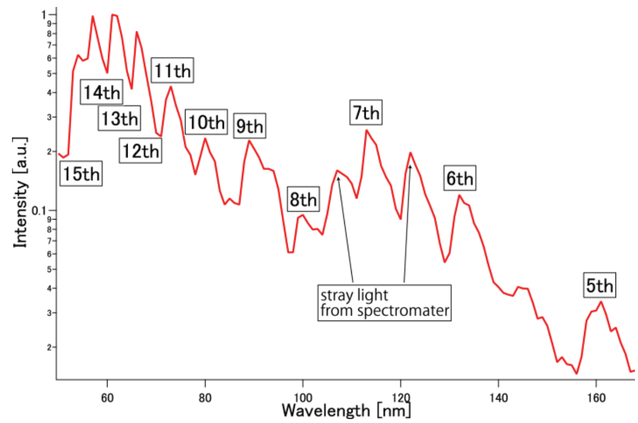

Figure 5: Spectrum of spontaneous emission in VUV range. Spectral resolution is limited by rotating pitch of the grating in the VUV spectrometer.

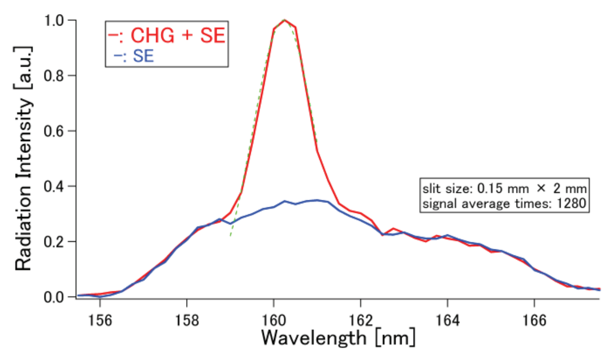

Figure 6: Spectra of spontaneous emission (SE; blue line) and coherent emission (CHG; red line) at the 5th harmonic.

SUMMARY AND FUTURE PLAN

As a part of the five year research project of coherent light source development based on the seeding technology, a new undulator system is under designing. The construction of the modulator part will start in this year. A VUV light diagnostic system has been constructed and is under testing. In the first preliminary experiment, we have successfully observed CHG spectra in the VUV range. More precise measurement will be done in the nearest future. A HHG (Higher Harmonics in Gas) system is under designing preparing for a HHG-seeding, which was successfully demonstrated on the linac-based FEL [9].

ACKNOWLEDGEMENT

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