CONSTRUCTION AND COMMISSIONING OF COHERENT LIGHT SOURCE EXPERIMENT STATION AT UVSOR

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Abstract

At UVSOR, coherent light source technologies, such as resonator free electron laser, coherent harmonic generation and coherent synchrotron radiation via laser modulation, had been developed by parasitically using an undulator and a beam-line normally used for photo-electron spectroscopy. Under Quantum Beam Technology Program of MEXT in Japan, we started constructing a new experiment station dedicated for the source developments. We created a new straight section by moving the beam injection line. An optical klystron was constructed and installed there. Two beam-lines, BL1U and BL1B, were constructed, the former of which is for free electron laser and coherent harmonic generation and the later for the coherent synchrotron radiation in the terahertz range. The seed laser system was reinforced and a new laser transport line was constructed. Generation of coherent synchrotron radiation by laser modulation was successfully demonstrated at the new station.

INTRODUCTION

At UVSOR, coherent light source technologies, such as resonator free electron laser, coherent harmonic generation and coherent synchrotron radiation via laser modulation, had been developed by parasitically using an undulator and a beam-line normally used for photo-electron spectroscopy [1-7]. Under Quantum Beam Technology Program of MEXT in Japan, we started constructing a new experiment station dedicated for the coherent light source developments. FY2010, we created a new straight section by moving the injection line. FY2011, a new optical klystron was constructed and installed. FY2009-2010, the seed laser system was moved and upgraded. FY2011, two beam-lines dedicated for coherent light source development were constructed. We describe the present status of the new coherent light source experiment station at UVSOR.

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CONSTRUCTION OF COHERENT LIGHT SOURCE EXPERIMENTAL STATION

The new experiment station of coherent light source is comprised of an optical klystron, a seed laser system and beam-lines.

Construction of Optical Klystron

FY2009-2010, the beam injection line was extended by adding three bending magnets and four quadrupole magnets, and the injection septum was relocated to a short straight section. The new straight section of 4 m became available for coherent light source development [8]. An optical klystron was constructed and installed in the new straight section. Previously, a conventional, optical klystron had been used for many years, in which the radiator, the modulator and the buncher were integrated in one undulator [9]. The new optical klystron consists of separated undulators, a modulator and a

Table 1: Optical Klystron Parameters

Magnetic configuration	Apple-II
Number of Periods	10 + 10
Period length	84 mm
Max. R_{56} of buncher (600 MeV)	67 μm
Overall length of buncher	442 mm

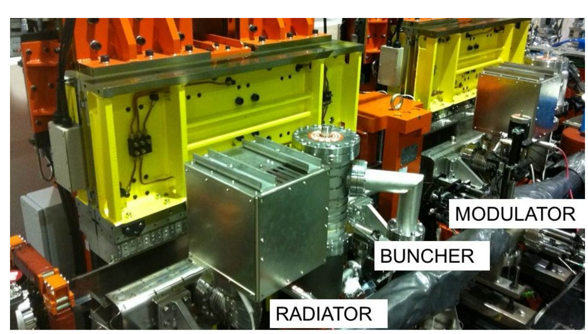

Fig. 1 : Optical klystron.

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radiator, and a buncher magnet in between (Fig. 1). The main parameters are summarized in Table 1. The magnetic configuration of the modulator and the radiator is Apple-II type. The fundamental wavelength of these undulators can be tuned at 800nm for the beam energy of 600 MeV, and 400 nm for 750 MeV, which corresponds to the fundamental and the second harmonic of the seed laser (Ti:Sa), respectively.

Upgrade and Relocation of Seed Laser System

The new experiment station was constructed at the opposite side of the storage ring to the old station. FY 2010, a multipath amplifier (COHERENT : Hidra-50) and a single-path amplifier (COHERENT : Legend-cryo) were added for a higher output power. The main parameters of the laser system are summarized in Table 2. FY2011, the laser system was moved to the new station and was installed in an air-conditioned laser hatch for better stability.

A new laser transport line was constructed. Fig. 2 shows the layout of the laser system and the laser transport line. The upper figure is the old layout and the lower is new one. The laser hatch in the new layout is located in the downstream side of the optical klystron. Therefore, the seed laser is transported to the upstream side of the optical klystron and then is injected to the ring. The overall length of the new laser transport line is about 20 m which is much longer than the in the old layout, 5 m. This transport line is mounted on the top of the

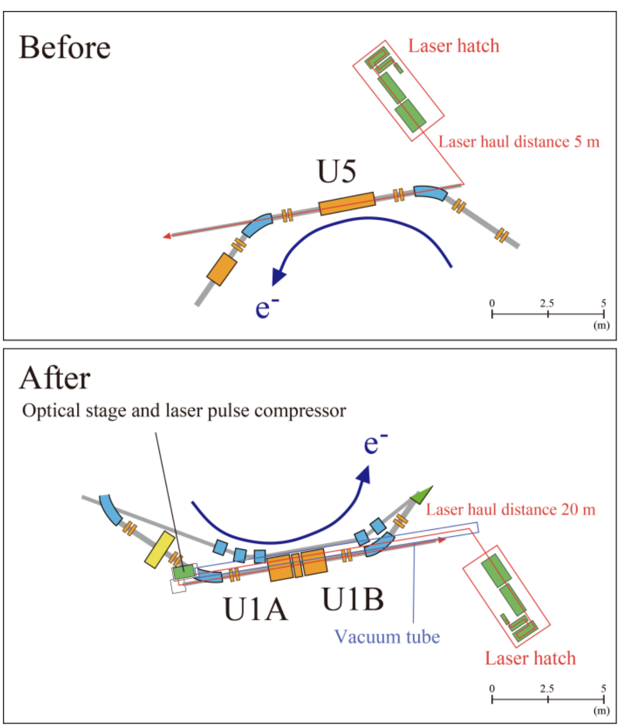

Fig.2 : Layout of the laser system and the laser transport line.

Table 2: Seed Laser Parameters

Legend-HE	Pulse energy	2.5 mJ/pulse
	Pulse duration	100 fs - 2 ps
	Repetition rate	1 kHz
Legend-cryo	Pulse energy	10 mJ/pulse
	Pulse duration	100 fs - 2 ps
	Repetition rate	1 kHz
Hidra-50	Pulse energy	50 mJ/pulse
	Pulse duration	100 fs - 2 ps
	Repetition rate	10 Hz

radiation shielding wall to avoid interference with the existing synchrotron radiation beamlines. However, the laser transport line is strongly affected by the fluctuation of the air, warm air from the accelerator power supplies and cool air from the outside. This air fluctuation causes laser pointing instability. In order to exclude the instability, we covered the laser transport line with aluminum pipe of 40 mm inside diameter. The both ends of the pipe are sealed with silica glass Brewster's windows and the inside is evacuated by a scroll pump.

We also considered the self-focusing and the damages on the optical components. First, we expand the beam diameter from 5 mm to 10 mm by adding two lenses at the position 2 m from the laser output point of in the laser hatch, one is concave (f = -75 mm) and another convex (f = 25 mm) of 1 inch diameter. The laser beam is transported as a parallel beam. In addition, we enlarged the laser pulse width before the transportation. The laser pulse is transported to an optical stage on the radiation shielding wall, where a pulse compressor is installed. The beam diameter is expanded from 5 mm to 10 mm before entering the laser pulse compressor that is an adequate beam diameter for the pulse compression. Afterwards, the seed laser is entered to an interaction point. This laser transport system can be used for the high power amplifiers such as Hidra-50 and Legend-cryo.

THz-CSR and VUV-CHG Experiment Beam-line

Fig.3 shows the layout of new beam-lines for THz-CSR (from 0.5 to 2.0 THz), VUV-CHG (to 9 eV or higher) and FEL (from 800 to 200nm). THz-CSR from a bending magnet (B1) at the downstream of the optical klystron is extracted by a magic mirror mounted inside of the vacuum duct. VUV-CHG from the optical klystron is extracted on the straight line. The beam-line, BL1U, will be used for the FEL experiment by installing an optical resonator. At BL1B, the coherent THz light is collected

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with the M0 magic mirror and transported to the end point with the M1, M2, M3 mirrors, Michelson interferometer, the M4 mirror. The M0 magic mirror was designed newly to have acceptance angle 244 × 80 $mrad^2$. M1 and M4 mirror is 45° toroidal mirror, M2 and M3 is plane mirror.

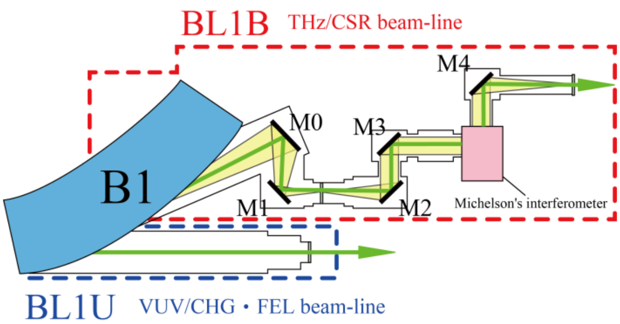

Fig. 3 : THz-CSR and VUV-CHG experiment beam-line.

COMMISSIONING OF COHERENT LIGHT SOURCE EXPERIMENT STATION

Observation of THz-CSR

For the test of the laser transport line, the optical klystron and beam-lines, we have carried out the THz-CSR generation by the laser modulation. THz-CSR was successfully observed at BL1B as shown in Fig. 4. In this observation, the electron energy was 600 MeV, the beam current was 1 mA in single bunch mode. An InSb hot electron bolometer (QMC Instruments : detection wavelength range 2～50 cm^{-1}) was used for the THz detection.

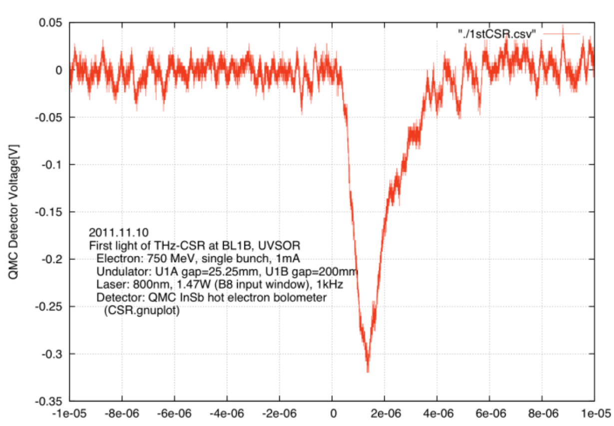

Fig. 4 : First THz-CSR signal observed by a bolometer

Observation of Spontaneous Emission Spectrum of Optical Klystron

The performance of the optical klystron was checked by observing the spontaneous emission spectrum. The result is shown in Fig. 5. The observation condition is that the electron energy was 600 MeV and the beam current was 5 mA in single bunch mode. The peak of the spectrum was in the vicinity of 800 nm. The fine spectral modulation was compared with the numerical calculation using the magnetic field data. They agreed well as taking into the account the hysteresis of the buncher magnet.

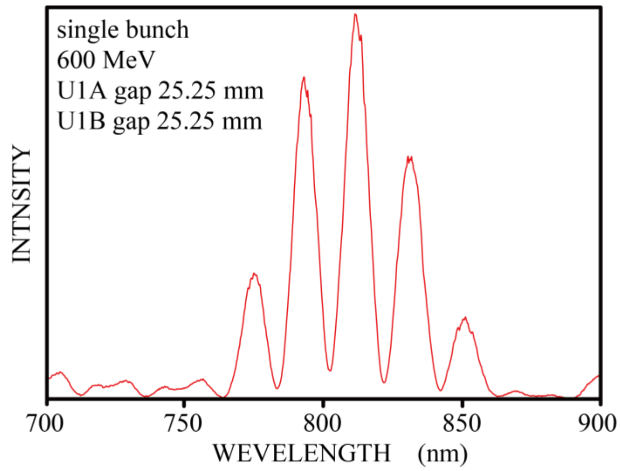

Fig. 5 : Spontaneous emission spectrum of optical klystron

SUMMARY AND PROSPECTS

The new experimental station for the coherent light source development has been successfully constructed at UVSOR. A few early experiments were also successful. Some user's experiments using THz-CSR and VUV-CHG will start in this fiscal year. We are preparing a seed laser system which is capable of producing the second and higher harmonics of the Ti:Sa laser using crystal and gas harmonic generation cell. The optical cavity for the resonator FEL will be installed within this year.

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