Light Source Developments by Using Relativistic Electron Beams

UVSOR Facility
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This project involves researches and developments on synchrotron light source, accelerator technologies, beam physics, free electron laser and related technologies. All these works are performed at UVSOR-II electron storage ring and its injector.

1. Developments on UVSOR-II Accelerators

After the major upgrade in 2003,[1)] the UVSOR-II electron storage ring and its injector has been continuously improved. In this year an undulator was constructed and installed as the fourth undulator in the facility (Figure 1). The magnetic configuration is so-called APPLE-II type. The undulator can provide VUV light of various polarizations (horizontal /vertical plane and right-/left-handed circular) to a beam-line dedicated for photo-electron spectroscopy.[2)] Its main parameters are summarized in Table 1. The commissioning was successful. The electron orbit movement caused by the magnetic field changes could be suppressed to smaller than 10 microns by a feed-forward system.

Figure 1. New variable polarization undulator for BL7U.

Table 1. Parameters of New Variable Polarization Undulator.

Configuration	APPLE-II	
Number of Periods	40	
Period Length	76 mm	
Pole Length	3.04 m	
Pole Gap	24–200 mm	
Max. K Parameter	5.4	(horizontal)
	3.6	(vertical)
	3.0	(helical)

The beam lifetime of UVSOR-II is severely limited by Touschek effect due to its low emittance and low electron energy. The electron beam should be re-filled every 6 hours. To solve the lifetime problem eternally, we are preparing for top-up injection scheme. In this scheme, the electron beam is re-filled with a short interval, typically one minutes, to keep the beam current almost constant.

Figure 2. New magnet power supply for the booster synchrotron.

To realize the top up injection, the maximum operating energy of the injector and the beam transport line had to be increased from 600 MeV to 750 MeV. In this year, the magnet power supplies of the booster synchrotron and the beam transport line were replaced. The new power supplies are capable of exciting the existing magnets sufficiently strong for the 750 MeV operation. The new power supplies were successfully commissioned. Soon, we have succeeded in accelerating electrons up to 750 MeV on the booster synchrotron and also in transporting those electrons to the storage ring. In July, we have started the full energy injection in the user runs. After some improvements on the beam transport efficiency and reinforcements on the beam monitor system and the safety interlock system, we will start testing the top-up injection soon.

2. New Method to Measure Touschek Lifetime

Touschek effect is a dominant beam loss mechanism in a low emittance and low energy storage ring such as UVSOR-II. It is difficult to measure the beam loss rate due to Touschek effect separately from those due to other effects such as scattering by residual gas molecules. We have developed a new method to measure the Touschek lifetime separately from other process.[3] The method is based on the single photon counting technique. By measuring the change of the relative intensities of two successive bunches, we can estimate the Touschek lifetime independently.

3. Storage Ring Free Electron Laser

The low emittance and the high peak current of UVSOR-II make the free electron laser oscillate in the deep UV region with high output power exceeding 1W.[4] At present the shortest wavelength is 215 nm. Lasing around 200 nm seems promising. Users' experiments using this high power and tunable laser beam are in progress.[5]

The interaction between the electron beam and the laser pulse in the optical cavity produce strong electron bunch heating. This process limits the output power of the free electron laser. This heating process and its effects on the lasing were experimentally investigated.[6]

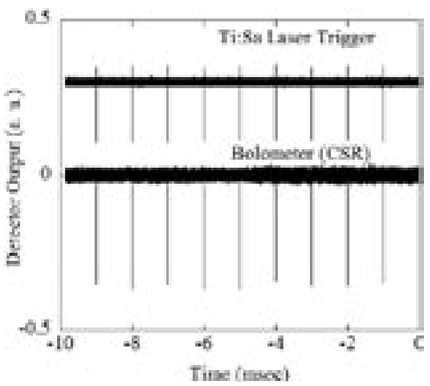

Figure 3. Coherent terahertz radiation induced by laser injection.

4. Terahertz Coherent Synchrotron Radiation by Laser-Electron Interaction

We have developed a system to create micro-density structure on electron bunches circulating in the storage ring.[7] The density structure, whose typical scale is ranging from a few hundred femtoseconds to a few picoseconds, is created through the interaction between the ultra-short laser pulses and electron bunches. Such electron bunches emit coherent synchrotron radiation in terahertz region, as shown in Figure 3. It was successfully demonstrated that, by controlling the shape of the micro-structure, the spectra of the coherent radiation could be controlled.

5. Coherent Harmonic Generation

Coherent harmonic generation is a method to produce coherent harmonics of laser light by using relativistic electron beam. The laser-electron interaction in an undulator produces density modulation of a period of laser wavelength. When the energy modulation is sufficiently larger than the natural energy spread, the density modulation contains higher harmonic component of the laser wavelength. Such an electron bunch emits coherent harmonics of the injected laser. We have successfully observed the coherent third harmonics of Ti:Sa laser.[8] Optical properties of the coherent harmonic radiation were experimentally investigated.

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