Light Source Developments by Using Relativistic Electron Beams

UVSOR Facility
Division of Advanced Accelerator Research

KATOH, Masahiro	Professor
ADACHI, Masahiro	Assistant Professor
SHIMADA, Miho	IMS Fellow*
TANIKAWA, Takanori	Graduate Student
KOIKE, Masashi	Graduate Student†
SUZUKI, Yasuhiro	Graduate Student†
YOSHIDA, Mitsuhiro	Graduate Student†
NAGATANI, Atsumune	Graduate Student†
FURUI, Yuta	Graduate Student†

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

1. Developments on UVSOR-II Accelerators

Even after the major upgrade in 2003,[1)] the UVSOR-II electron storage ring and its injector have been continuously improved. In these years, the ring has been operated with a small emittance of 27 nm-rad, that enables four undulators to produce highly brilliant synchrotron radiation in the VUV region. This small emittance, on the other hand, makes the beam lifetime short through the intrabeam scattering, so called Touschek effect. To solve this 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 minute, to keep the beam current almost constant.

To realize the top up injection, the maximum operating energy of the injector and the beam transport line was increased from 600 MeV to 750 MeV, by reinforcing the magnet power supplies. Since July, 2007, we have been operating the ring with full energy injection in the user runs. Generally, during injections, the beam loss rate becomes higher. An interlock system for the radiation safety is being developed, which limits the number of injected electrons. Test operation of the top-up scheme will be started in September, 2008.

2. Storage Ring Free Electron Laser

The low emittance and the high peak current of UVSOR-II enable the free electron laser to oscillate in the deep UV region with high output power exceeding 1W.[2)] In 2007, the shortest wavelength has reached 199 nm. Lasing around 190 nm will be tried soon.

Several users' experiments using this high power and tunable laser beam in the deep UV are in progress. However, during the high power operation of the free electron laser, a rapid change of the output power was observed, which was presumably due to the thermal deformation of the mirrors of the optical cavity. A feedback system is being developed to stabilize the output power.

Table 1. Parameters of UVSOR-II Free Electron Laser.

Electron Energy	600–750 MeV
Wave Length	800–199 nm
Spectral Band Width	~10^{-4}
Polarization	Linear/Circular
Repetition Rate	11.26 MHz
Average Output Power	~1 W

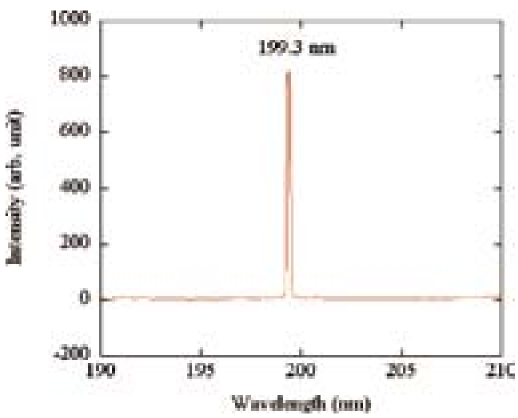

Figure 1. Successful lasing at 199.3 nm of UVSOR-II Free Electron Laser.

3. Terahertz Coherent Synchrotron Radiation by Laser-Electron Interaction

When an electron bunch has a micro-structure on its longitudinal density distribution whose typical scale is close to the radiation wavelength, the synchrotron radiation fields

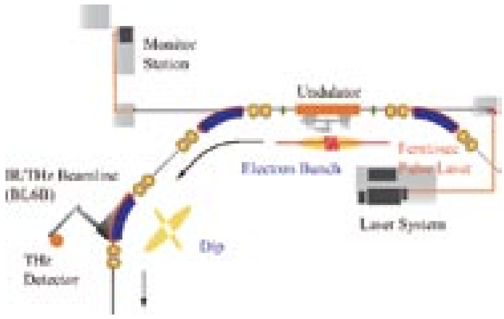

Figure 2. Laser Modulation System at UVSOR-II.

emitted by each electron are linearly accumulated and the total radiation power is proportional to the square of the number of the electrons. This is called coherent synchrotron radiation (CSR).

We have developed a system to create micro-density structure on electron bunches circulating in the storage ring, as shown in Figure 2.[3] Laser pulses are injected to the ring and interact with the electron beam in an undulator. The electrons lose or gain its energy depending on the phase to the laser field. As the result, energy modulation is created on the electron bunch. As the bunch is proceeding in the ring, the energy modulation is converted to a density modulation. By controlling the laser pulse shape, we can create various density structures. When we use a sub-picosecond laser pulse, we can produce a short dip structure. When we use a amplitude modulated laser pulse, we can produce periodic density structure. In the former case, broadband coherent terahertz radiation was produced.[3] In the latter case, quasi-monochromatic coherent terahertz radiation was produced, as shown Figure 3.[4] This was the first experiment in which monochromatic synchrotron radiation was produced in a uniform magnetic field.

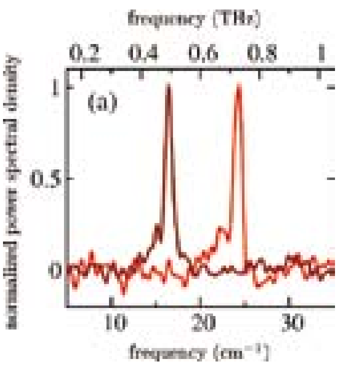

Figure 3. Quasi-monochromatic synchrotron radiation emitted in a uniform magnetic field.

4. 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.[5] Optical properties of the coherent harmonic radiation were experimentally investigated.

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* Present Address; High Energy Accelerator Research Organization (KEK), Tsukuba, 305-0801
† carrying out graduate research on Cooperative Education Program of IMS with Nagoya University