Light Source Developments by Using Relativistic Electron Beams

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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

After the major upgrade in 2003,[1)] the UVSOR-II electron storage 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 intra-beam scattering, so called Touschek effect. To solve this lifetime problem eternally, we have been preparing for top-up injection. In this operation scheme, electron beam is re-filled with a short interval, typically one minute, to keep the beam current almost constant.

In 2008, we have started test operation with the top-up injection on every Thursday night. The electron beam is kept at 300 mA for 12 hours, as shown in Figure 1. We have observed instability on the injection efficiency, which causes gradual reduction of the beam current. We have found that the instability is mainly caused by some drifts of the electron energy from the linear accelerator and also of the high voltage of the injection septum electrode of the booster synchrotron. A feedback system is being developed. It has been demonstrated that this system could stabilize the injection efficiency.

In 2009, we have successfully demonstrated a top-up operation in single bunch mode. Short electron pulse produced by the electron gun was successfully accelerated and transferred to the storage ring. This new operation scheme drastically improves not only the performances of the single bunch users' runs but also the free electron laser and other coherent light sources as described below.

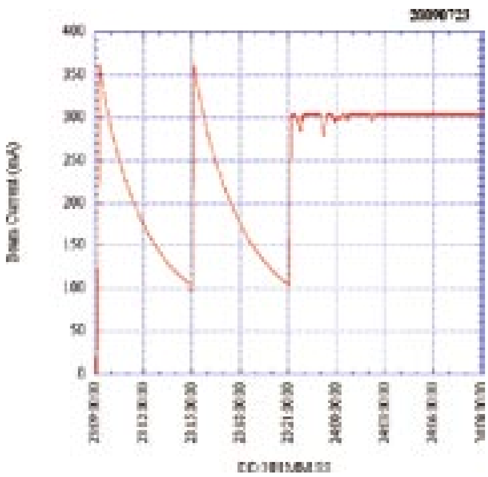

Figure 1. Beam current history in the top-up test operation. After operated for 12 hours in the ordinary operation mode, the ring was operated for about 12 hours in the top-up mode as keeping the beam current at 300 mA.

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] During the high power operation of the free electron laser, a rapid change of the output power was observed, which was partly due to the decrease of the electron beam intensity and partly due to the thermal deformation of the mirrors of the optical cavity. To solve this problem, a feedback system has been developed, which control the mirror alignment as monitoring the FEL output power. It was successfully demonstrated to stabilize the output power.[3] In adding to this, FEL operation with top-up injection was tried. We have succeeded in lazing for several hours as keeping the output power almost constant.

3. 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.[4] By controlling the laser pulse shape, we can create various density structures such as a short dip structure or periodic structure. In the former case, broadband coherent terahertz radiation was produced.[4] In the latter case, quasi-monochromatic coherent terahertz radiation was produced.[5]

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 the laser wavelength. When the energy modulation is sufficiently larger than the natural energy spread, a density modulation is created which 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.[6] We have demonstrated a generation of variable polarization coherent harmonics using a variable polarization undulator.[7]

The coherent radiation experiments using laser has come into a new phase as supported by the Quantum Beam Technology Program of JST/MEXT. In the new research project, a part of the storage ring was reconstructed. By moving the injection point to anther short straight section, we will have a new long straight section dedicated for the coherent radiation experiments. A new undulator system is under designing. The laser system is being upgraded. A VUV diagnostic system is under preparation.

4. Developments of Accelerator Technologies

The stabilization of the electron orbit of the storage ring is important to provide stable synchrotron radiation to users. At UVSOR-II, a drift of the orbit in a time scale of minutes to hours has been observed. An orbit feedback system has been developed which observes the orbit drift and control the orbit steering magnets in the ring. It was successfully demonstrated that the system can suppress the orbit drift of a few hundred of microns to a few tens of microns.[8]

A 5T super-conducting bending magnet has been designed for a 1.2 GeV synchrotron light source to produce hard X-rays planned at Nagoya University. The bending angle is 12 degree and the peak magnetic field is above 5T. The pole shape was optimized by using a 3D simulation to provide X-rays to three beam-lines separated by a few degrees.

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