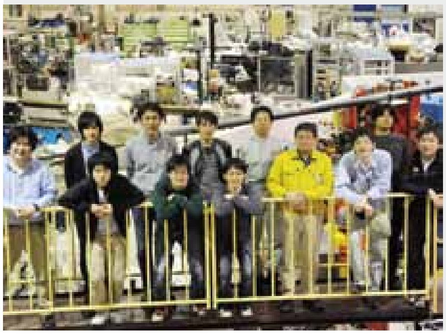
Light Source Developments by Using Relativistic Electron Beams

UVSOR Facility
Division of Advanced Accelerator Research



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This project involves researches and developments on synchrotron light source, free electron laser, beam physics and their related technologies. Most of these works are performed at the UVSOR Facility.

1. Developments on UVSOR Accelerators

In these years, we have been preparing for a new injection method called top-up injection at the UVSOR-II electron storage ring.[1] In this operation scheme, electron beam is re-filled with a short interval, typically one minute, to keep the beam current approximately constant. It was expected that synchrotron radiation experiments under more stable condition would be possible. In July 2010, we have started operating UVSOR-II with the top-up injection fully in the users beam time, which is usually 12 hours a day. The stability of the injection efficiency is essentially important for the stable top-up operation. However, some drifts of the pulse power supplies for the injector and the beam transport system in various time scales, minutes to hours, made the injection efficiency unstable. We have developed a feedback system based on digital oscilloscopes and PC's, and have succeeded to stabilize them.[2]

In spring 2010, we have installed a new undulator at a straight section created last year by moving the injection point to another short straight section, as shown in Figure 1. The undulator is APPLE-II type and will be used as a modulator in the coherent synchrotron radiation experiments as described later. Another undulator, which will work as a radiator producing coherent harmonic radiation, will be installed in this autumn.

Figure 1. New APPLE-II type undulator just after the installation in spring, 2011. Another undulator will be installed in autumn 2011. Both of them will be used to produce coherent synchrotron radiation.

We have designed a new magnetic lattice for the storage ring, in which the emittance could be reduced by factor of about 2. An upgrade program has been funded based on this design. Eight bending magnets, which have been used for more than 25 years, would be replaced with combined-function ones. The design and construction of new magnets are in progress. A pulse sextupole magnet system was designed and is under construction, which will be used to realize more sophisticated beam injection scheme, in which the electron beam movement during the injection would be reduced significantly not to disturb users experiments. A new 1m long in-vacuum undulator has been designed and is under construction, which will be installed at the last straight section reserved for insertion devices. This upgrade would make UVSOR-II the world brightest low energy synchrotron light source. The reconstruction work would be completed in summer, 2012.

2. Light Source Developments

We have demonstrated that coherent synchrotron radiation of various properties could be generated in an electron storage ring by using an external laser source.[3–5] This research is supported by the Quantum Beam Technology Program of JST/MEXT. Under this support, a new experimental station is being constructed.[6] A new undulator was installed. The upgrade of the laser system was completed. Two new beamlines dedicated to the coherent lights in the VUV range and in the THz range is under construction.[7] The experiments in the new site will be started this winter.

Coherent harmonic generation is a method to produce coherent harmonics of laser light by using relativistic electron beam. We have succeeded in producing the coherent harmonics of Ti:Sa laser in the VUV range, up to 9th harmonic.[8)] We observed saturation of the coherent radiation intensity as increasing the laser power. After the saturation, the intensity of the coherent harmonics oscillates with the laser intensity. We have explained this phenomenon as the result of the micro-bunch formation in the over-bunching regime.[9)]

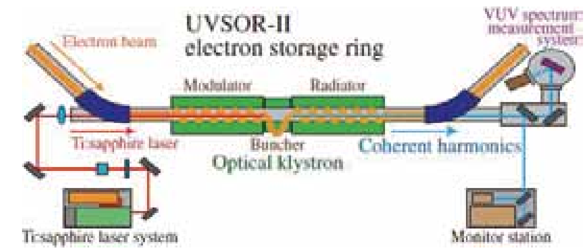

Figure 2. Experimental set-up of Coherent Harmonic Generation at UVSOR-II.

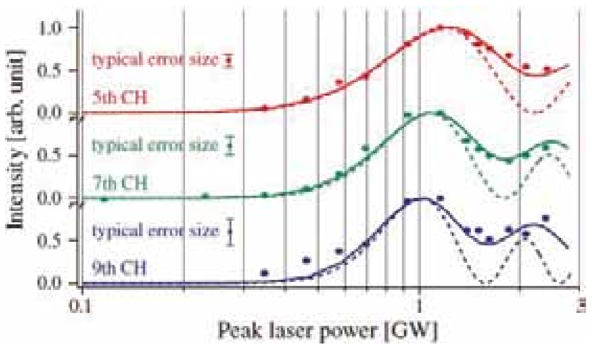

Figure 3. Coherent Harmonic Radiation Intensity vs. Injected Laser Power.

Laser Compton scattering is a technique to produce a quasi-monochromatic X-rays and gamma-rays by using a relativistic electron beam and laser. The laser photons are Compton back-scattered by the high energy electrons and are converted to gamma-rays. The electron beam circulating in the storage ring is very thin in the vertical direction. The typical diameter is in the order of 10 microns. By injecting laser light from the vertical direction to the beam, it is possible to produce ultra-short, quasi-monochromatic, energy tunable, polarization variable gamma-ray pulses. We have already confirmed the tunability of the energy and the polarization.[10)] Techniques to measure the pulse width is under development.

3. Developments of Accelerator Technologies

We have observed that operation of the undulators at UVSOR-II affects the beam lifetime and the injection efficiency and sometimes causes problems on the top-up operation. We consider that this is due to the non-linear magnetic field produced by the undulators. To reduce these effects, we are developing multi-wire correction coil system. The coil consists of tens of thin wires on the beam duct at the undulator and produces various correction fields depending on the electric current of each wire. Based on the preliminary experiment last year, we have fabricated a coil with 14 flat wires, in collaboration with Equipment Development Center. It was confirmed that the coil could correct the non-linear field produced by the undulators.[11)]

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