RESEARCH FACILITIES

UVSOR Synchrotron Facility

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Outline of the UVSOR Synchrotron Facility

Since the first light in 1983, the UVSOR Synchrotron Facility has been successfully operated as one of the major synchrotron light sources in Japan. After the major upgrade of accelerators in 2003, UVSOR Synchrotron was renamed to UVSOR-II Synchrotron and became one of the world’s brightest low energy synchrotron light sources. In 2012, it was upgraded again and has been renamed to be UVSOR-III Synchrotron. The brightness of the electron beam was increased further. Today, six undulators are installed in total, and the storage ring, that is approximately 53 meters in circumference, is regularly operated in the top-up mode, in which the electron beam current is kept constant, irrespective of multi bunches or single bunch.

The UVSOR accelerator complex consists of a 15 MeV injector LINAC, a 0.75 GeV booster synchrotron, and a 0.75 GeV storage ring. The magnet lattice of the storage ring consists of four extended double-bend cells with distributed dispersion function. The storage ring is normally operated under multi-bunch mode with partial filling. The single bunch top-up operation for time-resolved measurements or low current measurements is also conducted for two weeks per year.

Six undulators and eight bending magnets provide synchrotron radiation (SR). The bending magnet, its radius of 2.2 m, produces SR with the critical energy of 425 eV. There are eight bending magnet beamlines (Table 1). Three of the six undulators are in-vacuum soft X-ray (SX) linear-polarized undulators (BL3U, BL4U, and BL6U) and the other three are vacuum/ultraviolet (VUV/XUV or EUV) circular-polarized undulators (BL1U, BL5U, and BL7U). In total, fourteen beamlines are now operating. Two beamlines, BL1U and BL6U, are so-called “in-house beamlines,” which are dedicated to strategic projects conducted by internal IMS groups in tight collaboration with domestic and foreign scientists. Other twelve beamlines are so-called “public beamlines,” which are open to scientists from universities, governmental research institutes, public and private enterprises, and also to overseas scientists. Since 2018, BL1U is partly opened for using as public beamline.

From the viewpoint of photon energies, we have one SX station equipped with a double-crystal monochromator, seven SX stations with a grazing incidence monochromator, three VUV stations with a normal incidence monochromator, two IR/THz stations equipped with Fourier transform interferometers and one beamline for light source development without any monochromators.

Table 1. List of beamlines at UVSOR-III Synchrotron.

<table>
<thead>
<tr>
<th>Beamline</th>
<th>optics</th>
<th>Energy Range (eV)</th>
<th>Targets</th>
<th>Technique</th>
</tr>
</thead>
<tbody>
<tr>
<td>BL1B</td>
<td>Multi-crystal</td>
<td>3-1000</td>
<td>Solid</td>
<td>Reflection/ Transmission</td>
</tr>
<tr>
<td>BL6B</td>
<td>Single-crystal</td>
<td>3-20</td>
<td>Solid</td>
<td>Absorption</td>
</tr>
<tr>
<td>BL7B</td>
<td>3-m normal-incidence</td>
<td>3-30</td>
<td>Solid</td>
<td>Absorption</td>
</tr>
<tr>
<td>BL3B</td>
<td>3-m grazing-incidence</td>
<td>3-30</td>
<td>Solid</td>
<td>Absorption</td>
</tr>
<tr>
<td>BL2B</td>
<td>Single-crystal</td>
<td>800-1800</td>
<td>Solid</td>
<td>Polarization</td>
</tr>
<tr>
<td>BL4B</td>
<td>Single-crystal</td>
<td>20-2000</td>
<td>Gas, Solid</td>
<td>Polarization</td>
</tr>
<tr>
<td>BL2A</td>
<td>Double-crystal</td>
<td>N/A</td>
<td>Solid</td>
<td>Reflection/Transmission</td>
</tr>
<tr>
<td>BL1U</td>
<td>Triple-crystal</td>
<td>30-3000</td>
<td>Gas, Solid</td>
<td>Interferometry</td>
</tr>
<tr>
<td>BL7U</td>
<td>Single-crystal</td>
<td>30-3000</td>
<td>Solid</td>
<td>Interferometry</td>
</tr>
<tr>
<td>BL5U</td>
<td>Laser interferometry</td>
<td>20-2000</td>
<td>Solid</td>
<td>Interferometry</td>
</tr>
<tr>
<td>BL6U</td>
<td>Single-crystal</td>
<td>20-2000</td>
<td>Solid</td>
<td>Interferometry</td>
</tr>
<tr>
<td>BL4U</td>
<td>Interferometry</td>
<td>50-2000</td>
<td>Gas, Solid</td>
<td>Interferometry</td>
</tr>
<tr>
<td>BL3U</td>
<td>Single-crystal</td>
<td>60-800</td>
<td>Solid</td>
<td>Interferometry</td>
</tr>
</tbody>
</table>

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Recent Developments

The UVSOR accelerators have been operated for 37 years. We have been upgrading and replacing the machine components, such as magnet power supplies or RF power amplifiers, to continue the stable operation. In these years, troubles occurred on some core components, such as the vacuum chambers and the magnets. We are carefully planning their replacements with short shutdown periods and under the limitation of the facility budget.

On the other hand, we are also putting effort into setting up state-of-the-art experimental stations that takes advantage of our unique beamline performance. A new photoelectron momentum microscope (PMM) station for 3D momentum-resolved photoelectron spectroscopy is constructed at beamline BL6U. The PMM, a combination of projection-type electron analyzer and photoelectron microscope, simultaneously realizes a microscope function for magnifying and observing minute parts of complicated-structured samples with element selectivity and a spectroscopy function for visualizing electron behavior (momentum) that determines the electronic properties of a functional materials. Microscopy with a spatial resolution of 50 nm and photoelectron spectroscopy (field of view: 2 µm) with energy/momentum resolutions of 20 meV / 0.01 Å\(^{-1}\) at 9 K are successfully demonstrated (Figure 1). The momentum microscope opens the door to direct observation of the Fermi surface and band structure of µm-sized targets such as surface atomic sites, thin films and interfaces, molecular adsorbates, and polycrystals, which was difficult with conventional electron energy analyzers.

Research Highlights

One of the highlights of the UVSOR research activities this year is the discovery of the ability of synchrotron radiation to perform coherent control.\(^1\)\(^,\)\(^2\) Coherent control is a method to manipulate the populations and pathways in matters by light and is currently one of the most attractive research areas in optical physics and photochemistry. Lasers have been considered as unique light source enabling one to perform coherent control. Synchrotron radiation is usually considered as being of poor temporal coherence, therefore nobody thought that it has a hidden capability of coherent control. However, researchers have demonstrated the capability of synchrotron radiation on the coherent control using the double undulator system which is capable of producing light pulses with tailored waveform.

Figure 2 shows the schematic view of the double undulator system and the result of population control in the photoexcitation of helium atoms. The double undulator generated pairs of radiation wave packets in the extreme ultraviolet wavelength. The duration of each wave packet pair was a few femtoseconds and the time delay between them can be adjusted with attosecond precision. The individual excited states can be controlled by adjusting the interference between the electron wave packets produced in the atomic system. Moreover, the researchers succeeded also in controlling the shape and orientation of the electron cloud in a helium atom, formed as a coherent superposition state, by tuning the time delay between the circularly polarized radiation wave packets on the attosecond level.

In contrast to standard laser technology, there is no technical restriction on the extension of this method to shorter wavelengths. This new capability of synchrotron radiation not only advance the frontier of coherent control technology, but may also open up new applications in the development of functional materials and electronic devices in the future.

References