UVSOR Synchrotron Facility

KERA, Satoshi	Director, Professor
MATSUI, Fumihiko	Professor
KATOH, Masahiro	Project Professor (Hiroshima Univ.)
TANAKA, Kiyohisa	Associate Professor
TAIRA, Yoshitaka	Associate Professor
OHIGASHI, Takuji	Associate Professor (Cross Appt.)
KANEYASU, Tatsuo	Associate Professor (SAGA-LS)
ARAKI, Tohru	Senior Researcher
IWAYAMA, Hiroshi	Assistant Professor
SUGITA, Kento	Assistant Professor
KATAYANAGI, Hideki	Research Associate
HAGIWARA, Kenta	IMS Fellow
MATSUDA, Hiroyuki	Post-Doctoral Fellow
SALEHI, Elham	Post-Doctoral Fellow
HAYASHI, Kenji	Engineer (Unit Leader)
NAKAMURA, Eiken	Chief Engineer
MAKITA,Seiji	Engineer
SAKAI, Masahiro	Chief Technician
YANO, Takayuki	Chief Technician
OKANO, Yasuaki	Chief Technician
TESHIMA, Fumitsuna	Chief Technician
KONDO, Naonori	Chief Technician
YUZAWA, Hayato	Chief Technician
OTA, Hiroshi	Technician
SHIMIZU, Kohei	Technician
HORIGOME, Toshio	Technical Fellow
MINAKUCHI, Aki	Technical Fellow
MIZUKAWA, Tetsunori	Technical Fellow
SUGIMOTO, Yasunobu	Technical Fellow
YAMAZAKI, Jun-ichiro	Technical Fellow
ISHIHARA, Mayumi	Secretary
KAMO, Kyoko	Secretary
YOKOTA, Mitsuyo	Secretary

Outline of the UVSOR Synchrotron Facility

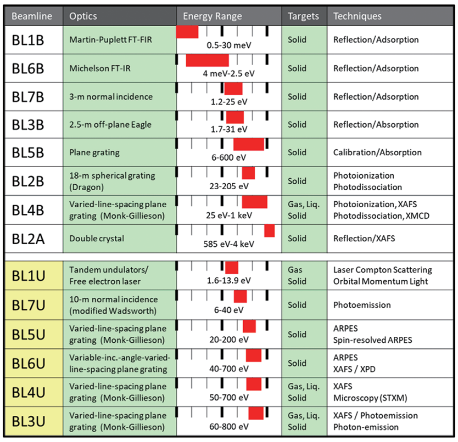
Since the first light in 1983, the UVSOR Synchrotron Facility has been successfully operated as one of the major synchrotron light sources in Japan. After the major upgrade of accelerators in 2003, UVSOR Synchrotron was renamed to UVSOR-II Synchrotron and became one of the world's brightest low energy 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 *ca.* 53 meters in circumference, is regularly operated in the top-up mode, 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 single bunch top-up operation (176 ns, 5.6 MHz) 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/extreme ultraviolet (VUV/XUV or EUV) circular-polarized undulators (BL1U, BL5U, and BL7U). 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. After each development, the in-house beamline will be opened for use as a 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.



Beamline	Optics	Energy Range	Targets	Techniques
BL1B	Martin-Puplett FT-FIR	0.5-30 meV	Solid	Reflection/Adsorption
BL6B	Michelson FT-IR	4 meV-2.5 eV	Solid	Reflection/Adsorption
BL7B	3-m normal incidence	1.2-25 eV	Solid	Reflection/Adsorption
BL3B	2.5-m off-plane Eagle	1.7-31 eV	Solid	Reflection/Absorption
BL5B	Plane grating	6-600 eV	Solid	Calibration/Absorption
BL2B	18-m spherical grating (Dragon)	23-205 eV	Solid	Photoionization Photodissociation
BL4B	Varied-line-spacing plane grating (Monk-Gillieson)	25 eV-1 keV	Gas, Liq. Solid	Photoionization, XAFS Photodissociation, XMCD
BL2A	Double crystal	585 eV-4 keV	Solid	Reflection/XAFS
BL1U	Tandem undulators/ Free electron laser	1.6-13.9 eV	Gas Solid	Laser Compton Scattering Orbital Momentum Light
BL7U	10-m normal incidence (modified Wadsworth)	6-40 eV	Solid	Photoemission
BL5U	Varied-line-spacing plane grating (Monk-Gillieson)	20-200 eV	Solid	ARPES Spin-resolved ARPES
BL6U	Variable-inc.-angle-varied-line-spacing plane grating	40-700 eV	Solid	ARPES XAFS / XPD
BL4U	Varied-line-spacing plane grating (Monk-Gillieson)	50-700 eV	Gas, Liq. Solid	XAFS Microscopy (STXM)
BL3U	Varied-line-spacing plane grating (Monk-Gillieson)	60-800 eV	Gas, Liq. Solid	XAFS / Photoemission Photon-emission

Inter-University and International Collaboration Programs

A variety of molecular science and related subjects have been carried out at UVSOR Synchrotron Facility by IMS and external/overseas researchers. The cumulative total number of visiting researchers (person-days) per year tops > 5000, who come from > 60 different institutes. International collaborations are also pursued actively, and the number of visiting foreign researchers reaches ~70. UVSOR-III Synchrotron invites new/continuing research proposals twice a year. The proposals both for academic and public research (charge-free) and for private enterprises (charged) are acceptable. The fruits of the research activities using UVSOR-III Synchrotron are published as the UVSOR ACTIVITY REPORT annually.

Recent Developments

UVSOR has several angle-resolved photoemission spectroscopy (ARPES) beamlines and users can choose proper beamline according to their purpose. At BL7U, users can perform high-energy resolution measurements with extremely low energy of photons (6 eV~) using low-temperature 6-axis manipulator with sample temperature 4 K.

For a long time, when changing photon energies in this beamline, users themselves had to optimize the beamline by using motors to adjust the mirror angle of the beamline to maximize the photon flux at the endstation. This was due to the lack of reproducibility of the position and angle of the mirrors by the motors. Recently, we performed ray-trace simulations and found that the mirror angle at which the photon flux is maximized is optically using the edge of the diffraction grating, which does not yield the correct photon energy. In fact, for some users, there was a difference of up to 500 meV between the actual photon energy and the set photon energy. This was a major problem for a high-energy-resolution beamline discussing a 1 meV superconducting gap, and made it difficult to perform automatic photon energy dependent ARPES measurements.

Therefore, we reviewed the mechanics of mirror position and angle control and introduced new motor control settings accordingly, and succeeded in precise control of photon energy with excellent reproducibility. As a result, we succeeded in setting the optically correct mirror angle, which enabled us to provide users with the correct photon energy within ±3 meV over the entire photon energy range available at BL7U ($h\nu$ = 6–40 eV). Users no longer need to adjust the mirror angle themselves. It should be noted that while many synchrotron radiation facilities have problems with photon energy reproducibility and energy drift with time at the endstations due to cooling problems of mirrors and changes in the electron trajectory of the accelerator and so on, BL7U is a normal-incident beamline, which is less susceptible to these problems. This is another reason why we were able to control photon energy so precisely. Having achieved accurate photon energy control, we plan to introduce various automated ARPES measurements in the future, including automatic photon energy dependent measurements.

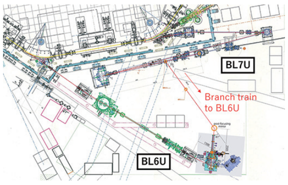


Figure 1. Schematic view of beamlines BL7U and BL6U. The low-energy photon of BL7U will be introduced to BL6U for multi-modal experiments.

Reserch Highlights

We started to develop resonant soft X-ray scattering (RSoXS) at BL3U. RSoXS can be used similarly to small angle X-ray scattering (SAXS) and can provide information on samples' mesoscopic structure (1 ~ 100 nm). Due to the resonance process, RSoXS have selectivities of elements, functional groups, and molecular orientations. In particular, since SX regions include K-edge energies of light elements such as carbon, nitrogen, and oxygen, RSoXS will be a powerful tool to investigate soft matter such as liquid-crystal and polymer materials, mainly consisting of light element atoms. Wang group in ALS recently applied the carbon K-edge RSoXS method to investigate polymer blends, block copolymers, organic bulk heterojunction solar cells, and polymeric transistors, as all of which the complex refractive indices of the different components have distinct energy and polarization dependences for X-ray energies near the edge.

As a first experiment, RSoXS was applied to the helical filamentary phase of liquid-crystals, a twist-bend liquid-crystal phase. As shown in Figure 2(a), the structure has spatial periodicity without electron density modulation. The sample is sandwiched with SiN and isolated from the vacuum. In addition, the sample temperature was controlled from 0 to 150 °C, and the structure was analyzed in various phases.

Figure 2(b) shows typical scattering RSoXS images at carbon K edge for helical nanofilaments.[1)] Photon energies were 285 and 270 eV, corresponding to carbon K-edge resonance and non-resonance energies. Diffraction rings derived from a clear periodic structure were observed at the resonant energy. For the resonant RSoXS image, the scattering angle 2θ is approximately 3°, corresponding to 80 nm. This pitch corresponds to the half pitch of the helical structure. Conventional SAXS cannot unravel helical structures due to no electron density modulation. Thus, by observing the molecular orientation order, we succeeded in characterizing the helix pitch of self-assembled liquid-crystal materials in situ.

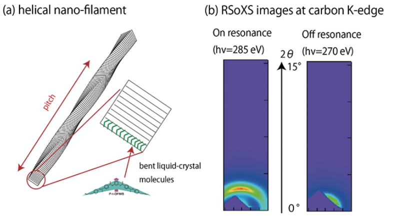


Figure 2. (a)Self assembled helical nanofilament of bent liquid-crystal molecules. (b) RSoXS images of helical nanofilaments at photon energies of 285 eV (resonance) and 270 eV (non-resonance).

Reference

1) Y. Takanishi *et al.*, *RSC Adv.* **12**, 29346 (2022).

Award

NAKAMURA, Eiken; The 10th Japan Society for Synchrotron Radiation Research (JSSRR) Achievement Award (2023).