National Institutes of Natural Sciences
Institute for Molecular Science

UVSOR

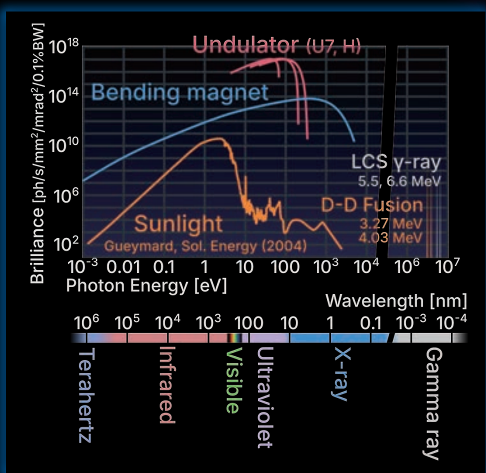
Synchrotron Facility

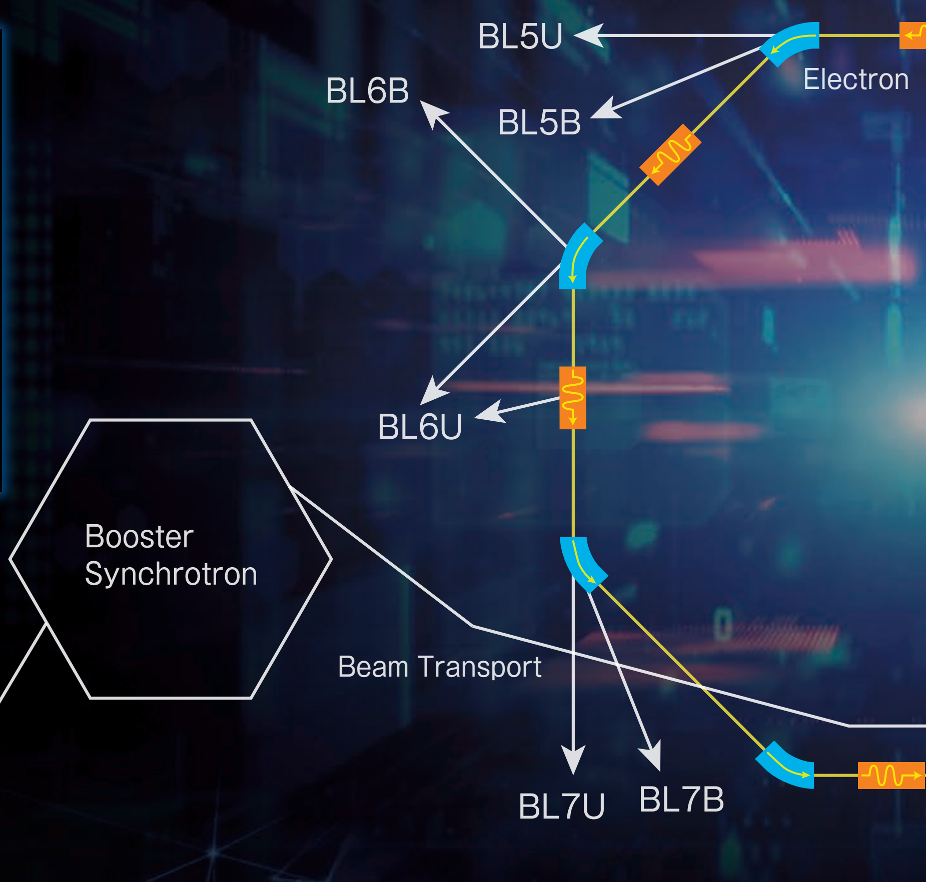
Create Light, Capture Insight

Create Light, Capture Insight

We create unique light to explore how matter and molecules take shape, form structures, and perform their functions.

Bright, specialized light is required to observe atoms, molecules, and materials. Sunlight, the most familiar bright light, contains the seven colors of the rainbow as well as ultraviolet (UV) light, which causes sunburn, and infrared light, which produces heat. UV light has higher energy than visible light, whereas infrared light has lower energy. Solar radiation also includes X-rays, gamma rays, terahertz radiation, and microwaves. The UVSOR facility provides synchrotron radiation that is 1,000–1,000,000 times brighter than sunlight in outer space and delivers light through various beamlines to meet users' needs. While sunlight is brightest in the green (2 eV region in the viewgraph), synchrotron radiation from UVSOR shows its highest intensity in the approximately 10–1,000 eV range. Radiation in this energy range interacts strongly with matter and is widely used to investigate the origins of various material properties across fields ranging from the life sciences to astronomy. Moreover, by leveraging the flexibility of a compact facility, fundamental research on accelerator physics and synchrotron radiation is eagerly conducted. Studies on advanced, "structured" light, such as optical vortices. and their applications are also underway.



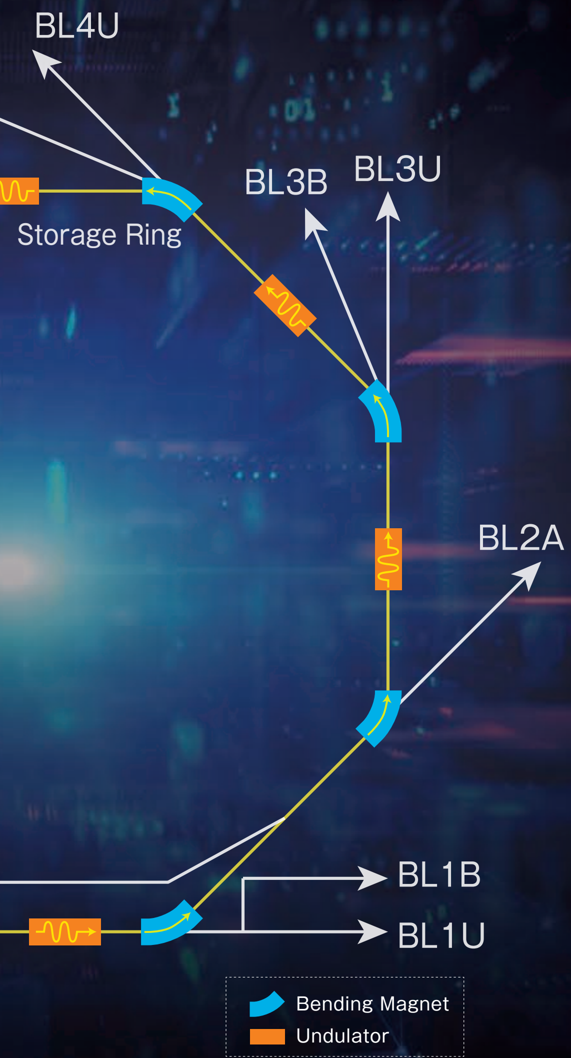



Electron Gun, Linac and Booster Synchrotron


Beam Transport

UVSOR-III Synchrotron

UVSOR-III is an accelerator complex comprising a 53-meter electron storage ring for light generation and an injector (electron gun, linear accelerator, and booster synchrotron) that injects electrons accelerated to nearly the speed of light into the storage ring. Although UVSOR was constructed over 40 years ago, it underwent major upgrades in 2003 (UVSOR-II) and 2012 (UVSOR-III). By actively incorporating new technologies, the facility maintains world-class performance as a compact, low-energy synchrotron light source. Looking ahead, the UVSOR-IV conceptual design has been proposed to develop a new type of light source aimed at revolutionizing the life sciences, and efforts toward its realization are ongoing.

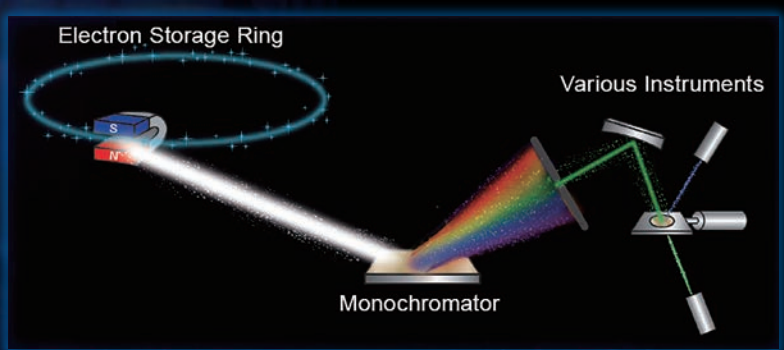


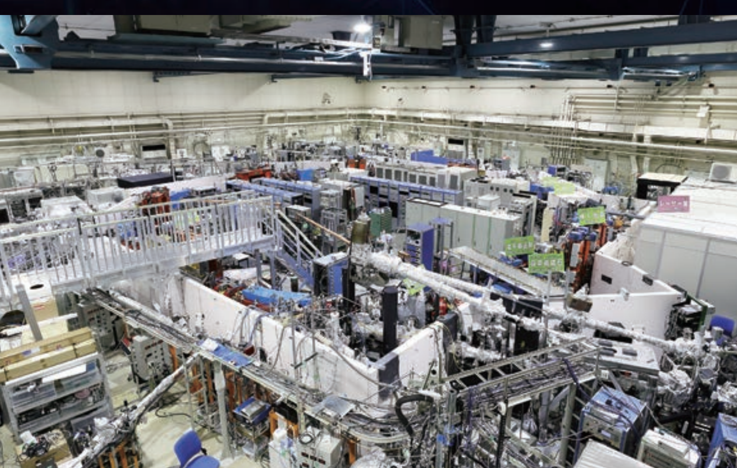
Generation of Synchrotron Radiation and Energy (Color) Selection at Each Beamline (BL)

Electrons circulate at nearly the speed of light within an octagonal electron storage ring. At each vertex of the octagon, bending electromagnets deflect the electrons, generating highly intense light. Additionally, six of the eight straight sections contain devices called “undulators,” which comprise many small magnets arranged in a specific pattern. As electrons pass through these undulators, even more intense light is generated. The emitted light is then filtered by “spectrometers” installed at 13 beamlines (BL1U, 1B, 2A, ..., 7U, 7B), as shown in the diagram below. Only the required light is selected and supplied to the experimental apparatus, called “endstations,” connected to each BL.

Experiments Utilizing Light at Endstations

Light from each beamline is directed to the endstation, where various experiments explore the structure, mechanisms, and functions of materials and molecules. UVSOR endstations are widely accessible to academic researchers and industrial users, both domestically and internationally, and support research and development in fields such as molecular science. Detailed information and experimental results for each UVSOR beamline are available online.





Electron Storage Ring and Beamlines

Synchrotron Radiation at an Endstation

Beamlines & End-stations

UVSOR

Accelerators and Instruments | Material Sciences | Chemistry

BL1U : Gamma-rays and Extreme UV Irradiation Instrument

Leading the World in New Light Source Development and Application

BL1U generates light with various polarizations across a broad wavelength range, from visible to extreme UV. It also produces ultrashort gamma rays in the MeV range using ultrafast pulsed lasers. Researchers can conduct diverse experiments, including photoelectron spectroscopy and irradiation with quasimonochromatic light, using either their own or facility equipment.

Surface, Interface and Thin Films

BL5B : Instrument Calibration Equipment

Enabling Evaluation of Large Optical Elements in a Spacious Chamber

BL5B contains the largest vacuum measurement chamber at UVSOR (a cube with approximately 1 m sides) for evaluating optical elements, such as large mirrors and diffraction gratings, that cannot be assessed elsewhere. The positions and orientations of optical elements and detectors can be freely adjusted, enabling comprehensive measurements of light energy and angular dependence.

Material Sciences

BL1B : Terahertz Spectroscopy

Providing Experiments Using Terahertz Waves with Diverse Potential Applications

Terahertz waves, with wavelengths between those of light and radio waves, represent an unexplored region for research and development. BL1B, a bending-magnet beamline at UVSOR, produces the facility's longest wavelengths, enabling spectroscopic experiments such as reflection, transmission, and absorption using terahertz radiation.

Material Sciences

BL6B : Infrared Spectromicroscopy

Supporting Research Across Diverse Fields with Infrared Synchrotron Radiation

BL6B is a bending-magnet beamline utilizing infrared synchrotron radiation capable of macroscale and microscale measurements with beam sizes of approximately 200 and 30μm, respectively. A cryostat has been installed in recent years, allowing measurements at temperatures from 5 to 300 K for macroscale and microscale experiments.

Material Sciences | Surface, Interface and Thin Films

BL3B and BL7B : Absorption, Reflection, and Luminescence Measurement System

Supporting Research on Photofunctional Materials

BL3B and BL7B perform absorption, reflection, and luminescence measurements from visible to vacuum UV. BL3B is widely used across Japan, and efforts in remote measurement and digital transformation (DX) have advanced since the COVID-19 pandemic. BL7B supports experiments with user-provided instruments, offering a highly flexible measurement section.

Material Sciences | Surface, Interface and Thin Films

BL7U : High-Resolution Angle-Resolved Photoelectron Spectroscopy

Realizing Ultra-High-Resolution Photoelectron Spectroscopy on Vacuum UV Beamline

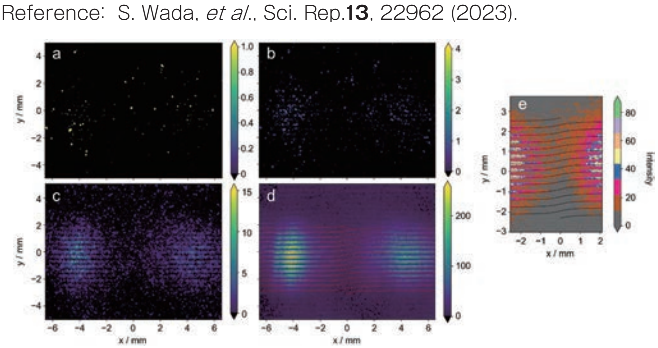
BL7U enables high-energy-resolution angle-resolved photoelectron spectroscopy using low-energy excitation light in the 6–40 eV range. It features a variable-polarization undulator that can generate linearly polarized light (horizontal and vertical) and circularly polarized light (left- and right-handed). Samples can be cooled to cryogenic temperatures as low as 4 K.

Recent Topics 1

BL1U: Observation of Photon Vortices

Young's double-slit interference experiment demonstrated that individual photons—the particles of light—can exhibit vortex properties, forming a special type of light known as a light vortex. The experiment was conducted under conditions of extremely low light intensity, allowing photons to pass through the double slit one at a time. As photon spots accumulated, a characteristic light-vortex pattern emerged, featuring a dark central region surrounded by distorted stripes. This result revealed that light spontaneously emitted by spiraling high-energy electrons possesses the properties of a light vortex, including a spiral wavefront, even at the single-photon level.

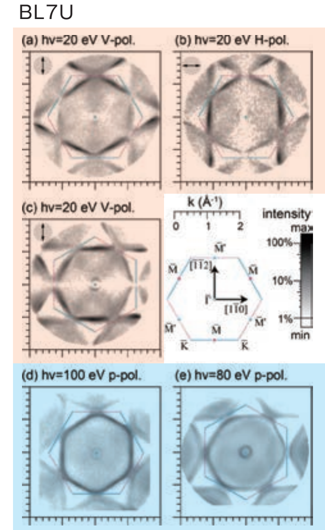
Reference: S. Wada, *et al.*, Sci. Rep.**13**, 22962 (2023).



BL6U and BL7U: Development and Installation of the Unique PMM Experimental Station

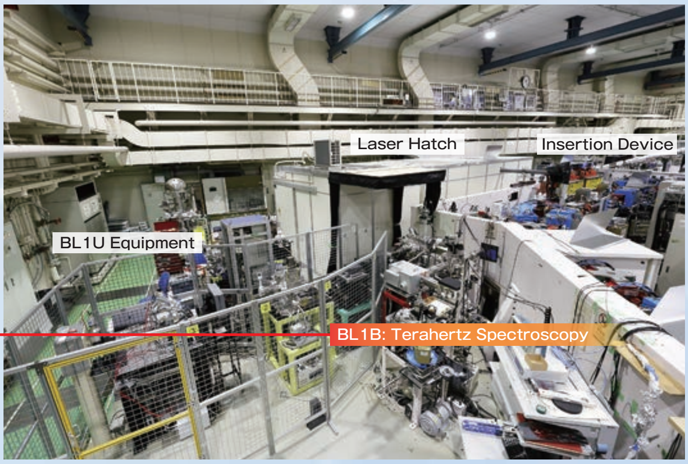
The world's first PMM experimental station that can use synchrotron radiation from two beamlines has been developed. In the PMM, the sample surface, aligned directly with the objective lens, is illuminated obliquely by light from BL6U. Moreover, a new branch from BL7U now allows vacuum UV light to be used at normal incidence. This configuration advances atomic orbital analysis of valence bands, providing more comprehensive and high-precision insights into the electronic behavior that determines material properties.

BL7U

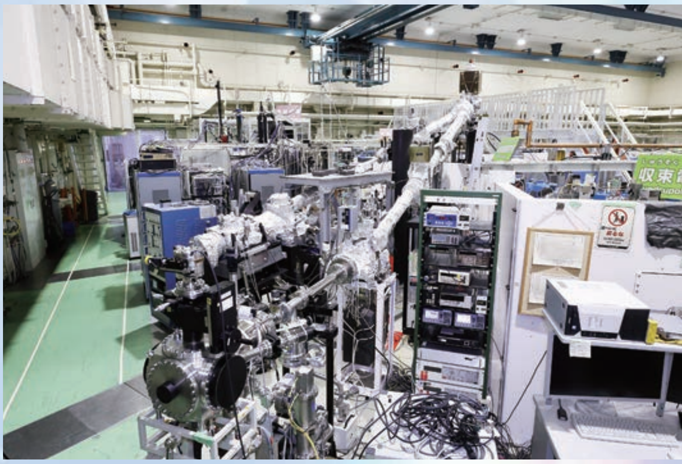


BL6U

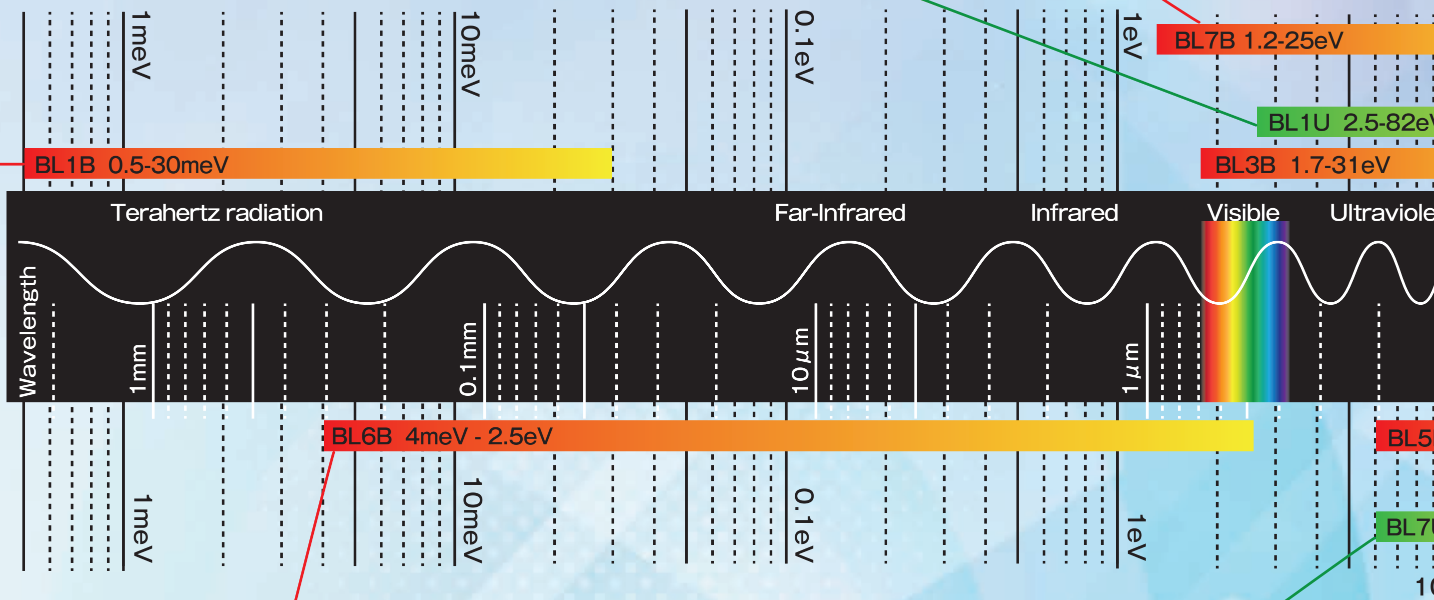
Reference: K. Hagiwara, *et al.*, J. Synchrotron Rad. **31**, 540 (2024).

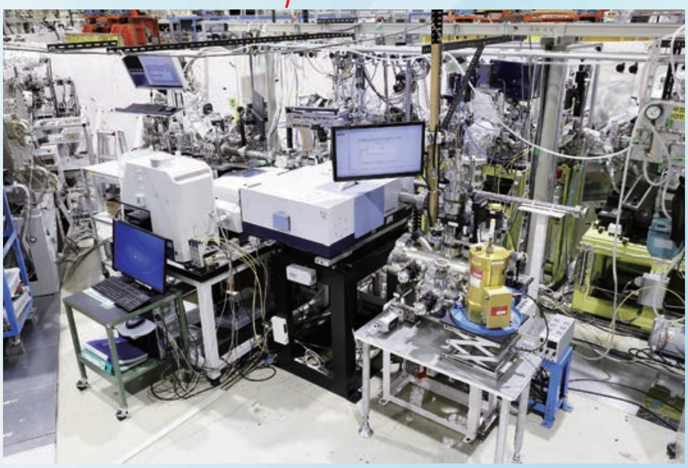


Gamma-Rays and Extreme UV Irradiation Instrument（Gamma-ray : 1-10 MeV）

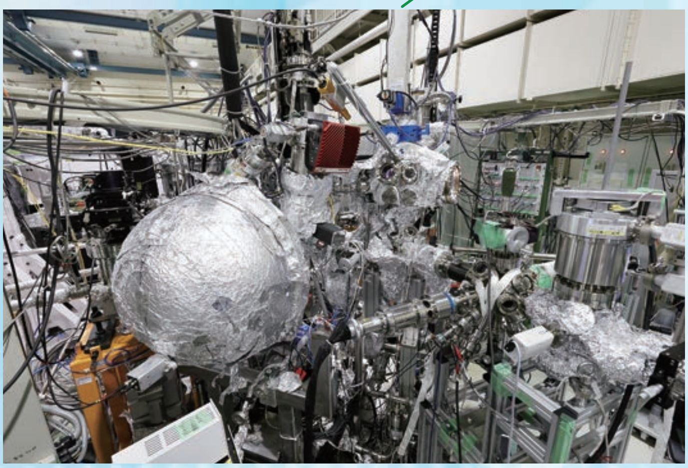


BL7B : Absorption, Reflection, and Luminescence Measurement System

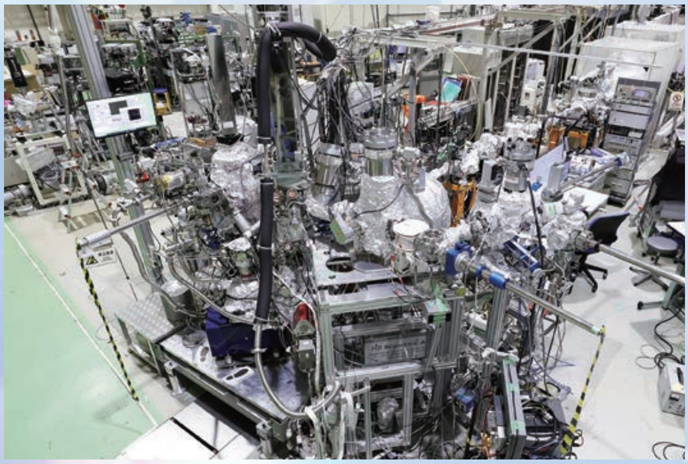




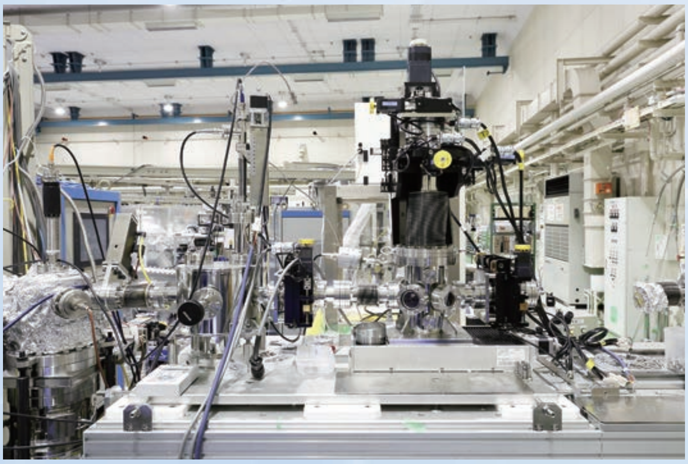
BL6B : Infrared Spectromicroscopy



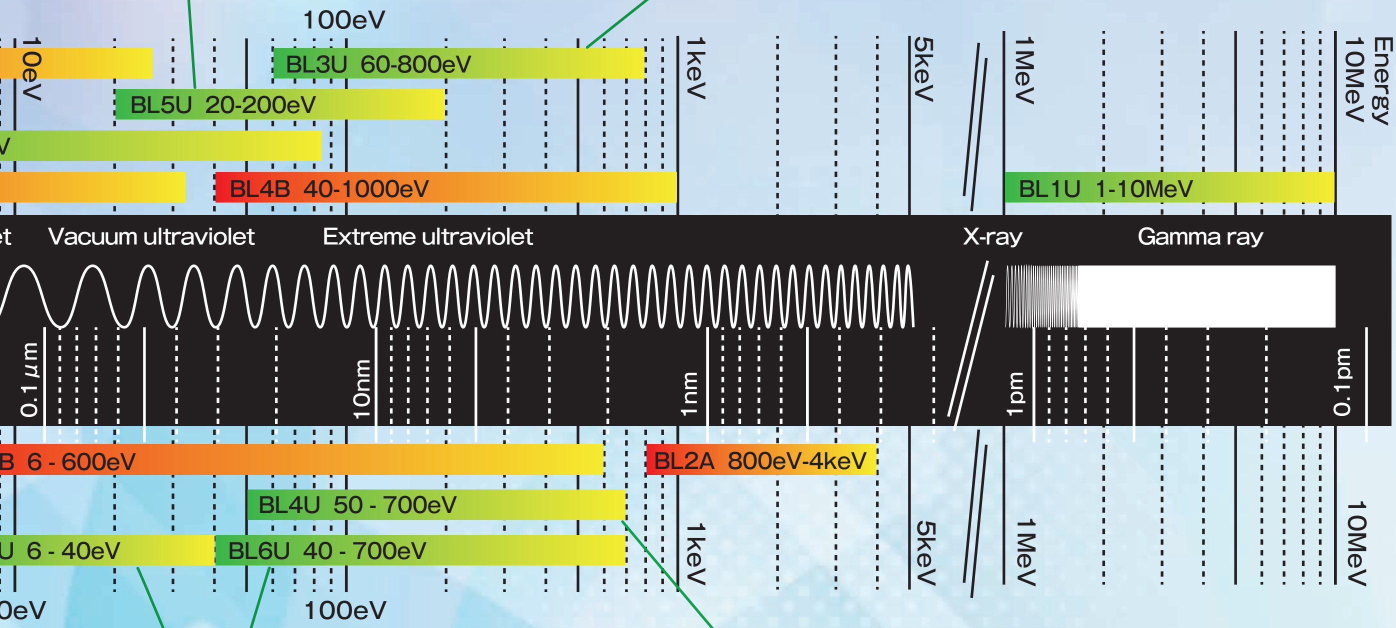
BL7U : High-Resolution Angle-Resolved Photoelectron Spectroscopy

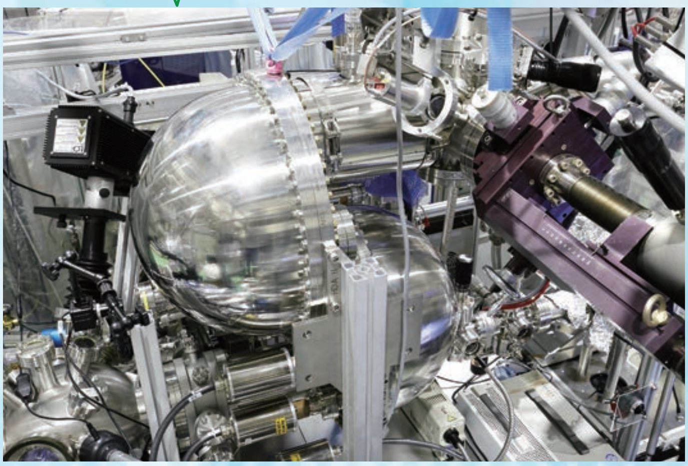


BL5U : Spin, Spatial, and Angle-Resolved Photoelectron Spectroscopy System



BL3U : Operando Transmission Soft X-ray Spectroscopy





BL6U and BL7U : Photoelectron Momentum Microscope (PMM)

BL4U : Scanning Transmission X-ray Microscope (STXM)

Chemistry

BL3U : Operando Transmission Soft X-ray Spectroscopy

Pioneering Operando Transmission Soft X-ray Spectroscopyof Liquids with Original Technology

At BL3U, a liquid cell with precisely controlled thickness (20–2000nm) has been developed, enabling soft X-ray spectroscopy of liquids using transmission methods previously difficult to perform. The original liquid cell enables operando measurements of catalytic and electrochemical reactions in solution.

Surface, Interface and Thin Films | Material Sciences

BL5U : Spin, Spatial, and Angle-Resolved Photoelectron Spectroscopy System

Advancing New Material Development with Microfocusing and Spin Resolution

A focused microbeam of approximately 30μm at BL5U enables ARPES measurements. Moreover, high-efficiency spin-resolved measurements in the inplane direction of the sample are now available.Preparations are underway to expand spin information acquisition to the perpendicular direction by introducing the latest spin rotator.

Life, Earth and Planetary Sciences | Material Sciences

BL4U : Scanning Transmission X-ray Microscope (STXM)

Contributing to Energy, Environmental, Earth, and Life Sciences and Actively Promoting Industrial Applications

At BL4U, absorption-contrast images are obtained by scanning samples in two dimensions with a focused soft X-ray beam and detecting transmitted X-rays. By performing spectroscopic measurements while varying the incident X-ray energy, STXM provides chemical-state maps of samples. This capability supports diverse research purposes, including commercial applications. Further development of the measurement environment aims to enhance contributions to the life sciences from new perspectives.

Surface, Interface and Thin Films | Material Sciences

BL6U and BL7U : Photoelectron Momentum Microscope (PMM)

Revealing the True Nature of Electrons with a Unique Photoelectron Analysis System

The PMM experimental station utilizes soft X-rays from BL6U and vacuum UV light from BL7U. PMM combines two main functions: microscopy for element-selective, magnified observation of samples and microARPES for visualizing the valence-band dispersion in targeted regions.

Surface, Interface and Thin Films | Chemistry

BL4B : Various Analytical Instruments

Meeting Diverse Needs Through Instrument Switching

BL4B enables diverse experiments via instrument switching. Available instruments include an X-ray absorption fine structure (XAFS) spectrometer, an X-ray magnetic circular dichroism spectrometer, and an angle-resolved photoemission spectrometer (ARPES). Although light intensity is moderate, it enables experiments with minimal radiation damage.

Material Sciences

BL2A : Double-Crystal Monochromator

Providing Low-Noise Absorption Spectroscopy using Soft and Tender X-rays

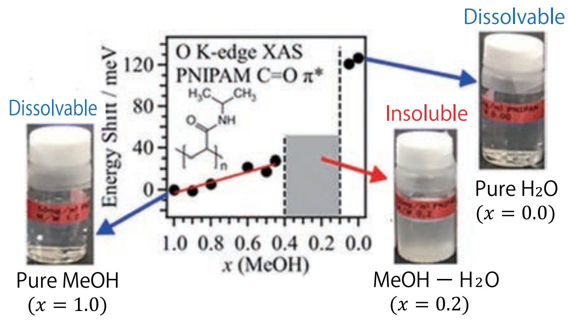
BL2A produces the highest-energy tender X-rays at UVSOR and is primarily used for X-ray absorption measurements of inorganic compounds and organometallic complexes. Although the light intensity is low, the low background yields low-noise spectra with reduced radiation exposure.

Recent Topics 2

BL3U:Elucidating the Phenomenon Where Polymers Become Insoluble When Mixed with Solvents

Poly(N-isopropylacrylamide) (PNIPAM) exhibits a cosolvent effect: it dissolves individually in water and methanol but becomes insoluble when the two are mixed. To investigate this counterintuitive phenomenon, we employed soft X-ray absorption spectroscopy to selectively examine intermolecular interactions complemented by computer simulations. The cosolvent effect arises because hydrophobic interactions between small methanol clusters disrupt the existing hydrophobic hydration of PNIPAM. Changes in hydrophobic hydration characteristics explain precipitation when two good solvents are combined.

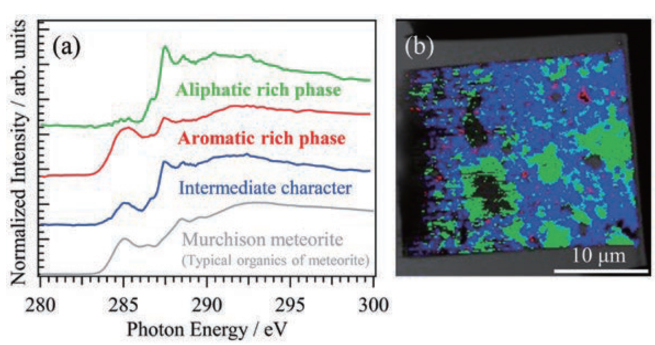
Reference: M. Nagasaka, *et al*., Phys. Chem. Chem. Phys. **26**, 13634 (2024).



BL4U:Distribution of Organic Molecules in Hayabusa2 Returned Samples

Analysis of Hayabusa2 samples, sectioned and examined using STXM without exposure to air, revealed that the diverse organic molecules within Ryugu particles can be broadly categorized into three types, as shown in the figure. Furthermore, combined with high-resolution transmission electron microscopy, the analysis revealed that organics rich in aliphatic hydrocarbons form complex, intermingled structures with coarse-grained hydrated silicate minerals.

Reference: M. Ito, *et al*., Nat. Astron. **6**, 1163 (2022).



History of UVSOR

April 1975 Institute for Molecular Science founded
April 1979 Continuous light source for extreme UV radiation planned
The facility named “Extreme UV experimental facility” and nicknamed “UVSOR”

June 1982 First-phase construction of the UVSOR building(1,281m²) completed
March 1983 Second-phase construction of the UVSOR building(1,463m²) completed
November 1983 Storage of 0.45 GeV, 1 mA electron beam succeeded
April 1985 Joint use begins
Electron storage ring 0.75 GeV(injection 0.6 GeV), 330mA operation
March 1991 Third-floor extension(283m²) of the UVSOR building completed
1992 FEL oscillation(460nm)successfully demonstrated
April 1995 UVSOR User's Union launched
July 1995 UVSOR Future Vision Committee established in the institute
Discussions on UVSOR-II begin
1996 World’s shortest-wavelength FEL oscillation (239nm) successfully demonstrated

April 2003 UVSOR-II upgrade work begins
Emittance improved from 165 to 27 nm·rad.
The facility focuses on insertion devices
September 2003 UVSOR-II operation begins
Energy resolution reaches a world-class level
2003 BL7U SAMRAI project initiated
April 2004 National Institutes of Natural Sciences established through incorporation
The facility renamed to "Extreme UV Research Facility"
December 2004 Discussions on further advancement (UVSOR-III) begin
July 2007 Power supply strengthened for full-energy injection at 0.75 GeV
October 2008 Top-up operation partially introduced
2008 Successful generation of coherent synchrotron radiation by laser bunch slicing

2008 BL3U Liquid XAFS project started
2010 BL4U STXM project started
2011 BL5U microARPES project started
April 2012 Modification work to upgrade UVSOR-III begins
Emittance reduced from 27 to 17.5 nm·rad
August 2012 UVSOR-III operation begins
Spatial resolution reaches the world-class level
Six insertion devices to be operated
September 2014 Laser Compton scattering gamma rays successfully generated at BL1U
2014 BL5U spin-ARPES project started
October 2019 Plans for the next facility construction started
February 2020 BL6U PMM project started
September 2022 BL3U Resonant Soft X-ray Scattering Spectroscopy project started
September 2023 New branch at BL7U (to BL6U PMM) established for multimodal experiments

How to Use UVSOR

Universities and national research institutes

UVSOR is a facility of the Institute for Molecular Science, an Inter-University Research Institute. University and national/-public research institutes can use the facility free of charge in principle. Travel expenses may also be reimbursed.

Private companies, etc.

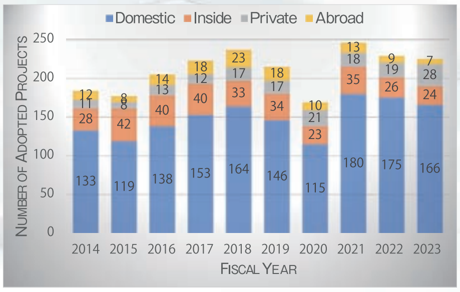
Access may be available depending on the device and the time of year; in principle, fees apply.
Please refer to the UVSOR website for details.

For more details, visit the UVSOR website!

UVSOR | Search

Usage Statistics

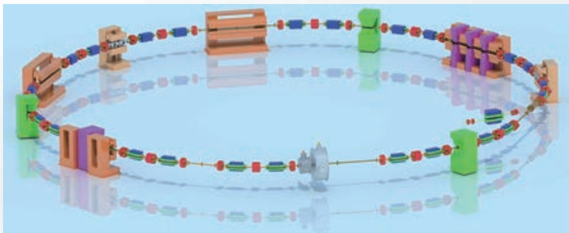
UVSOR serves researchers and students from universities, research institutions in Japan and abroad, and researchers from private companies. In recent years, the facility has accepted just over 200 projects annually, with approximately 400 users visiting each year (totaling approximately 5,000 person-days), excluding the 2020 fiscal year, which was affected by the COVID-19 pandemic.



Future Vision

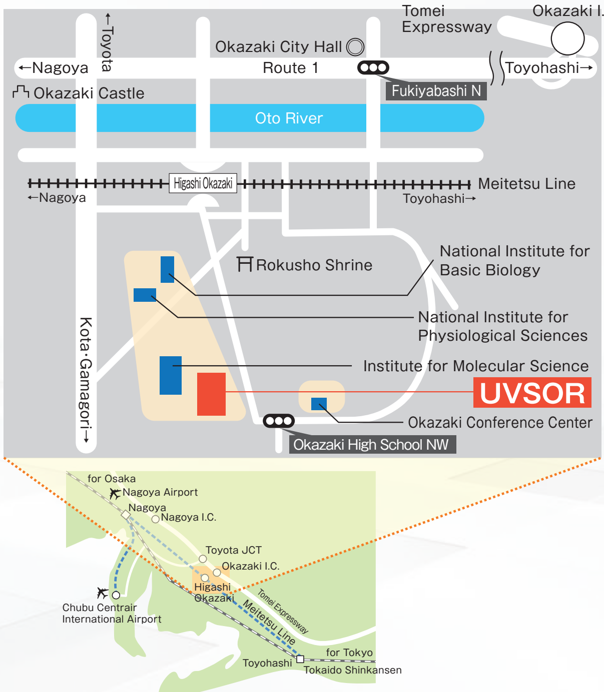
To support sustainable development in science and technology for the next generation, UVSOR plans to rebuild its light source facility while continuing to promote academic research through joint use and collaborative projects. Specifically, a new compact-ring, next-generation high-brilliance synchrotron radiation source will be constructed, and laser light sources will be actively integrated into the beamlines. The goal is to create an advanced facility that can provide diverse light types in a single location to meet user’s needs.

For more details, scan this code.



Electron Storage Ring for UVSOR-IV (Draft)

ACCESS



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