BL27SU Soft X-ray Photochemistry

BL27SU studies the various photochemical processes caused by soft X-ray excitation from both a fundamental and an applied viewpoint. The beamline consists of three branches. The A- and B-branch are high flux experimental stations without monochromator. The A-branch is used for the development of an elliptically bent cylinder mirror to make a micro focusing soft X-ray beam. At the B-branch, creation of a new functional material is performed using the soft X-ray CVD, etching, and ablation methods. Equipped with a varied-line-spacing plane grating monochromator, the c-branch provides a linearly polarized intense photon beam at high-energy resolution in the range from 170 to 2800 eV. Two experimental stations (C1 and C2) are devoted to the atomic and molecular science. At C3 station, users can connect their own apparatus and small spot size photon beam is available (10 μm in vertical).

Area of research

Industrial research --- B branch
- Growth of thin film of functional material
- Micro fabrication by functional material etching

Atomic and molecular spectroscopy --- C branch (C1, C2 station)
- Search of novel photochemical processes
- High resolution atomic and molecular electron spectroscopy
- Complete determination of electronic decay channel
- Dissociation dynamics of inner-shell excited molecules
- Site-specific dissociation processes of isolated molecules

Surface analysis and solid state physics --- C branch (C3 station)
- Search of electronic structure of solids
- Elucidation of electronic state of molecule on surface

Keywords

Scientific field

Photochemistry, Atomic and molecular physics, Surface science, Solid state physics, Growth of thin film, Fabrication of material

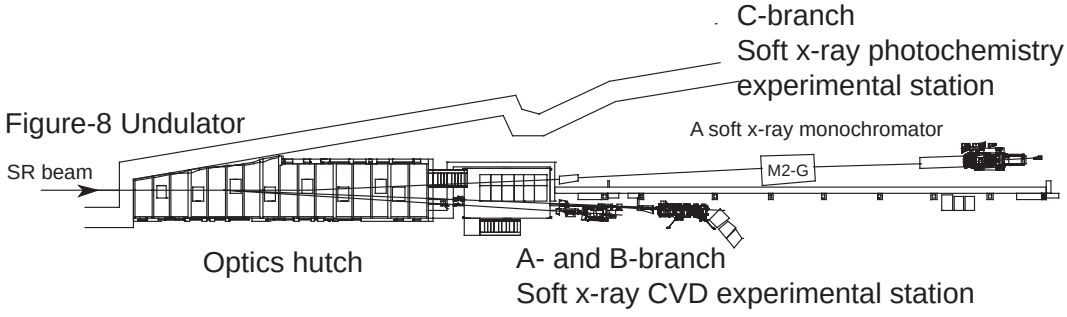
Equipment

High-resolution soft X-ray monochromator, Micro-focus optics, High-resolution electron energy analyzer, Multi-coincidence apparatus

Source and optics

Light source

The light source is a Figure-8 undulator which can produce linearly polarized radiation with low on-axis heat load. Figure-8 undulator provides both horizontally and vertically polarized soft X-ray beams by choice of an appropriate undulator gap, the linear electric vector lying horizontally (0°) from the integer–order-harmonic light and that vertically (90°) from the half-integer-order light.



Schematic view of BL27SU

Parameter of pre-mirrors

Branch	A	B	C	
Mirror name	M0'		M0	M1
Incident angle	88.4°	88.9°	89.4°	89.4°
Focusing	---		Sagittal (vertical focus)	Tangential (horizontal focus)
Shape	Plane		Cylinder	Bent cylinder
Material	Pt/Si		Au/Si	Au/Si

Pre-mirrors

The pre-mirrors that installed in an optics hutch deflect the photon beam to one of three branches. M0' at 3.2° or 2.2° diverts the photon beam into A- or B-branch, respectively. M0 and M1 deflect and focus the photon beam to the C-branch.

Experimental stations

A- and B- branch (Soft X-ray CVD station)

In soft X-ray CVD experimental station, soft X-rays from the figure-8 undulator is used without further dispersion. By irradiating gaseous or solid samples with them in the range of 0.2 ~ 2 keV, the creation, synthesis, or processing of a variety of new materials is aimed at.

Optics

The M0' plane mirror reflect the photon beam to the A and B-branch. At A-branch, an elliptically bent cylinder mirror for micro focusing is under development for several applications requiring higher photon density.

X-rays at sample

Energy range 0.2 ~ 2 keV

Photon flux 1×10^{15} photons/s/100 mA @ ID gap:76 mm, FE slit 0.25 × 0.4 mm^2

Beam size 2×4 mm^2

Experimental chamber

The experimental station consists of a differential pumping system, two reaction chambers with preparation chamber and analysis instruments. The reaction chamber allows irradiation of solid samples under ultra-high vacuum conditions, as well as under heated or cooled conditions in the presence of an added gas, such as rare gases, nitrogen, oxygen and various reactive gases. The differential pumping system can keep the ultra-high vacuum in upstream, even when the reaction gases are introduced into reaction chamber at pressures up to 1×10^2 Pa.

Facilities

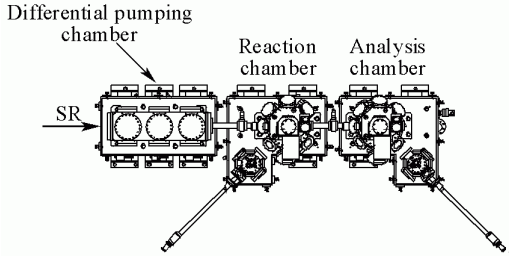
Reaction chamber

Ultimate pressure : 5×10^{-8} Pa

Sample support : x, y, z, 15 mm square

Temperature range : -140 ~ 1000 °C

Load lock mechanism with 500 L/sec-TMP vacuum pump



Schematic drawing showing arrangement of three chambers of the soft X-ray CVD station
SR : synchrotron radiation

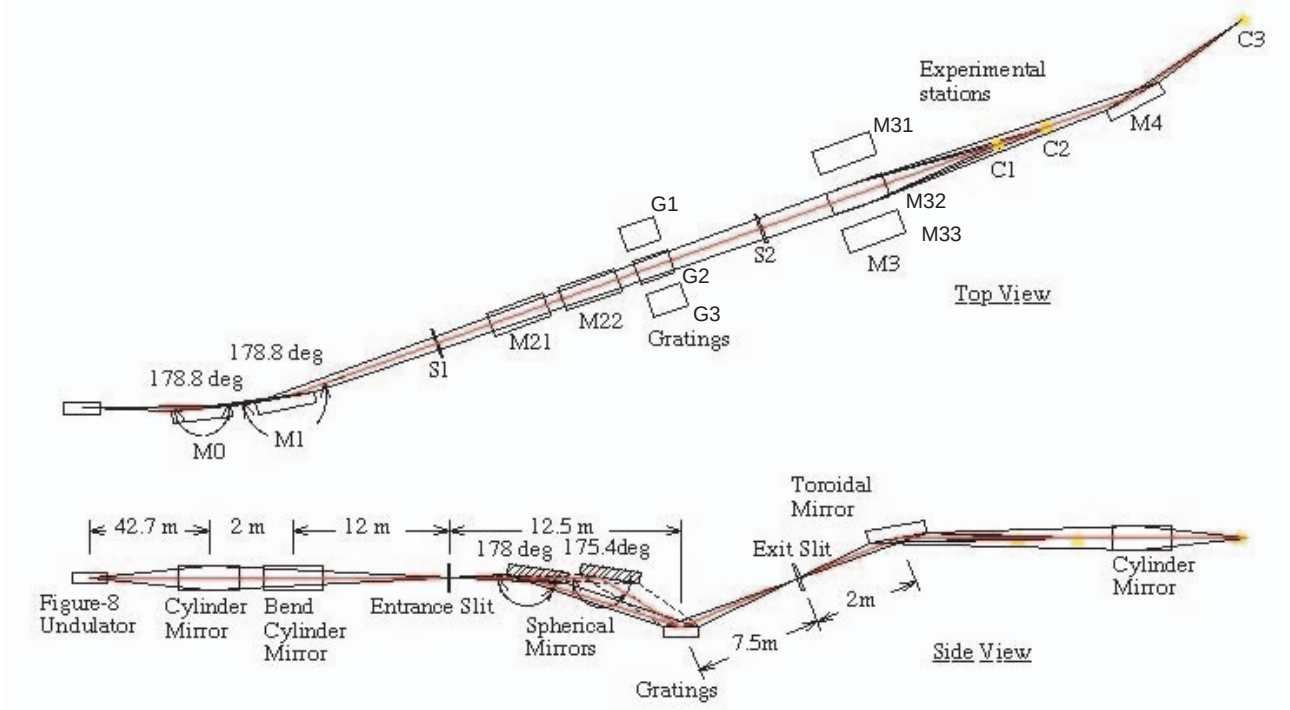
C-branch (Soft X-ray photochemistry)

The C-branch serves a high-resolution soft X-ray spectroscopy experiments. The VLS-PGM provides the intense photon beam with a photon bandwidth narrower than natural line width. Characteristic features of photon beam (high flux, high-resolution, high degree of polarization, wide energy range, and small spot size) make this experimental station suited for investigating various core-electron excitation phenomena.

Monochromator and post-focusing mirrors

The monochromator is a varied-line-spacing plane grating (VLS-PGM) fixed deviation instrument of the Hettrick type. The monochromator consists of the entrance slit (S1), spherical mirrors (M21, M22), three gratings (G1, G2, G3), and exit slit (S2). Two spherical mirrors and three gratings allow the scanning of an energy range from 170 to 2800 eV.

Three re-focusing mirrors are designed for focusing the photon beam on three experimental stations arranged in tandem. The M31 and M32 is the toroidal mirror, which focus the photon beam on the sample point of C1 and C2 station, respectively. The M33 focuses the photon beam horizontally on the C3 station. The second re-focusing mirror (M4) vertically focuses the photon beam on the sample points. Especially, the photon beam on the C3 station is focused to about 10 μm in vertical direction.



Layout of valid line-spacing plane grating monochromator

Parameters of spherical mirrors and gratings

Energy range (keV)		0.8 ~ 2.7	0.3 ~ 1.2	0.1 ~ 0.6
Angle (deg)		88.0	86.7	86.7
Grating	Grating	G1	G2	G3
	Groove density	1200/mm/VLSPG	400/mm/VLSPG	600/mm/VLSPG
	Material	Au/Si	Au/Si	Au/Si
Spherical mirror	Mirror	M21	M22	M22
	Material	Au/Si	Au/Si	Au/Si

Parameters of re-focusing mirrors

Station	C1	C2	C3	
Mirror name	M31	M32	M33	M4
Shape	Toroid	Toroid	Cylinder (horizontal focus)	Cylinder (vertical focus)
Incident angle (deg)	89.0	89.0	89.0	89.0
Material	Au/Si	Au/Si	Au/Si	Au/Si
Beamsize V×H (μm)	200 × 200	200 × 200	10 × 200	

X-rays at sample

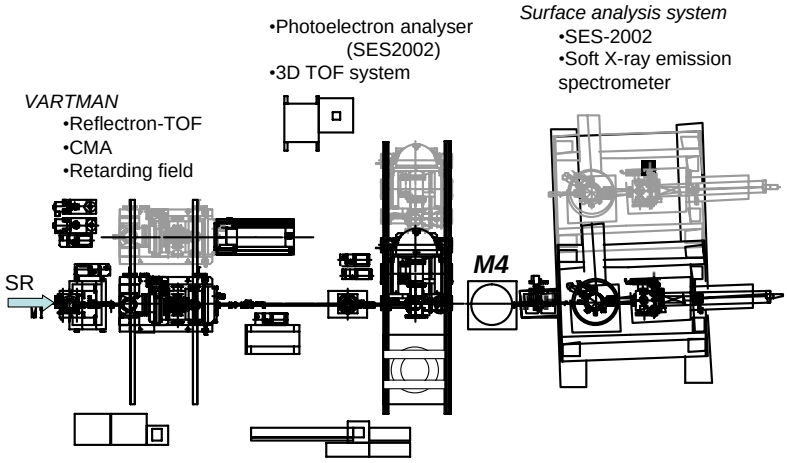
Energy range 1st (Horizontal polarization) : 0.3 ~ 2.8 keV
0.5th (Vertical polarization) : 0.17 ~2.8 keV

Photon flux > 10^{11} photon/s/100 mA/0.01% B.W. (< 1000 eV)

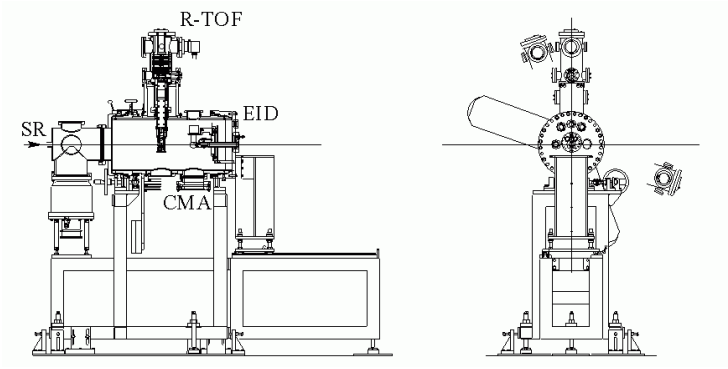
Energy resolution $E/\Delta E > 10^4$

Experimental stations

The inner-shell excitation processes in atoms and molecules are investigated using photoelectron spectroscopy, ion mass spectroscopy and various coincidence techniques (C1 and C2 station), and the electronic structure of solids and surface are researched by use of photoelectron and soft X-ray fluorescence spectroscopy (C3 station). All the experimental equipments are installed on the movable stage so that all equipments can easily remove from beam axis and users can bring their own apparatus into free space.



Schematic view of experimental station on the C-branch



Schematic drawing of experimental chambers and analysis of the soft X-ray photochemistry station

i) C1 station (Soft X-ray photochemistry experimental station I)

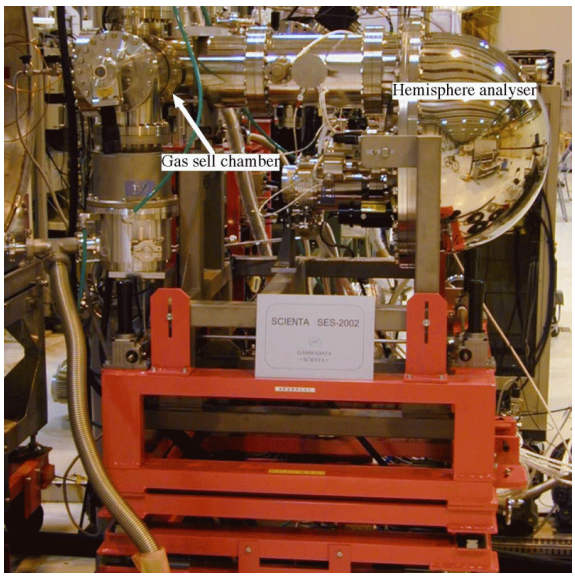
Rotatable chamber for gas phase photodissociation dynamics (standard equipment)

Rotatable chamber on the C1 station is equipped with a reflectron type time-of-flight mass analyzer (R-TOF), a cylindrical electron energy analyzer (CMA) and two retarding field ion detectors. The chamber which houses these analysis instruments can rotate around the photon beam axis in the range from -20^{o} to $+110^{o}$. Two energetic ion detectors (EID) are set at right angles (fixed) and positioned in front of the CMA. In addition, they are mounted on a turntable, which allows for the rotation of the detectors independently around the photon beam axis, so that angle between the ion and electron analyzer can be continuously varied.

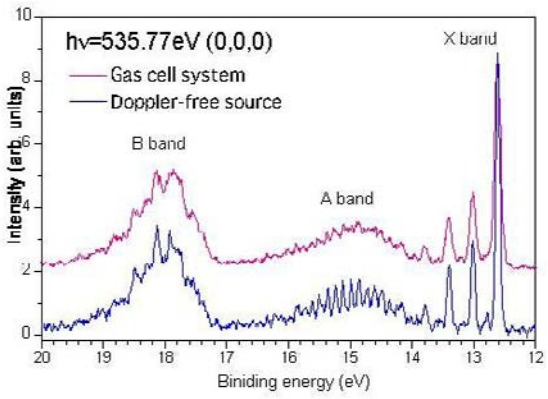
ii) C2 station (Soft X-ray photochemistry experimental station II)

C2a : High resolution photoelectron spectromator (standard equipment)

The C2 station is equipped with high resolution hemispherical electron energy apparatus for free atoms and molecules. The main apparatus is a 200-mm radius hemispherical electron energy analyzer SES-2002 (GAMMADATA SCIENTA). For providing a gaseous sample to the source volume, one can use a gas cell CG-50 (GAMMADATA SCIENTA) or a molecular beam source JD-01 (MB Scientific). If one uses the beam source, one can suppress the Doppler effect that originates from the thermal motion of the gaseous samples and causes spectral line broadening.



High resolution electron energy analyzer
(Gammadata SES-2002)



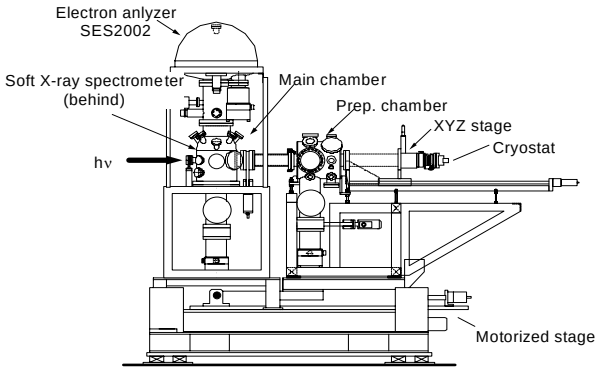
Example of Doppler-free resonant AES of H_2O. Comparison between the Doppler free system and conventional gas cell system for the resonant Auger electron spectrum of H_2O at 535.77 eV of photon energy. The vibrational structures at A band are clearly resolved in the Doppler-free spectra. Also the weak structures of the bending mode progression in the X band are resolved only in the Doppler-free spectra.

C2b : Multiple fragment ions momentum imaging (User's equipment; Tohoku University and HIT)

A skimmed vertical molecular jet cross perpendicularly the photon beam. Electrons are driven by a uniform electrostatic field E to one site of the acceleration region, where they are registered by an MCP detector. The same E field drives the ions to the opposite site of the spectrometer, where they enter a field-free TOF tube for time focusing, at the end of which they are registered by an 80mm diameter 2-dimensional position sensitive MCP detector.

iii) C3 station (Soft X-ray photochemistry experimental station III)

C3 : Surface analysis system (User's equipment ; RIKEN)



List of experimental equipments at C branch

Soft X-ray emission and photoelectron spectra can be measured using the SES-2002. The targets are solid, surface and biological (wet) systems. A newly developed soft X-ray spectrometer with high detection efficiency is equipped. Symmetry resolved spectra can be obtained by changing the polarization of incident X-rays.

• Standard equipments

Reflectron Time-of-Flight Mass spectrometer (R-TOF) (C1a)

Wiley-McLaren type Rotation angle : -20 ~ 110°

Mass resolution : 800 (thermal ions), 80 (energetic ions ; 5 eV of E_{kE})

Cylindrical Mirror type Electron Energy Analyzer (CMA) (C1a)

Acceptance solid angle: 10 % of 2 πsr.

Energy resolution : 0.1 eV

Energetic Ion Detector (EID) (C1a)

Two detectors are set at right angle on the rotating table.

High energy-resolution electron energy analyzer (C2a)

SCIENTA SES 2002

Ultra high resolution gas cell or Doppler free molecular beam source are available

Energy resolution (at 2 eV pass energy) : < 2 meV

• User's equipments

Multiple fragment ions momentum imaging (Tohoku University) (C2b)

Surface analysis system (RIKEN) (C3a)

• Special utility

Reactive gas supply and waste gas clean system

Available gases

Inflammable gases (CH_4, CO, etc.)

Toxic gas (NO_x, SiF_4, $SiCl_4$, BF_3, BCl_3 etc.)

(SiH_4, Si_2H_6, AsH_3, B_2H_6, PH_3, SeH_2 and GeH_4 are not allowed)

Maximum flow rate

10 SCCM

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