

## BL23SU JAERI Actinide Science I

BL23SU is a soft X-ray undulator beamline of Japan Atomic Energy Research Institute (JAERI). It has been constructed for a wide variety of scientific research areas, surface chemistry, biophysical spectroscopy and solid state physics. The experimental stations are located at the experimental hall and the RI building.

### Area of research

Surface chemistry with supersonic molecular beam  
Biophysical spectroscopy  
Photoelectron spectroscopy (activity at RI laboratory)  
Magnetic circular dichroism (activity at RI laboratory)

### Keywords

#### *Scientific field*

Surface chemistry, Chemical reaction dynamics, Real-time in-situ photoemission spectroscopy (Station 1)  
DNA damages, Transient radical species, Photon stimulated desorbed ions (Station 2)  
Photoelectron spectroscopy, Strongly-correlated electron system, Uranium compounds (Station 3)  
MCD, XAS, Strongly correlated electron system, Magnetic property (Station 4)

#### *Equipment*

Supersonic molecular beam, 64ch electron energy analyzer, Quadruple mass analyzer, LEED/AES, STM/AFM (Station 1)  
EPR, QMS (Station 2)

### Source and optics

#### Light source

A double-array variable undulator, so-called APPLE-2 (advanced planar polarized light emitter) or Sasaki-type which produces both linearly and circularly polarized soft X-rays is used as a light source. BL23SU covers the energy range of approximately 0.5~1.5 keV in the circular polarization mode. The magnetic period length is 120 mm and the number of periods is 16. ID23 can generate a linearly (horizontal and vertical plane), an elliptically or a circularly polarized radiation by phase shift. The first harmonic (fundamental) radiation covers the energy region from 0.5 to 3 keV in the circular polarization mode and the energy region from 0.28 to 3 keV in the linear polarization mode. The most unique performance of the undulator is the switching of right-circular-polarization(RCP) and left-circular-polarization (LCP) radiation by periodic phase shift of the magnet rows. The highest mechanical switching rate is at the frequency up to 0.5 Hz.

#### Schematic view of beamline and monochromator system

The main optics is a varied - line - spacing plane grating type (VLSPG) monochromator. This consists of an entrance slit, spherical mirrors, varied-line-spacing plane gratings, an exit slit, a post-focusing mirror, and refocusing toroidal mirrors. The soft X-rays are guided over 120 m from the undulator, crossing the two areas (experimental hall and RI hall).

Undulator period	120 mm
Number of periods	16
Tunable energy range	0.5 ~ 1.5 keV (Circular polarization)
Brilliance	$3 \times 10^{17}$ ph/s/mrad <sup>2</sup> /mm <sup>2</sup> /0.1% b.w. at 1 keV (Circular polarization, photon energy)

#### X-rays at sample

Energy resolution	$E/\Delta E > 10000$
Photon flux	$10^{11}$ ph/s/0.02% b.w.
Beam size	2 mm × 1 mm (Experimental hall) < $\phi$ 200 $\mu$ m (RI laboratory)

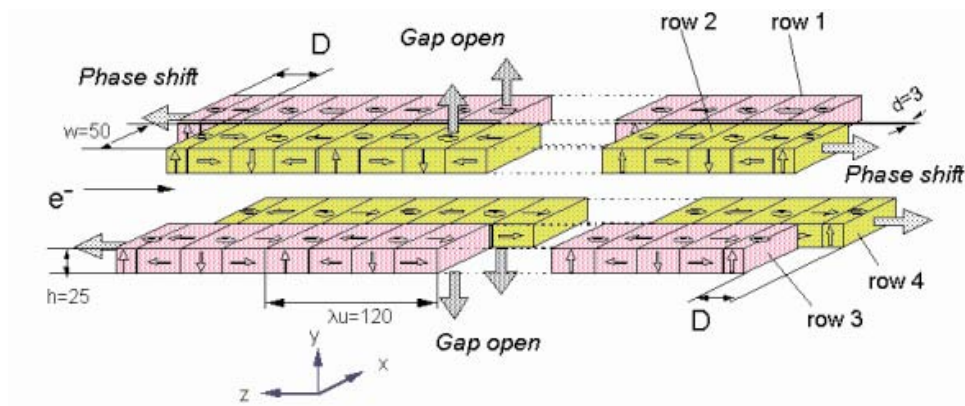
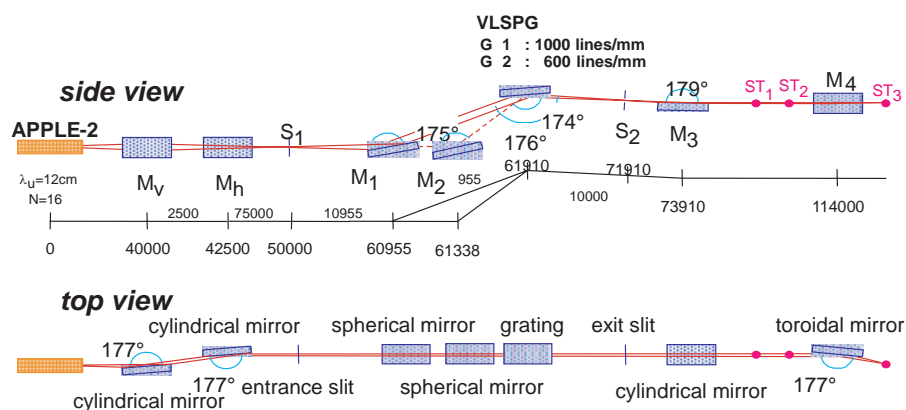


Fig.1 The magnetic structure of the APPLE II consists of two pairs of arrays of permanent magnets.



Optics : Distance from the source	Optical element	Function
40 m	Cylindrical mirror (Mv)	Vertical focusing at the entrance slit
42.5 m	Cylindrical mirror (Mh)	Deflection and horizontal focusing
50 m	Entrance slit (S1)	
60.1 m	Spherical mirror (M1, M2)	
61.91 m	Constant deviation monochromator with varied-space plane gratings (VLSPG)	Monochromatization
71.91 m	Exit slit (S2)	
73.91 m	Cylindrical mirror (M3)	Post focus
114 m	Troidal mirror (M4)	Refocus

## Experimental stations

### 1. Surface chemistry experimental station

The surface chemistry experimental station was designed to study chemical reaction dynamics at surfaces and was installed in the experimental hall of the storage ring building. The apparatus consists of 6 vacuum chambers; the load lock chamber, the surface preparation chamber, the scanning probe microscope (SPM) chamber, the reaction chamber, the

synchrotron radiation (SR) monitor chamber, and the supersonic molecular beam (SSMB) generator. Surface cleaning can be performed in the surface preparation chamber using an Ar-ion sputtering gun and sample annealing up to 1450 K. Reconstructed structures and chemical components at surfaces are observable by low-energy electron diffraction (LEED) and Auger electron spectroscopy (AES) techniques. A gas doser with a W

filament and a variable leak valve is used for adsorption of atoms and molecules with thermal energy. A scanning tunneling microscope (STM) and an atomic force microscope (AFM) are available at room temperature in the SPM chamber using an Omicron UHV-SPM apparatus. In the reaction chamber, the SSMB and the monochromatic SR beam can be irradiated simultaneously at a sample surface so that real-time *in-situ* photoemission spectroscopy can be performed in a temperature range of 150 K to 1450 K using an Omicron EA125 electron energy analyzer with 5 channeltrons or 64 channel detectors. Scattered and desorbed species from the sample are also detected by a differentially-pumped quadruple mass analyzer (Q-mass) using reactive molecular beam scattering (RMBS) techniques. This Q-mass is also used in temperature-programmed desorption (TPD) measurements. An Ar-ion sputtering gun, an Al/Mg twin-anode X-ray source and a gas doser with a variable leak valve are also available in the reaction chamber. The SR monitor chamber is used for absolute and relative SR intensity measurements with an Au-coated W mesh and an IRD photodiode, SR intensity attenuation with Al filters, and SR beam shaping with XY-slits. The chamber plays a role of differential pumping to prevent gas diffusion into the beamline. Gas dose with thermal and hyperthermal energy and measurements of fast XPS, TPD, RMBS, STM/AFM, LEED/AES are available in this experimental station.

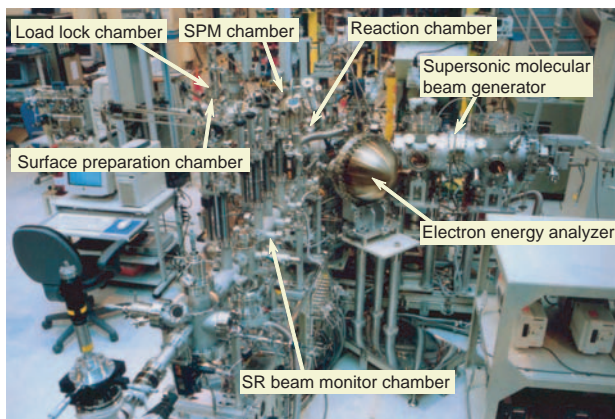


Fig. 2. A photograph of the surface reaction analysis apparatus (SUREAC2000)

The monochromatic synchrotron radiation and supersonic molecular beams can be irradiated to the sample surface simultaneously so that real-time *in-situ* photoemission spectroscopy and surface reaction dynamics studies can be performed in this experimental station.

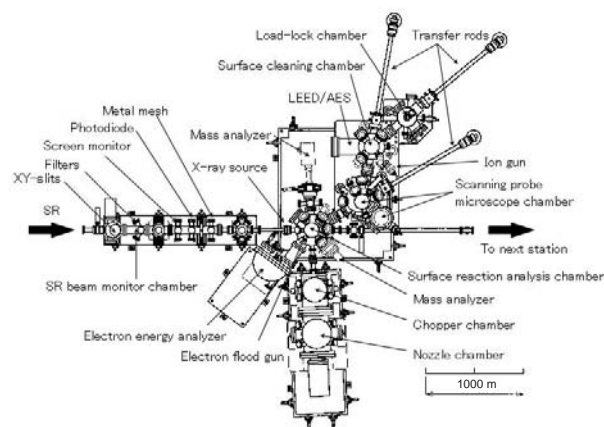
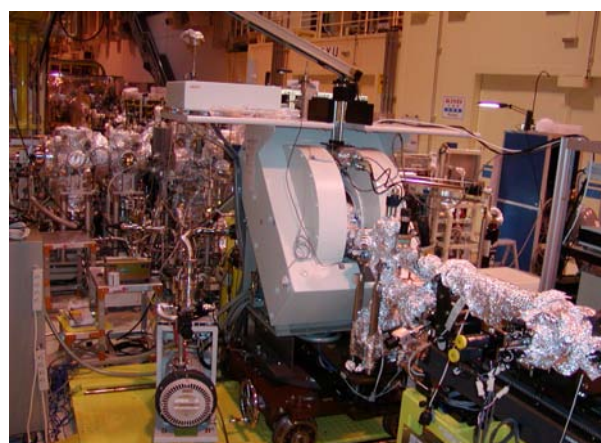
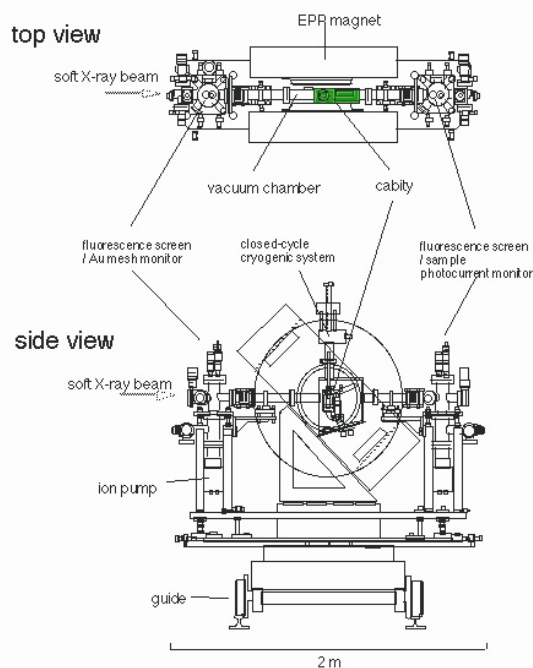


Fig.3. A Top view of the SUREAC2000

## 2. Biophysical spectroscopy

The Biophysical Spectroscopy Station at the BL23SU focuses on the various photochemical processes on biomolecules caused by soft X-ray excitation from the viewpoint of radiation damage to DNA. The station consists of two experimental apparatuses, an X-band EPR (SLEEPRS: Synchrotron Light Exited EPR Spectrometer) (Fig.4) and a quadruple mass spectrometer (QMS). SLEEPRS enable us to investigate transient radical species at the DNA damage site "*in situ*" for the first time. The photon stimulated desorbed ions from the irradiated DNA are pursued by the QMS. These unique spectrometers will identify the physicochemical pathways to DNA base damages and strand breaks, which are thought to induce genetic effects such as mutation and cancer.

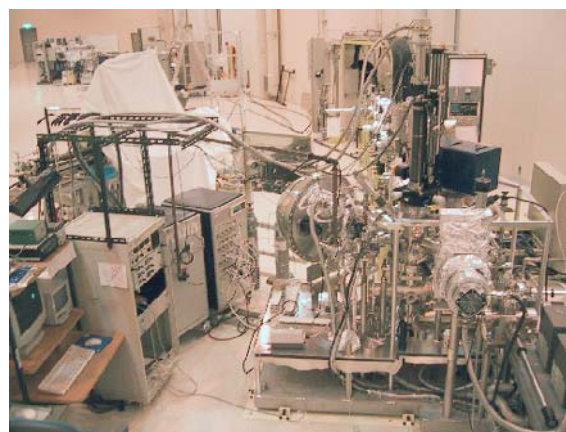
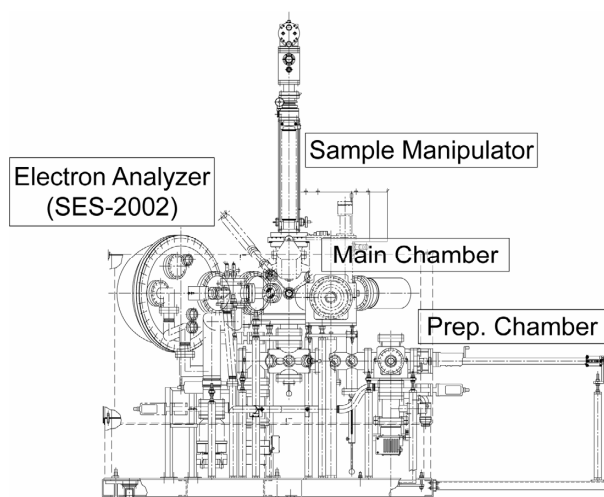




**Fig. 4 Schematic illustration of SLEEPERS**  
 The vacuum chamber is mounted in the magnet gap of about 150 mm (see top view). The chamber is connected to the beamline vacuum pipe at both the front- and back-end. These devices can be removed from the beamline along the guide for off-line experiments or maintenance.

### 3. Photoelectron spectroscopy

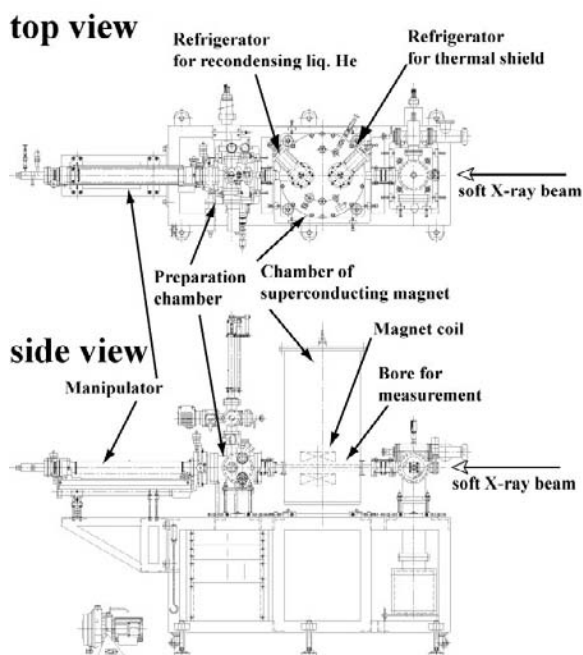
The photoelectron spectroscopy station at BL23SU is designed for the study on the electronic structure of strongly-correlated electron materials. The spectrometer is equipped with a high-energy-resolution electron energy analyzer (SES-2002), and the soft X-rays from BL23SU make it possible to perform the resonant photoemission experiments on various *f*- and *d*- based compounds. In addition, the spectrometer is set in the RI hot sample area of SPring-8, where the unsealed uranium compounds can be measured. The sample temperature can be controlled within the range of 10 K ~ RT.



**Fig. 5.** The schematic illustration and the photograph of the photoelectron spectroscopy station. The station is set at the RI laboratory building of SPring-8.

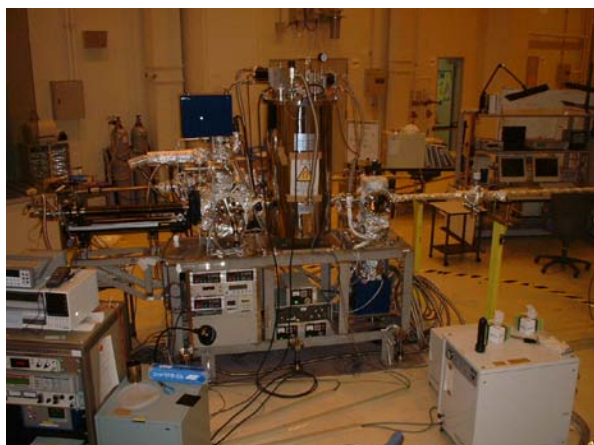
### 4. MCD station

Magnetic circular dichroism (MCD) Station at the BL23SU focuses on the study of the electronic structures which are related with the magnetic properties of strongly correlated electron systems. MCD in the core-level soft X-ray absorption spectroscopy is a powerful method to obtain information about the magnetic moments on each atom that composes the measured sample. Main character of the MCD measuring system (Fig. 6) is a superconducting magnet, which produces fields of up to 10 T. MCD study of paramagnetic and/or anti-ferromagnetic samples can be done by using this system, which generates a strong magnetic field enough to induce finite magnetization. Since the magnet coil is made of a NbTi wire, switching of the field direction can be easily made. MCD measurement can be done by changing the phase of the circularly polarized light at ~ 0.1 Hz as well as by turning the direction of the magnetic field.



Schematic illustrations of MCD measuring system

Fig. 6. This system is composed of a 10-T superconducting magnet and a sample preparation chamber. Temperature of the sample is controlled from room temperature to 10 K.




---

### Contact information

---

#### Akitaka YOSHIGOE

SPring-8 / JAERI

1-1-1 Kouto, Mikazuki-cho, Sayo-gun, Hyogo 679-5148

Phone : +81-(0)791-58-2701

Fax : +81-(0)791-58-2740

e-mail : yoshigoe@spring8.or.jp

#### Shin-ichi FUJIMORI

SPring-8 / JAERI

1-1-1 Kouto, Mikazuki-cho, Sayo-gun, Hyogo 679-5148

Phone : +81-(0)791-58-2701

Fax : +81-(0)791-58-2740

e-mail : fujimori@spring8.or.jp

Contact persons for the each experimental station:

- Surface Chemistry Experimental Station

#### Yuden TERAOKA

SPring-8 / JAERI

1-1-1 Kouto, Mikazuki-cho, Sayo-gun, Hyogo 679-5148

Phone : +81-(0)791-58-2701

Fax : +81-(0)791-58-2740

e-mail : yteraoka@spring8.or.jp

- Biophysical Spectroscopy Station

#### Akinari YOKOYA

SPring-8 / JAERI

1-1-1 Kouto, Mikazuki-cho, Sayo-gun, Hyogo 679-5148

Phone : +81-(0)791-58-2701

Fax : +81-(0)791-58-2740

e-mail : yokoya@spring8.or.jp

- Photoelectron spectroscopy and MCD station

#### Yasuji MURAMATSU

SPring-8 / JAERI

1-1-1 Kouto, Mikazuki-cho, Sayo-gun, Hyogo 679-5148

Phone : +81-(0)791-58-2701

Fax : +81-(0)791-58-2740

e-mail : murama@spring8.or.jp

