

## BL25SU Soft X-ray Spectroscopy of Solid

This beamline is designed for research on electronic states and surface structures of solids with high energy-resolution circularly polarized soft x-rays. The beamline monochromator is a constant deviation type with varied line-spacing plane gratings, which supplies soft x-rays in the energy region of 220 ~ 2,000 eV. The resolving power of the monochromator is more than 10,000 in the entire energy region. Left- and right-handed circularly polarized radiation is obtained along the same optical axis by twin helical undulators. The helicity of the radiation can be periodically switched by using five kicker magnets, which alternately select one of the two helical undulators. A switching mode of 1Hz is currently available.

Three kinds of spectrometers, for high energy-resolution photoemission, magnetic circular dichroism (MCD) of core absorption and two-dimensional angular distributions of photoelectrons, are installed at the experimental stations and provided for users. Measurements are performed in ultra high vacuum conditions down to  $10^{-8}$  Pa. RI (radioisotope) elements and activated gases cannot be used in this beamline.

### Area of research

High resolution photoemission, Photoelectron diffraction and holography, Magnetic circular dichroism in the core absorption (MCD), Photoelectron emission microscope (PEEM)

### Keywords

#### Scientific field

Soft X-ray photoemission spectroscopy (PES), Angle-resolved photoemission spectroscopy (ARPES), Magnetic circular dichroism (MCD) of soft X-ray absorption, Photoelectron diffraction (PED)

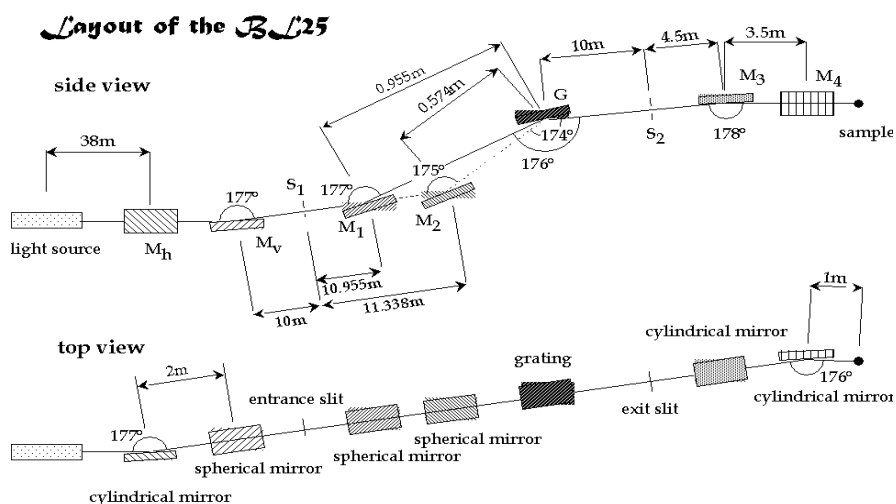
#### Equipment

Helicity switching of circularly polarized radiation, Soft x-ray monochromator using varied-line-spacing plane gratings, Photoelectron analyzer (SES200), Closed-cycle helium refrigerators for PES and MCD, Permanent magnets for MCD, Two-dimensional photoelectron analyzer for PED, Sample cleavers, Sample annealing systems, Ion guns, Evaporators (E-gun type)

### Source and optics

The monochromator of BL25SU is a constant deviation-angle type including a spherical mirror and a valid-line-spacing plane grating (VLSPG) between entrance and exit slits. The type of monochromator has an excellent feature in that the focal point of the VLSPG is unchanged near the exit slit throughout the scanning range,

when the space-variation parameters of the VLSPG are properly determined. This allows wavelength scanning by simple rotation of the VLSPG about its central groove, preserving high precision of energy scale. The monochromator has two deviation angles of  $176^\circ$  and  $174^\circ$  to cover a wide photon energy range from 220 to 2,000 eV. VLSPGs with two different central groove densities of 1,000 and 600 lines/mm are installed.



## X-rays at sample

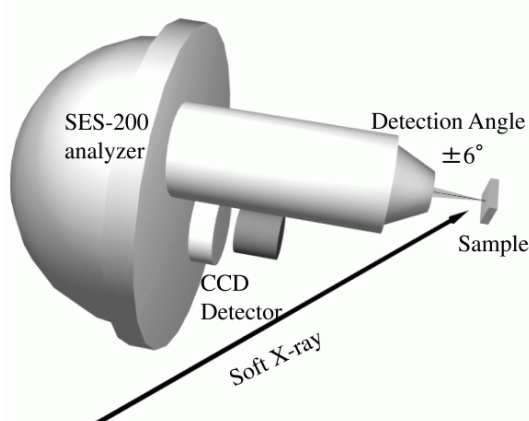
Energy resolution	$E/\Delta E > 10000$
Photon flux	$> 10^{11}$ ph/s/0.02 % b.w.
Beam size	$< 0.4$ mm $\phi$

## Experimental stations

### Soft X-ray PES

High-resolution photoemission spectroscopy (PES) is a means of directly probing electronic states in solids. At BL25SU, the high-resolution PES is possible at excitation energies in the range of 220 to 1500 eV. At low excitation energies ( $\leq 120$  eV) conventionally used for the high resolution PES, PES is a surface sensitive technique because of short photoelectron mean free paths ( $\leq 5$  Å). However at high excitation energies ( $\sim 1$  keV), the mean free paths become as long as 15 Å. This enables us to probe bulk electronic states in solids. The system consists of a GAMMADATA-SCIENTIA SES200 spectrometer combined with a varied line-spacing plane grating monochromator. Angle-resolved PES in the soft X-ray range can also be performed using this system, which provides band dispersions of bulk electronic states.

Excitation energy	220 ~ 1500 eV
Total energy resolution	$\sim 100$ meV at $\sim 1$ keV
Angular resolution	$\sim 0.2^\circ$
Detection angle	$\pm 6^\circ$
Spot size	$\sim 0.1 \times 0.1$ mm $^2$
Sample temperature	20 ~ 300 K

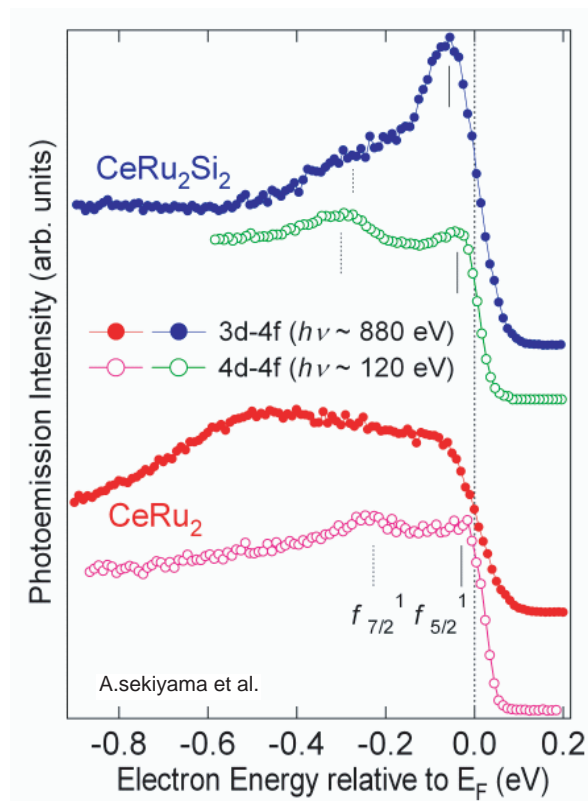


A Schematic view of experimental setup

### Typical data

High-resolution Ce  $4f$  spectra in the  $3d-4f$  (resolution, 100 meV) and  $4d-4f$  (resolution, 50 meV) resonances of  $\text{CeRu}_2\text{Si}_2$  and  $\text{CeRu}_2$ . The line shapes of the  $4d-4f$  RPES are mutually similar, but those of the  $3d-4f$  RPES are drastically

different each other. The different  $3d-4f$  RPES spectral weight are reflecting the substantial bulk  $4f$  states of the compounds, which have not been revealed by the "surface-sensitive"  $4d-4f$  RPES.



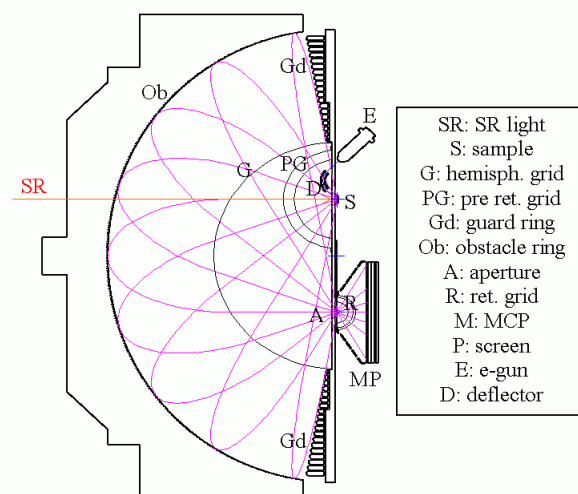
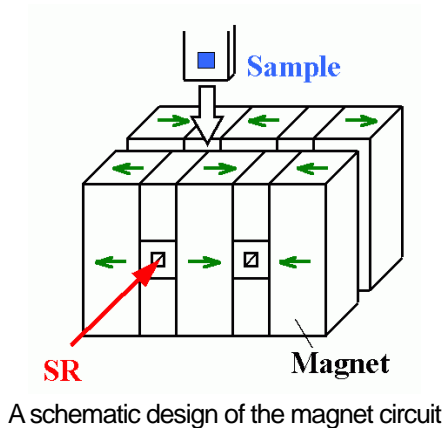
### Reference

A. Sekiyama *et al.*, Nature 403, 396 (2000).

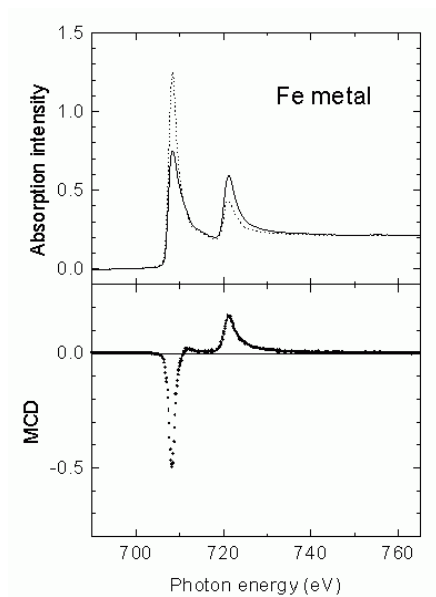
### MCD

Magnetic circular dichroism (MCD) of soft x-ray absorption is a powerful tool to study magnetic and electronic states of ferromagnetic and ferrimagnetic materials. At BL25SU, helicity switching of circularly polarized radiation performed by the twin helical undulators are used for MCD measurements. Two absorption spectra corresponding to an MCD are measured by one energy scan switching the helicity at each energy point. The helicity-switching method is effective for precise measurements. The switching frequency is currently 1 Hz.

Samples are magnetized by a magnet circuit composed of Nd-Fe-B permanent magnets. The direction of the magnetic field (1.4 T) can be reversed with respect to the light direction. Sample temperature can be controlled from 45 K to 300 K. Absorption intensity is measured by means of the total electron yield. A new measurement system with an electromagnet, which applies magnetic fields up to 1.9 T, is now under construction. A combination of the helicity switching technique and the new instrument will provide element selective magnetization measurements in the near future.

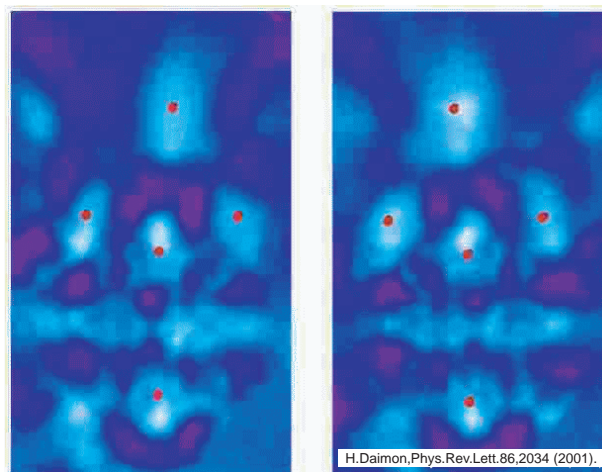


Typical data



A schematic view of display-type spherical mirror analyzer

Typical data



## 2D-PES

A display-type spherical mirror analyzer is employed at this station to study atomic- and spin- arrangements on surfaces. An advantage of this analyzer is that the emitted photoelectrons converge to a focal point keeping their emission angles. Hence we can measure angle-resolved intensity distribution of the photoelectrons at a given kinetic energy. The acceptance solid angle is  $\pm 60^\circ$ . The energy resolution of this analyzer is 0.2% of pass energies. Photoemission diffraction patterns measured using left and right circularly polarized lights provide stereo-photographs of atomic arrangements.

Energy range	200 ~ 1000 eV
Energy resolution	0.25 eV
Acceptance angle	$\pm 60$ deg
Angular resolution	0.6 deg
Spot size	0.4 mm

## Reference

H. Daimon, Phys. Rev. Lett. 86, 2034 (2001).

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