RIKEN Beamline

BL17SU RIKEN Coherent Soft X-ray Spectroscopy

BL17SU is aimed at advancing the spectroscopic studies for mainly solid state physics and materials science using high brilliant soft X-ray undulator radiation. Photoabsorption, photoemission and soft X-ray emission spectroscopies are adopted to investigate the electronic structure of various kinds of materials. The branched beamlines (a and b), which can be switched by the pre-mirror and used alternatively, are planned and the a-branch is ready for use. In the a-branch, there are three experimental stations (A1, A2, and A3). In A1 station, the photon-ion merged-beam apparatus is installed on the slide-rail, and that enables us to open the A1 station for free space where users can connect their own instruments. In A2 station, materials science by high resolution photoemission spectroscopy is performed to study the electronic structure of various kinds of materials. In A3 station, the electronic structure of solid as well as biological samples is investigated using soft X-ray emission spectroscopy.

Area of research

Spectroscopic study on multiply charged ions --- A1a station

Photoabsorption study on multiply charged ions

Fundamental research for X-ray astronomy using synchrotron radiation

High resolution photoemission spectroscopy --- A2 station

Angle-resolved photoemission (ARPES) study using soft X-rays to observe 'bulk' band structure

In situ ARPES measurement on strongly-correlated transition-metal oxide thin films fabricated by laser MBE method

Soft X-ray emission spectroscopy for solid and biological samples --- A3 station

Soft X-ray emission study on transition metal compounds to study electronic correlations in solids

Study of the electronic structure of biological samples by soft X-ray emission spectroscopy

Keywords

Scientific field

Solid state physics, Materials science

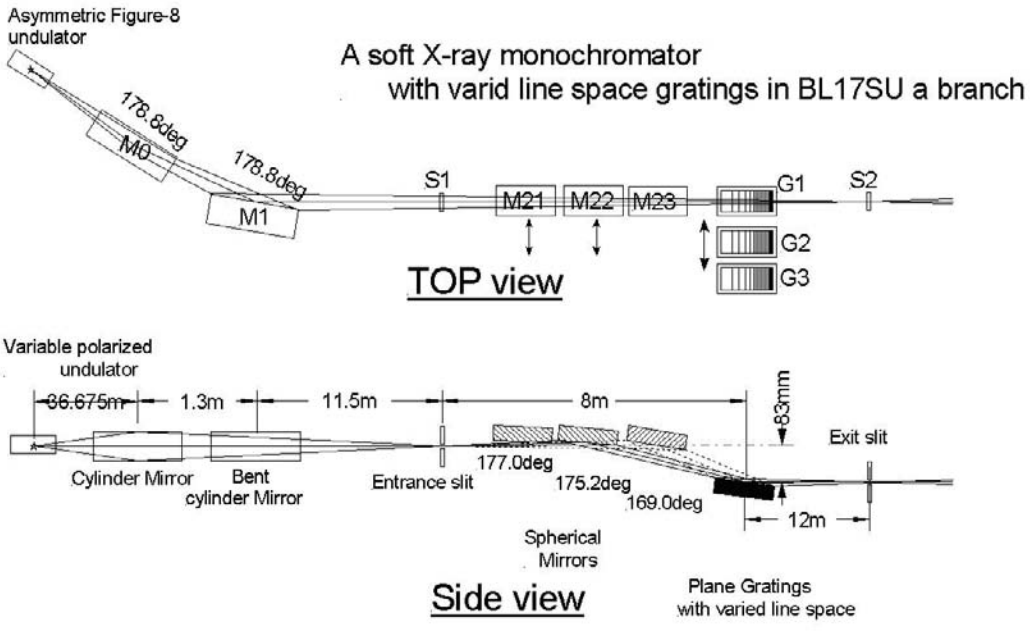
Equipment

High resolution photoelectron spectrometer, High efficiency photon analyzer (HEPA2)

Source and optics

X-rays at sample

Energy range	0.1 ~ 3 keV
Beam size	< 0.5 × 0.5 mm^2



Schematic view of BL17SU optics

Experimental stations

t-station (direct beam station, in optics hutch)

-----Special use for the characterization of undulator light.

a-branch

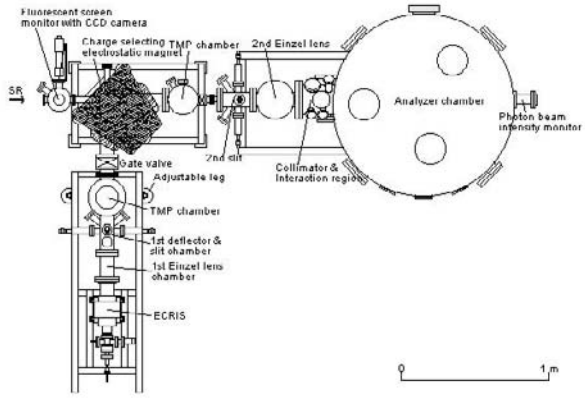
There are three experimental stations (A1, A2, and A3) in a-branch. Soft X-rays from the asymmetric figure-8 undulator is monochromatized by using a high resolution monochromator, which is equipped with varied line spacing plane gratings and covers the photon energy range from 0.1 to 3 keV. The resolving power (E/ΔE) of the monochromator is estimated to be better than 10000. A1 station is located between the exit slit S2 and the re-focusing mirror. A2 and A3 stations are located at their optimum positions where the re-focused photon beams with small spot size (~10 μm in vertical) are available.

ⅰ) A1 station

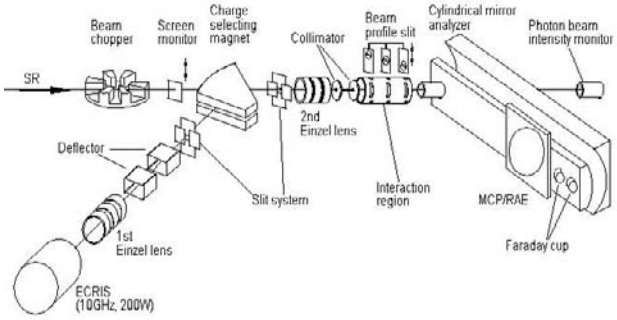
A1 station (Photon-ion merged-beam apparatus)

Photon-ion merged-beam apparatus is designed to study the photo absorption and subsequent relaxation processes on the multiply charged ions (MCI) to clarify their characteristics and electronic structure along isonuclear-, isoelectronic-, and isoionic-sequences. The apparatus consists of an MCI source, a charge-selecting magnet, an interaction region and a charge analyzer for product ions. [1,2] A compact electron cyclotron resonance ion source (ECRIS), composed of FeNdB permanent magnets, is employed as the MCI source and operated with 10 kV extraction voltage. The charge-selecting magnet is a double-focus 90°-sector magnet and covers a mass-to-charge ratio up to 70. The MCI-beams of various gaseous and metallic elements can be produced as the targets for photoabsorption studies. We can measure the two dimensional profiles of photon and ion beams at three points along beam direction in the interaction region. Thus the apparatus enables us to measure the absolute photoionization cross sections in the soft X-ray region through photoion yield spectroscopy.

A1b station (Free station, user can connect their own instruments)



Schematic drawing of the photon-ion merged-beam apparatus



Conceptual drawing of the photon-ion merged-beam apparatus

SR : synchrotron radiation

MCP : micro channel plates

RAE : resistive anode encoder

ⅱ) A2 station (High resolution soft X-ray photoemission spectroscopy with PLD equipment)

Soft X-ray photoemission experimental station equipped with the high resolution photoelectron analyzer (SES2002, Gammadata SCIENTA) is designed for the study on the electronic structure of various kinds of materials. This apparatus enables us to measure the angle-resolved photoemission spectrum using ±7° acceptance angle of photoelectron analyzer, the temperature dependence of the electronic structure down to 10 K using He cryostat as well as the polarization dependence using linearly (vertical and horizontal) and circularly polarized soft x rays. Photoemission apparatus is connected to laser molecular beam epitaxy (laser MBE) equipment in ultra high vacuum, enabling *in situ* observation of the electronic states of transition-metal oxide or nitride thin films fabricated in laser MBE equipment. The time-resolved photoemission spectroscopy using femto-second laser is also ready for the experiment. A time resolution of 40 ps is obtained for 100 fs and 40 ps pulse durations of the laser and the soft X-ray pulses, respectively.

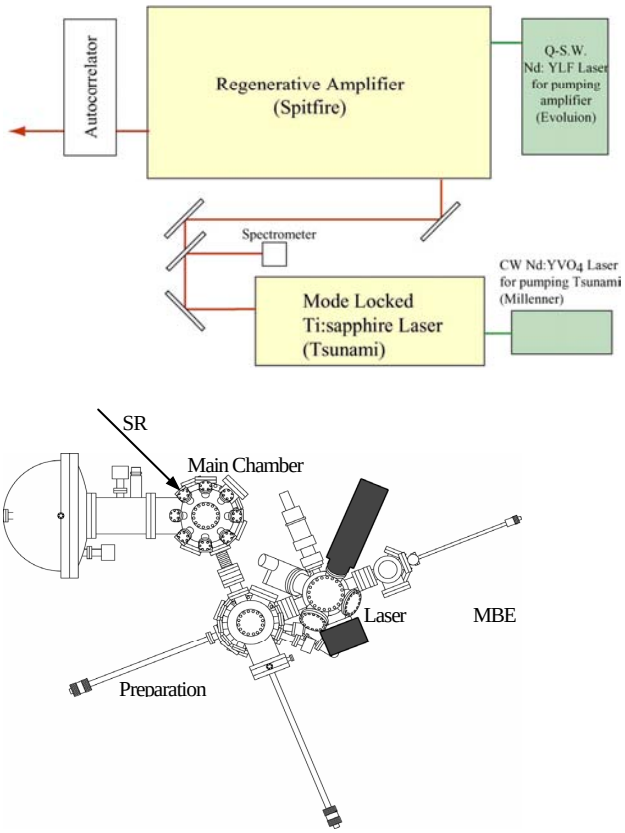
Specifications of laser system

Mode-locked Ti:sapphire laser

Average power	750 mW
Tuning range	720 ~ 850 nm
Pulse width	100 fs
Repetition rate	84.76 MHz

Regenerative amplifier

Pulse energy	1.1 mJ / pulse
Wavelength	800 nm
Pulse width	130 fs
Repetition rate	1 kHz



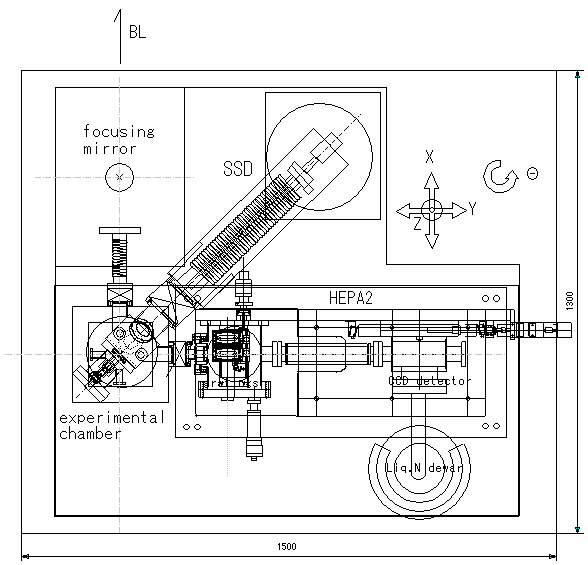
Schematic view of soft X-ray photoemission experimental station

Photograph of soft X-ray photoemission experimental station

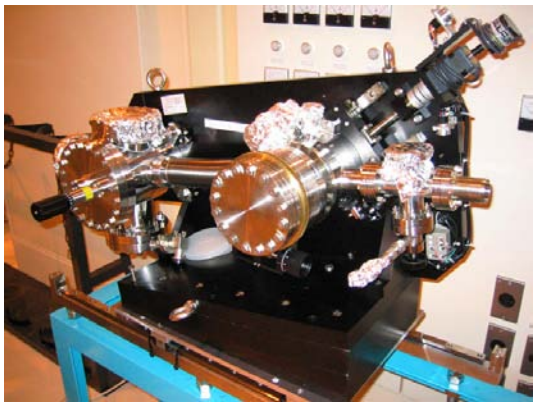
Ti : sapphire laser (Spectra Physics) for the time-resolved photoemission spectroscopy

iii) A3 station (High efficiency photon analyzer)

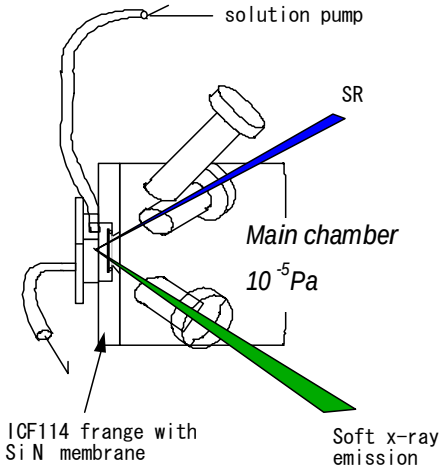
A progress in the study of valence electronic states in solids by using soft X-ray emission has made our interest in the electronic structure of solutions and substances in solutions. In this experimental station, two types of soft X-ray emission experiments are focused : microscopic investigation of a solution itself and study on the electronic structure of a metal center in aqueous metalloproteins. We can directly investigate effect of hydrogen bonding on the electronic structure of solutions, as well as the electronic structure of metal complexes in solutions. A representative of the former is water, where chemical reactions take place for many processes. An example of the latter is myoglobin, where only one iron atom is contained per approximately 16 kDa molecule. To approach the electronic structure of a solution itself, a solution cell has been developed which, by flowing solutions through a channel with external pumping system, enables us soft X-ray experiments free from radiation damage. The flowing channel passes a thin (~ 200 nm) Si_3N_4 membrane that isolates the solution in atmosphere from a high vacuum. The incident and emitted photons interact with the solution passing through the Si_3N_4 membrane. As the soft X-ray emission itself is insensitive to electric and magnetic fields, effect of external fields on solutions will be a future project. For metalloproteins and tiny amount of solutions we apply a sample freezing system on a rotation disk. During experiments frozen samples are placed close to the thin Si_3N_4 membrane and scanned by the rotation of the disk to eliminate signals from damaged part of the samples. Inside the sample chamber a pure helium gas is circulated to increase transmission of incident and emitted soft X-rays.



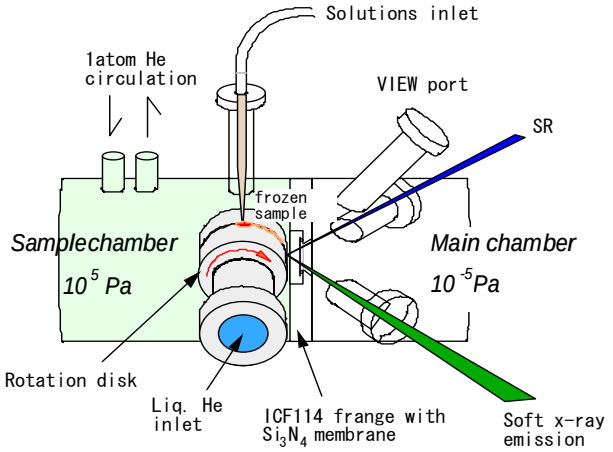
Schematic view of high efficiency photon analyzer (top view)



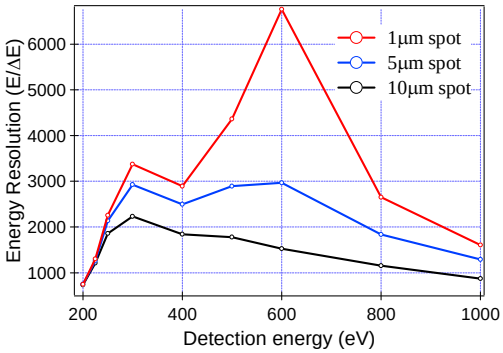
The soft X-ray emission spectrometer (HEPA2) has been developed from the original type of a high efficiency photon analyzer, HEPA, installed in the BL27SU-c3 station. [3] HEPA2 has a varied line spacing cylindrical grating for flat field focusing, a back-illuminated CCD detector with a linear drive, and no entrance slit for high detection efficiency.



A solution cell designed for a solution flow experiment



A sample freezing system for metalloproteins and tiny amount of solutions



Typical energy range and the energy resolution by ray-tracing for HEPA2. The energy resolution depends on the vertical spot size of the incident beam at focused position.

b-branch

----- Under designing

X-rays at sample

Energy range	0.1 ~ 3 keV
Linearly polarized	Horizontal : 0.27 ~ 3 keV
	Vertical : 0.14 ~ 3 keV
Circularly polarized	0.1 ~ 3 keV
Photon flux	> 10^{11} photon/s
Energy resolution	E/Δ E > 10^{4}

Standard equipments

High energy-resolution electron energy analyzer A2 station

SCIENTA SES 2002

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

Soft X-ray emission spectrometer A3 station

Typical energy range : 0.2 ~ 1.0 keV

Energy resolution : > 1000

Parameters of spherical mirrors and gratings

Energy (keV)		1.5 – 3	0.8 – 1.8	0.6 – 1.2	0.3 – 0.6	0.1 – 0.3
Angle (deg)		88.5	88.5	87.6	87.6	84.5
Grating	Grating	G1	G2	G1	G2	G1
	Material	Au / Si	Au / Si	Au / Si	Au / Si	Au / Si
	Groove	1200 / mm	600 / mm	1200 / mm	600 / mm	1200 / mm
Spherical Mirror	Mirror	M21a		M22a		M23a
	Radius (m)	332,971		217,497		98,213
	Material	Au / Si		Au / Si		Au / Si

References

[1] M. Oura, T. M. Kojima, Y. Awaya, Y. Itoh, K. Kawatsura, M. Kimura, T. Koizumi, T. Sekioka, H. Yamaoka and M. Cox, J. Synchrotron Rad. 5, 1058 (1998).

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[3] T. Tokushima, Y. Harada, M. Watanabe, Y. Takata, E. Ishiguro, A. Hiraya and S. Shin, Surf. Rev. Lett. 9, 503 (2002).

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