JAERI Beamlines

Hideo OHNO
Akinori YOKOYA

1. Introduction

Three beamlines, heavy element science (BL23SU), materials science-1(BL14B1) and materials science-2(BL11XU), are being constructed as JAERI beamlines. In this report, the source, layout of front-end and beamline, optics and scientific programs of heavy element science are summarized.

2. Heavy Element Science Beamline (BL23SU)

This beamline is being constructed for research of RI and actinide materials, surface photo chemistry and radiation biology. Although it is preferable that the construction of the beamline for the study of RI materials in an area specialized for the experiments with RI samples, such a beamline is not common in the present synchrotron radiation facilities. Recently, we have installed a beamline for radioactive materials in a second generation synchrotron radiation facility, the Photon Factory in the National Laboratory for High Energy Physics [1]. This beamline provides photons emitted from a bending magnet whose energy ranges from 1.8 to 6.0 keV.

2.1. Light source

A variably-polarized undulator called the "APPLE II type" is installed in this beamline. The undulator emits both linearly and circularly polarized X-rays[2,3]. The energy levels of the soft X-rays are from 0.3 to 1.5keV in the horizontal-polarization mode and from 0.5 to 1.5keV in the circular-polarization mode. The specifications are listed in Table 1. Figures 1a and 1b are spectral data for both the horizontal and circular polarization modes[4].

Table 1 The specification of variably-polarizing undulator

parameter	value		
type	variably-polarizing undulator		
period length	120mm		
number of periods	16 poles		
overall length	1920mm		
circular-polarizing mode			
magnet gap(mm)	39	54	58
K value	3.0	2.0	1.5
1st harm.(keV)	0.5	1.0	1.5
total radiation power (kW)	1.1	0.49	0.27
horizontal-polarizing mode			
magnet gap (mm)	36	63	73
K value	5.5	2.8	2.2
1st harm.(keV)	0.28	1.0	1.5
total radiation power(kW)	1.9	0.49	0.27
brilliance (photons/s/mrad2/mm2/0.1%b.W./100mA)	2 ~ $6x10^{17}$		

2.2 Layout of front-end and beamline

2.2.1 Front-end

Components in the front-end section are designed based on those developed by the JAERI-RIKEN SPring-8 project team[5]. A mask, an absorber and an XY-slit are mounted in the front-end to remove the photons of the off-axis components of the undulator beam. These have a water cooling system to avoid the high heat load by the intense beam.To measure the beam profiles and the centers, photon monitors of the carbon-wire type [6] are installed as a pair to be set at 10 and 20m from the light source, respectively. The change of the photon-beam position or direction caused by an error in the magnetic field of the undulator is calculated using signals from the position monitors at each gap or phase. The series of the data will be stored and used as parameters to control two steering magnets which are set at the just up- and down-stream of the undulator. A beam position monitor made of a graphite filter with an aperture size is used for the interlock system to avoid the beam irradiating on the wall of the vacuum chamber.

2.2.2 Beamline components

The beamline is to be installed at the BL23SU section of the SPring-8. The components of the beamline is schematically drawn in Fig.2. The beamline has three-experimental stations in a tandem fashion: an electron spectroscopy, surface photo chemistry and biological application station. To focus and monochromatize the soft X-ray undulator beam, two prefocusing mirrors, an entrance slit, a grating mono-chromator and an exit slit are set at about 30, 40, 52 and 64m from the light source point respectively. Two post-focusing mirrors are also set at downstream of the exit slit. The characteristics of the beamline are that the actinide science station is located in a building of SPring-8 for the Hot Sample Area (HSA) separated from the normal experimental area. The other two stations are placed at the normal area.

2.2.3. Special apparati to protect the beamline from RI pollution

The beamline has some mechanisms to protect users, the experimental devices or the storage ring from the intrusion of the RI pollution. A long beam-transport pipe containing seventy disks is mounted between the two buildings. The pipe is expected to delay acoustic waves from an accidental vacuum breakage. Three fast closing gate valves are closed immediately after an accidental vacuum-break occurs. Three RI inspection ports [1] and a vacuum chamber equipped with NaI counter or quadropole mass spectrometer permit the inspection of radioactivity inside the beamline without breaking the ultra-high vacuum.

2.3. Optics

The basic concept for the monochromator is adopted in the SPring-8 public-beamline for electron-spectroscopy studies of condensed matter at BL25SU[7-9]. The monochromator is equipped with three varied line spacing plane-gratings [10] that cover the energy region from 0.28 to 1.5 keV. The energy resolution of the monochromator, $E/\Delta E$, will be over 10000 in the whole energy range.

To focus the undulator beams, two pre-focusing mirrors, Mv and Mh, and two post-focusing mirrors, M3 and M4, are used. The cylindrical mirror, Mv, and the plane mirror, Mh, are placed at 40.0 and 42.5m from the source,respectively. A sagital-focusing system was adopted for Mv which focuses the beam in the horizontal direction on the entrance slit. Mh focuses in the vertical direction with a mechanical bending system. The incident angles of beam on the mirrors are 88.5 degrees. Both mirror systems have a water-cooled mirror holder. The troidal mirrors, M3 and M4, are used to refocus the monochromatized beams in vertical and horizontal directions on the actinide science station. The specification of the optical components is listed in Table 2.

Table 2 Specifications of the optical components.

distance from source	optical element size(mm)	incident angle (degree)
38m	plane mirror(Mx) with water cooling system(400x40x20)	88.5
39m	cylindrical mirror (Mh) with water cooling system (500x40x20)	88.5
40m	spherical mirror (Mv) with water cooling system (400x40x20)	88.5
49.3m	plane mirror (My) with water cooling system	88.0
50-71.9m	constant deviation (M1:350x40x20)	88.5
	monochromator with varied -space plane ratings(S1-M1 or M2-G-S2)with water cooling system M2:350x40x20 G: 220x50x20	88.7
73m	cylindrical mirrors (M3:400x40x10)	89.0
74m	cylindrical mirrors (M4:400x40x10)	88.0

2.4 Scientific programs

2.4.1 Electronic structures of 5f compounds

In the photoelectron-spectroscopy station at the Hot Sample Area, we will measure the magnetic circular dichroism (MCD) of the ferro-magnetic actinide compounds, and conduct the photoelectron spectroscopy (PES) experiments of the heavy-fermion compounds with high energy-resolution to clarify the physical properties of actinide compounds from the viewpoint of electronic structures.

MCD provides us with local information of magnetism, e.g., the element-specific magnetic moment, spin-orbit interaction and the origin of magnetic anisotropy [11,12]. The valence PES by means of the resonant photoemission would reveal the 5f partial density-of-states (DOS). In addition, analyses of the 5f DOS structure and the core-level spectrum using an appropriate theoretical model will supply advantageous knowledge about the electron correlation effects, e.g., hybridization between 5f and conduction states, Coulomb interaction between 5f electrons, etc.

2.4.2 Surface photo chemistry

Surface chemistry is also one of the important subjects studied in this beamline. Application of the high brilliant soft X-rays provides some advantages for the study of surface reaction dynamics such as photon stimulated desorption, surface photolysis and thermally induced surface rearrangement.

An interesting topic is that resonant inner-shell excitation at specific atoms in molecules can cause the photochemical reactions to be atom(site)-selective. Such instances have been demonstrated as the atom-selective fragmentation for gaseous molecules, atom-selective desorption, and bond-selective desorption from surfaces. These studies are considered to serve in the further understanding of technologically important photon induced etching and chemical vapor deposition. In addition, it is shown and is of great interest that the photon induced surface reaction gives significantly different reaction-products from those through thermal reaction. High energy-resolutional soft X-rays allow us to analyze the chemical state, geometry, and adsorption site of these products on surfaces, in detail, using X-ray photoelectron, X-ray absorption near edge structure, and photon stimulated desorption spectroscopies.

Two detection systems will be developed for the analysis of the neutral and ionic species desorbed from the reaction layers. First, a resonantly-enhanced multiphoton ionization (REMPI) detection system combined with high power lasers and a time-of-flight (TOF) mass-spectrometer is designed to obtain information on the soft X-ray photochemical reaction. Secondary, an electron-ion coincidence system is constructed by using the TOF mass-spectrometer and the hemispherical electron energy analyzer to obtain more detailed information on the pathway of surface fragmentation and ionic desorption.

2.4.3 Biological applications of site-selective soft X-ray absorption

Effects of the site-selective photoabsorption on biological molecules will be investigated at the experimental station by paying attention to the identification of the intermediate and the final photoproducts as well as the measurement of optical cross sections of biological samples. The high brilliance and the high resolving power of this beamline make it possible to show new approaches to the research area.

The first is a photoproduct detection system using an electron paramagnetic resonance (EPR) apparatus installed in the beamline. The EPR measurement at low temperatures realizes the in-situ detection of radical species as the intermediate products. A small single crystal of biological samples such as DNA-related molecules or amino acids will be irradiated with the linearly or the circularly polarized soft X-rays in the vacuum chamber of the EPR cavity.

Secondly, a 'site-selective' inner shell photoabsorption on carbon, nitrogen or oxygen, which are abundant in the biological system, is used to control the energy-deposition site in the sample. The photo-absorption spectrum of the sample is measured by a photo diode-detection system in another chamber located at the upper-stream of the EPR to obtain the data of photoabsorption cross-sections of the sample. After irradiation, the final stable photoproducts in the sample will be investigated by biochemical techniques such as chromatography.

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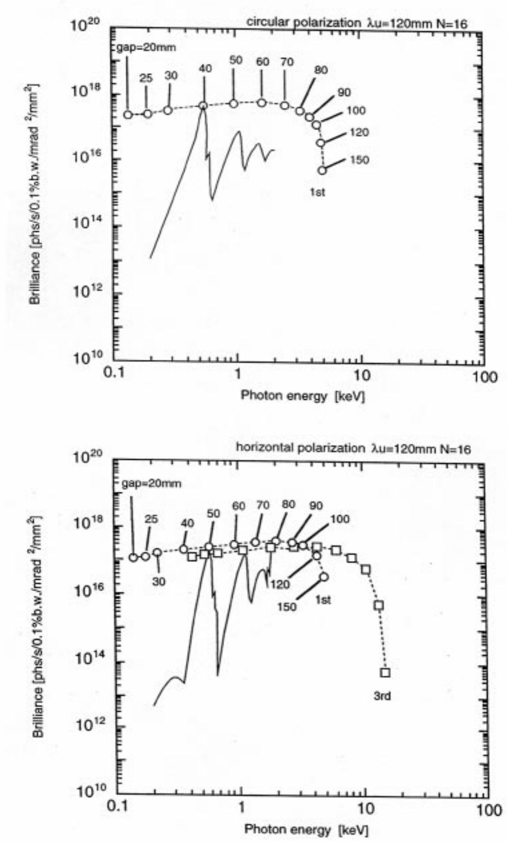

Figure 1: Brilliance of the undulator radiation as a function of gap distance at a) curcular and b) linear polarization mode. the solid lines indicate the spectrum at the magnet gap is a) 40 and b) 50mm.

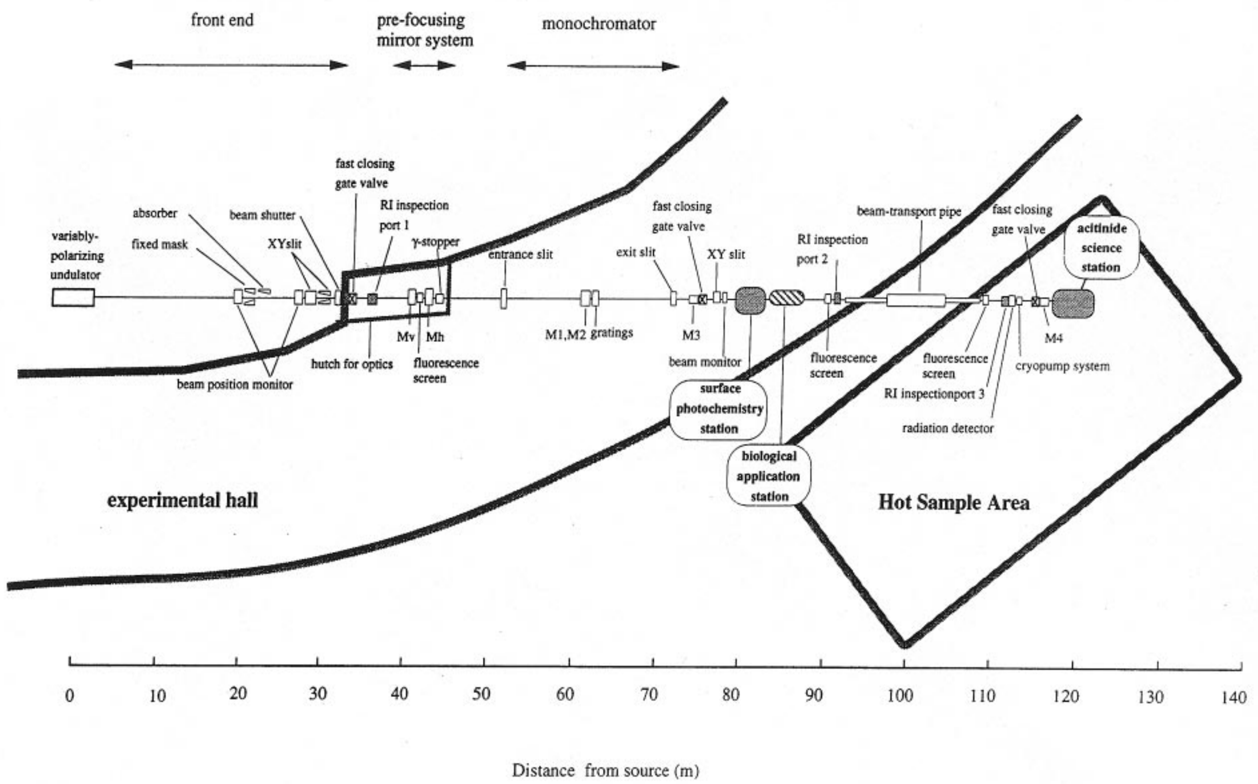

Figure 2: Schematic illustration of a layout of the whole beamline system on BL23SU