Light Source in 2004

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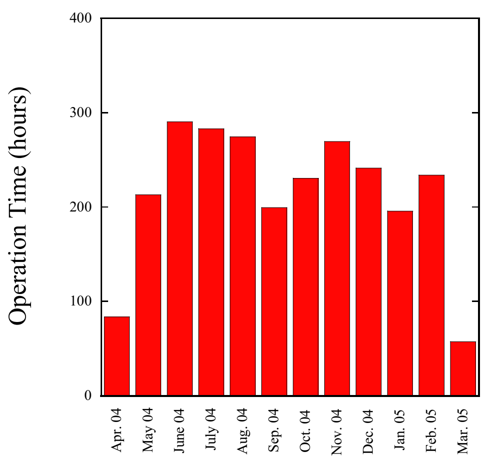
1. Status of UVSOR-II

In the fiscal year 2004, we have operated the UVSOR-II accelerators from May '04 to March '05. We had two shut-down periods, in April '04 and March '05. The former was to install a new vacuum chamber for the bending magnet, B6. This chamber was specially designed and constructed for the infrared beam-line BL6B(IR) [1]. The latter was to install the new RF accelerating cavity. The new cavity has capability of producing three times stronger accelerating field. We also stopped the operation for one week in September for some maintenance works and for two weeks around the New Years day.

We had only a few troubles on the accelerators during FY2004. The most serious one happened on the power supply of the booster-synchrotron magnets, which has been working for more than 20 years. Fortunately, the power supply was soon recovered by replacing the broken electronic device. The users operation was canceled only for one day. This power supply will be replaced in FY2006. The new one will have capability of increasing the maximum beam energy of the booster synchrotron from 600 MeV to 750 MeV. Then, we will be able to inject a full energy electron beam into the storage ring.

We had 36 weeks for the users operation in multi-bunch mode and had two weeks in single bunch mode. We had two weeks dedicated for machine studies. The monthly statistics of the operation time and the integrated beam current are shown in Figures 1. The normal operation pattern in a week is as follows. From Tuesday to Friday, the machine is operated for users. The beam injection is twice a day, at 9:00 and 15:00. The initial beam current of each run is 350 mA in multi-bunch mode and 100 mA in single bunch mode. On Monday, the machine is operated for machine studies.



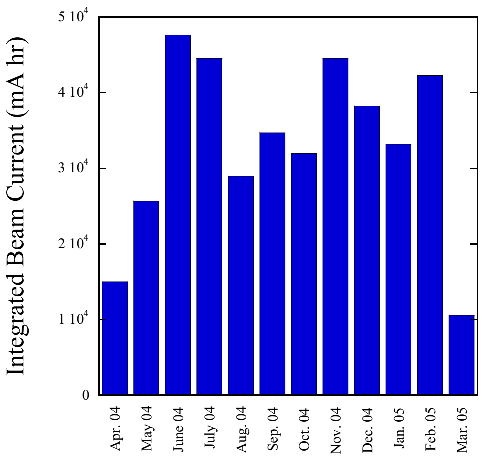


Fig. 1 Monthly statistics of the operation time (left) and Monthly statistics of the integrated beam current (right).

2. Improvements

New Vacuum Chamber for the Bending Magnet B6

The vacuum chamber of the bending magnet B6 was replaced in spring, 2004. The BL6A1 was an infrared beam-line, which had been in operational for many years [2]. This beam-line was converted to a new infrared beam-line BL6B, which would be the world most powerful beam-line in the far infrared regime. To construct this beam-line, we replaced the vacuum chamber of the bending magnet B6. The new chamber has a mirror room directly connected to the bending beam pipe, as shown in Figure 2. In this chamber, a distributed sputtering ion pump (DIP), a normal sputtering ion pump (SIP) and a titanium sublimation pump (TGP) are installed. Two sets of the button type beam position monitor were installed at the both ends. The chamber was made of stainless steel. The chamber was installed in the ring and baked. The vacuum was almost recovered after the high current operation for a few weeks.

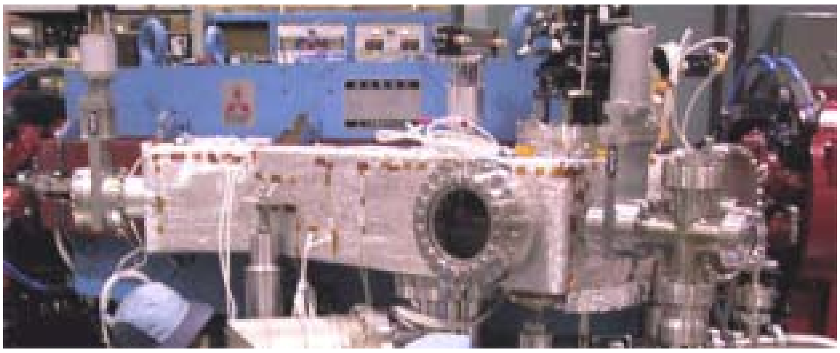


Fig. 2 New Bending Chamber for B6 just after the installation.

New RF Accelerating Cavity

In the fiscal year 2004, the new RF cavity will be constructed [3]. With the present RF power source whose maximum output power is 20 kW, the new cavity will produce 150 kV accelerating voltage for the beam current of 500 mA. This will greatly improve the Touschek lifetime.

The new cavity was delivered in March 2005. The old cavity was removed from a straight section between the bending magnet B6 and B7. In this section, a short in-vacuum undulator is in operation. This undulator will move to another short straight section. Then, this section will be available for a new long undulator. The new cavity was installed in the short straight section between B1 and B2.

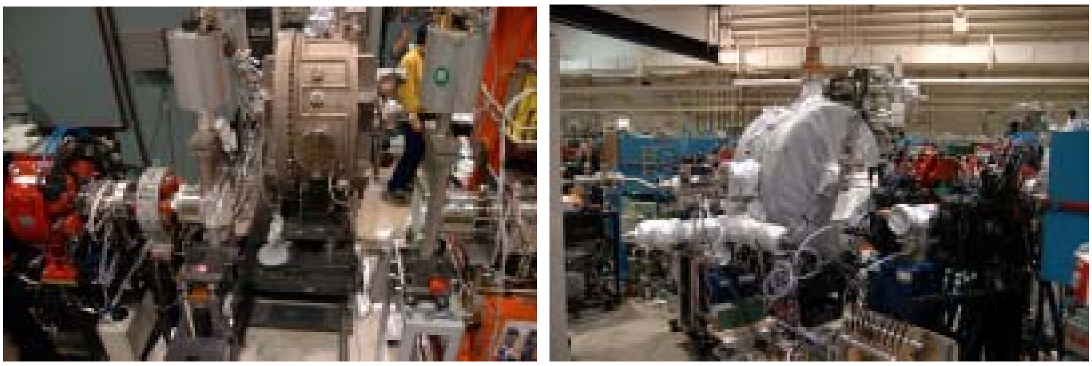


Fig. 3 Old (left) and new (right) RF cavities.

3. Researches and Developments

Free Electron Laser

The smaller emittance of UVSOR-II has increased the gain of the free electron laser [4]. We have succeeded in oscillating in deep UV region around 250 nm with an average power of a few hundred mW, as shown in Fig. 4. The reinforcement in the RF accelerating system is expected to increase the FEL gain more. We will try an oscillation in VUV region in near future.

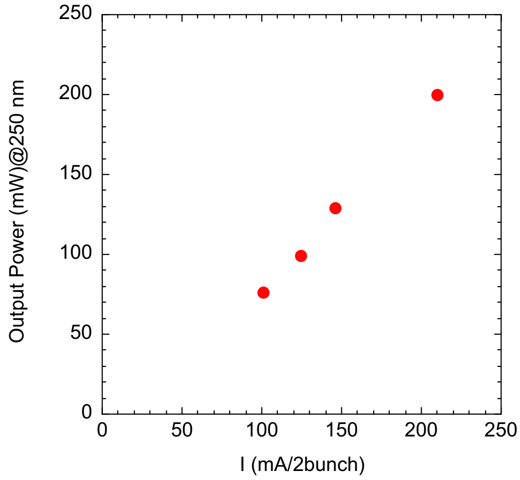


Fig. 4 Average Output Power of the Free Electron Laser oscillating at 250 nm.

Observation of Terahertz Bursts

At the UVSOR-II storage ring, possible coherent synchrotron radiation was observed in the wavelength region between 0.2 and 3.0 mm [5]. Bursts of terahertz emission were detected, as shown in Fig. 5 when the ring was operated in single bunch mode and the beam current exceeded a certain threshold current, typically around 100 mA. Typical duration and interval of the bursts are about 200 micro-seconds and 10 - 15 milliseconds, respectively. Each burst contains many peaks and shows quasi-periodicity of about 30 micro-seconds. The peak intensities of the bursts are 10000 times higher than that of normal synchrotron radiation in the same wavelength region. The threshold current depends on the operation condition of the storage ring, especially that of the RF system.

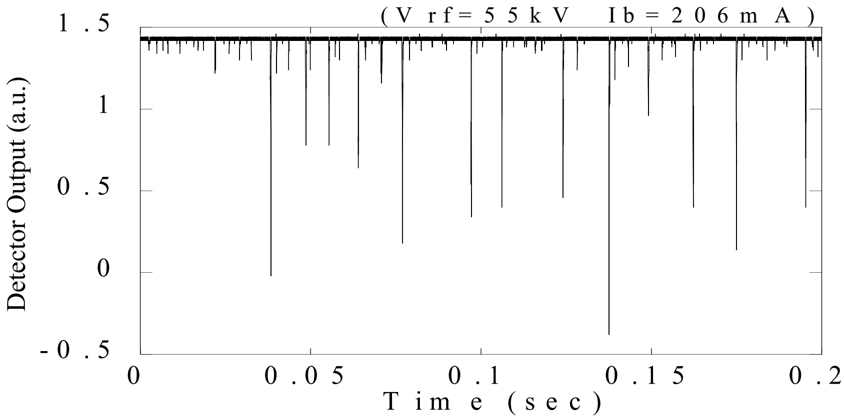


Fig. 5 Terahertz Bursts observed at BL6B(IR) in a single bunch operation.

[1] S. Kimura, E. Nakamura, J. Yamazaki, M. Katoh, T. Nishi, H. Okamura, M. Matsunami, L. Chen, T. Nanba, Proceedings of 8th International Conference on Synchrotron Radiation Instrumentation (2004) 416.

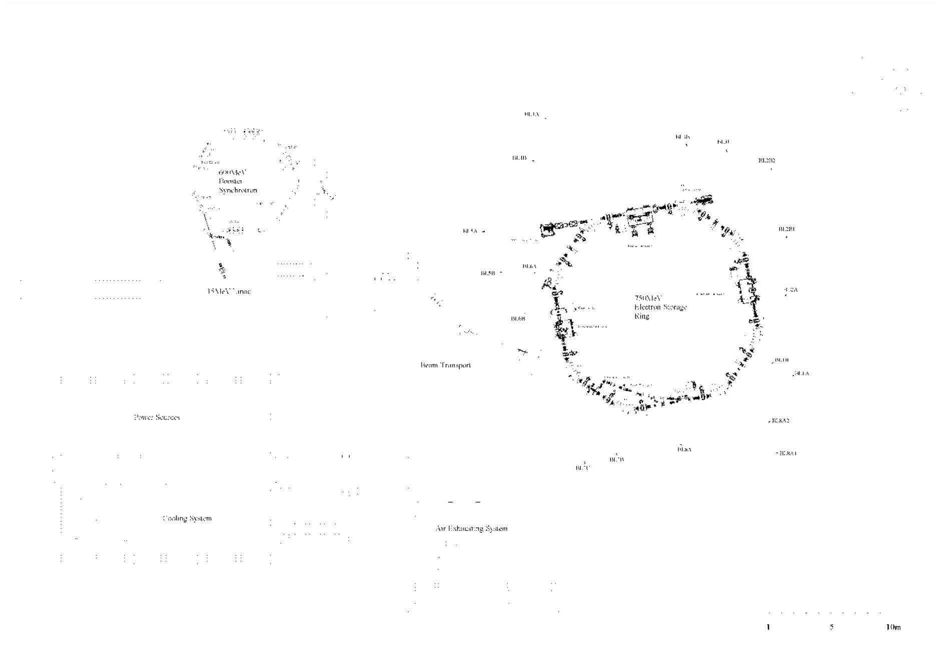
[2] T. Nanba *et al.*, Int. J. Infrared and Millimeter Waves **7** (1986) 1769.

[3] A. Mochihashi *et al.*, in this report.

[4] M. Hosaka, M. Katoh, A. Mochihashi, J. Yamazaki, K. Hayashi, Y. Takashima, Nucl. Inst. Methods Phys. Res. A **528** (2004) 291.

[5] Y. Takashima *et al.*, in this report

Parameters of UVSOR Accelerator Complex



Accelerator complex in the UVSOR facility

Parameters of UVSOR-II Storage Ring

Energy	750 MeV
Injection Energy	600 MeV
Maximum Stored Current	500 mA (multi bunch) 100 mA (single bunch)
Natural Emittance	27.4 nm-rad
Circumference	53.2 m
RF Frequency	90.1 MHz
Harmonic Number	16
Bending Radius	2.2 m
Lattice	Extended DBA × 4
Straight Section	(4 m × 4) + (1.5 m × 4)
RF Voltage	55 kV
Betatron Tune Horizontal Vertical	 3.75 3.20
Momentum Compaction	0.028
Natural Chromaticity Horizontal Vertical	 -8.1 -7.3
Energy Spread	4.2×10^{-4}
Natural Bunch Length	160 ps

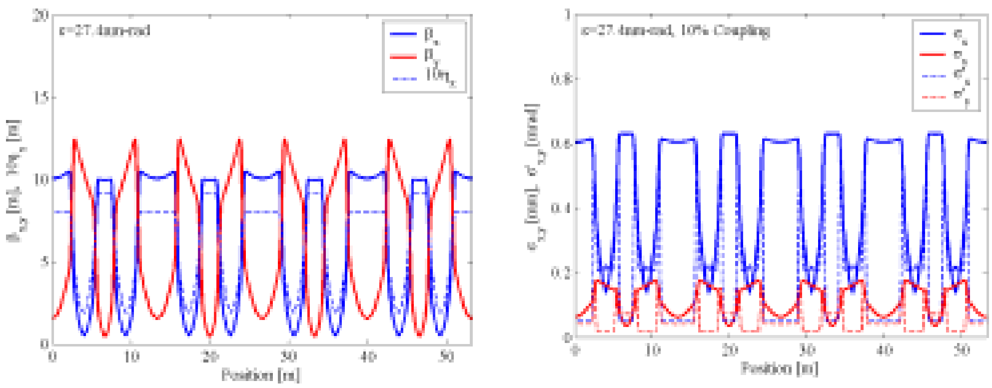
Parameters of Injection Linear Accelerator

Energy	15 MeV
Length	2.5 m
Frequency	2856 MHz
Accelerating RF Field	2π/3 Traveling Wave
Klystron Power	1.8 MW
Energy Spread	~ 1.6 MeV
Repetition Rate	2.6 Hz

Parameters of Booster Synchrotron

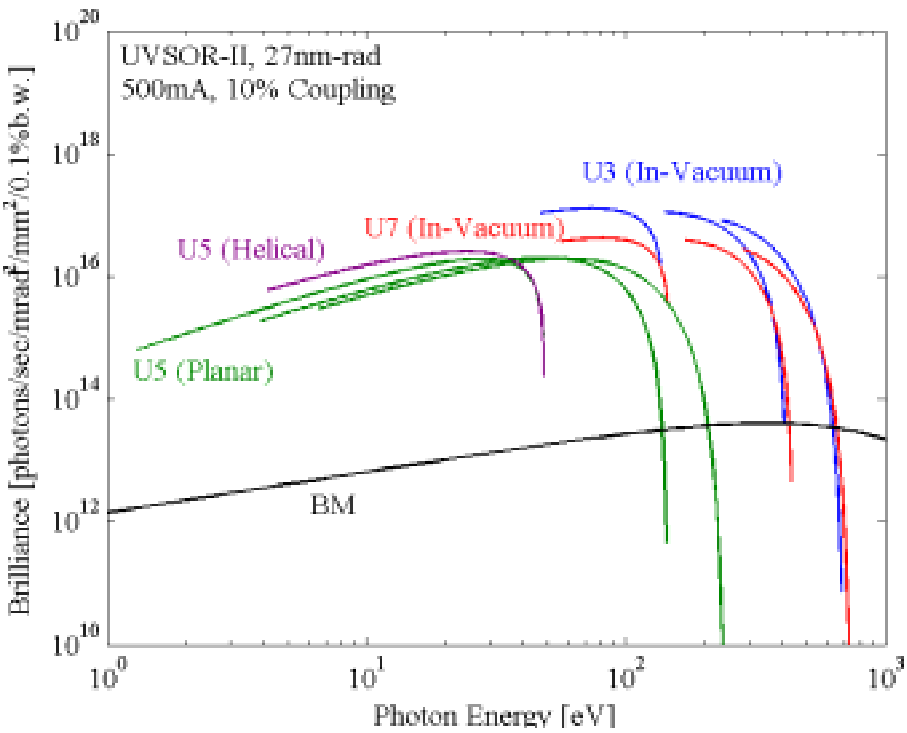
Energy	600 MeV
Injection Energy	15 MeV
Beam Current	32 mA (uniform filling)
Circumference	26.6 m
RF Frequency	90.1 MHz
Harmonic Number	8
Bending Radius	1.8 m
Lattice	FODO × 8
Betatron Tune	
Horizontal	2.25
Vertical	1.25
Momentum Compaction	0.138
Repetition Rate	2.6 Hz

Electron Beam Optics of UVSOR-II Storage Ring



Horizontal/vertical betatron functions and dispersion function (left), and horizontal/vertical electron beam sizes and beam divergences (right) of UVSOR-II

Parameters of the insertion devices



Brilliance of radiation from the insertion devices (U3, U5 and U7) and a bending magnet of UVSOR-II

BL3U In-vacuum Undulator

Number of Periods	50
Period Length	38mm
Pole Length	1.9 m
Pole Gap	15~40mm
Deflection Parameter	2.0~0.24

BL7U In-vacuum Undulator

Number of Periods	26
Period Length	36mm
Pole Length	0.94m
Pole Gap	15~40mm
Deflection Parameter	2.0~0.19

BL5U Helical Undulator / Optical Klystron

Number of Periods	21 / 9+9(Opt. Kly.)
Period Length	110mm
Pole Length	23.5mm
Pole Gap	30~150mm
Deflection Parameter	4.6~0.07(Helical) 8.5~0.15(Linear)

Bending Magnets

Bending Radius	2.2 m
Critical Energy	425 eV

Beamlines in 2004

Eiji SHIGEMASA
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Eight bending magnets and three insertion devices are available for utilizing synchrotron radiation at UVSOR. There is a total of sixteen operational beamlines, which are classified into two categories. Eight of them are so-called "Open beamlines", which are open to scientists of universities and research institutes belonging to the government, public organizations, private enterprises and those of foreign countries. The rest of the eight beamlines are so-called "In-house beamlines", and are dedicated to the use of research groups within IMS. We have one soft X-rays station equipped with a double-crystal monochromator, seven extreme ultraviolet and soft X-rays stations with a grazing incidence monochromator, three vacuum ultraviolet stations with a normal incidence monochromator, one infrared (IR) station equipped with Fourier-Transform interferometers, one station with a multi-layer monochromator, and three non-monochromatized stations for irradiation of white-light, as shown in the appended table for all available beamlines at UVSOR.

Discussion with users, concerning the improvements and upgrades of the beamlines at UVSOR, has been continuously held as series of UVSOR workshops. The upgrade project of the UVSOR storage ring, in which the creation of four new straight sections and the achievement of much smaller emittance (27 nm-rad) were planned, has been approved in the fiscal year of 2002 and has been accomplished on schedule. Keeping pace with this project, a new in-vacuum undulator and high performance monochromator for BL3, and a new high-resolution photoelectron energy analyzer for the end station at BL5U, have been successfully installed. The renewal of the vacuum duct at BL6 has been made during the regular shutdown in the spring of 2004. In coincidence with this, a so-called magic mirror has been installed as the first mirror for a new IR beamline, BL6B. It has been confirmed that the highest intensity in the world, has been achieved in the wavelength range from sub-milli to near IR region. Two vacant lots are left at BL2A and BL6A to construct novel beamlines. A new RF cavity has been installed to the short straight section between B01 and B02 before the end of March 2005; BL2A will be a bending-magnet beamline while BL6A is to be an undulator one, which will be called BL6U. Regarding the utilization for the long straight section between B06 and B07, a UVSOR workshop has been held in March 2005. On the basis of the review and evaluation report on the present status of UVSOR in 2004, a high resolution and high flux variable polarization beamline for spectroscopy in the VUV range has been proposed and possible scientific cases performed on this beamline have been discussed. Further serious discussion toward utilizing the available straight sections most effectively and formulating a basic plan on the beamline construction, will be continued.

All users are required to refer to the beamline manuals and the UVSOR guidebook (latest revision in 1999), on the occasion of conducting the actual experimental procedures. Those wishing to use the open and in-house beamlines are recommended to contact the stationmaster/supervisor and the representative, respectively. For updated information of UVSOR, http://www.uvsor.ims.ac.jp/.

Station Masters and Supervisors of Open Beamlines in FY2004

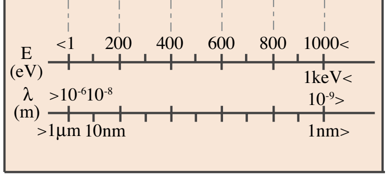
Beamline	Station Master	Sub Master	Supervisor
1A	N. Kondo	E. Shigemasa	E. Shigemasa
1B	M. Hasumoto	S. Kimura	S. Kimura
5U	T. Ito	S. Kimura	S. Kimura
5B	M. Hasumoto	E. Nakamura	E. Shigemasa
6B	S. Kimura	E. Nakamura	S. Kimura
7B	M. Hasumoto	S. Kimura	S. Kimura
8A	E. Nakamura	Y. Hikosaka	E. Shigemasa
8B1	Y. Hikosaka	E. Nakamura	E. Shigemasa

Representatives of In-House Beamlines in FY2004

Beamline	Representative	Affiliation
2B	K. Mitsuke	Dep. VUV Photoscience
3U	N. Kosugi	Dep. VUV Photoscience
3B	K. Mitsuke	Dep. VUV Photoscience
4A1	T. Urisu	Dep. VUV Photoscience
4A2	T. Urisu	Dep. VUV Photoscience
4B	E. Shigemasa	UVSOR
7U	T. Urisu	Dep. VUV Photoscience
8B2	T. Urisu	Dep. VUV Photoscience

Beamlines at UVSOR-II

Beam-line	Monochromator, Spectrometer	Energy Region (eV)	Experiments	Beamline master
1A	Double-Crystal	600 eV – 4 keV	Solid (Absorption)	N. Kondo nkondo@ims.ac.jp
1B	1m Seya-Namioka	1.9 eV – 40 eV	Solid (Reflection, Absorption)	M. Hasumoto hasumoto@ims.ac.jp
2B	18m Spherical Grating	20 eV – 200 eV	Gas (Photoionization, Photodissociation)	K. Mitsuke mitsuke@ims.ac.jp
3U	Varied-Line-Spacing Plane Grating (Monk-Gillieson)	40 eV – 600 eV	Gas (Photoionization, Photodissociation), Solid (Photoemission)	T. Hatsui hatsui@ims.ac.jp
3B	3m Normal Incidence (Dragon)	3 eV – 40 eV	Gas (Photoemission)	K. Mitsuke mitsuke@ims.ac.jp
4A1	Multi-Layered-Mirror	50 eV – 95 eV	Irradiation	T. Urisu urisu@ims.ac.jp
4A2	None		Irradiation	T. Urisu urisu@ims.ac.jp
4B	Varied-Line-Spacing Plane Grating (Monk-Gillieson)	80 eV – 800 eV	Gas (Photoionization, Photodissociation), Solid (Photoemission)	E. Shigemasa sigemasa@ims.ac.jp
5U (FEL)	None (Optical Klystron)		Free Electron Laser	J. Yamazaki yamazaki@ims.ac.jp
5U	Spherical Grating (SGM-TRAIN*)	5 eV – 250 eV	Solid (Photoemission)	T. Ito tito@ims.ac.jp
5B	Plane Grating	5 eV – 600 eV	Calibration, Solid (Absorption)	M. Hasumoto hasumoto@ims.ac.jp
6B (IR)	Martin-Puplett FT-FIR, Michelson FT-IR	0.25 meV – 2.5 eV	Solid (Reflection, Absorption)	S. Kimura kimura@ims.ac.jp
7U	None		Irradiation	Y. Nonogaki nonogaki@ims.ac.jp
7B	3m Normal Incidence	1.2 eV – 30 eV	Solid (Reflection, Absorption)	M. Hasumoto hasumoto@ims.ac.jp
8A	None or Filters		Irradiation, Users' Instruments	E. Nakamura eiken@ims.ac.jp
8B1	15m Constant Deviation Grazing Incidence	30 eV – 600 eV	Solid (Absorption)	Y. Hikosaka hikosaka@ims.ac.jp
8B2	Plane Grating	1.9 eV – 150 eV	Solid (Photoemission)	D. Yoshimura daisukey@ims.ac.jp



* Spherical Grating Monochromator with Translating and Rotating Assembly Including Normal incidence mount

BL1A

Soft X-Ray Beamline for Photoabsorption Spectroscopy

BL1A is a soft X-ray beamline for photoabsorption spectroscopy. The beamline is equipped with a focusing premirror and a double crystal monochromator [1]. The monochromator serves soft X-rays in the energy region from 585 to 4000 eV by using several kinds of single crystals such as β-Al_2O_3, beryl, KTP ($KTiOPO_4$), quartz, InSb, and Ge. The throughput spectra measured by a Si photodiode (AXUV-100, IRD Inc.) are shown in Fig. 1. Typical energy resolution (E/ΔE) of the monochromator is about 1500 for beryl and InSb. There are no experimental setups specific of this beamline, except for a small vacuum chamber equipped with an electron multiplier (EM) detector. Photoabsorption spectra for powdery samples are usually measured in a total electron yield mode, with the use of the EM detector.

[1] Hiraya *at al*, Rev. Sci. Instrum., **63**, 1264 (1992).

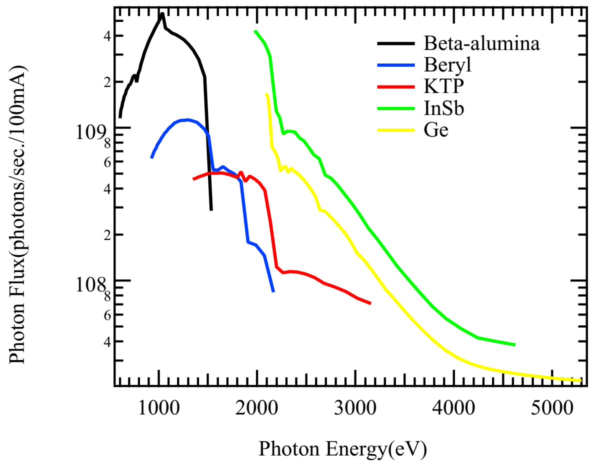


Fig. 1 Throughput spectra of the double crystal monochromator at BL1A.

Fig. 2 A side view of BL1A.

Beamline Specifications

Monochromator	Double crystal monochromator
Monochromator crystals: (2d value, energy range)	β-Al_2O_3 (22.53 Å, 585-1609 eV), beryl (15.965 Å, 826-2271 eV), KTP (10.95 Å, 1205-3310 eV), quartz (8.512 Å, 1550-4000 eV), InSb (7.481 Å, 1764-4000 eV), Ge (6.532 Å, 2094-4000 eV)
Resolution	E/ΔE = 1500 for beryl and InSb
Experiments	Photoabsorption spectroscopy

BL1B

Seya-Namioka Monochromator for General Purposes

BL1B has been constructed to perform various spectroscopic investigations such as absorption, reflectivity, and luminescence in condensed matters. This beamline consists of a pre-focusing mirror, a 1-m Seya-Namioka type monochromator, and post-focusing mirrors with different focal lengths. Three gratings of 600, 1200, and 2400 l/mm can cover the wavelength region ranging from 40 to 650 nm ($h\nu = 2 - 30$ eV). The post mirror with a longer focal length is usually used with an LiF window to separate the vacuum condition of the monochromator from a main experimental station, which make experiments for liquids and bio-specimens possible, while the other is mainly utilized for solid-state spectroscopy. The output flux from this monochromator is about 10^{10} photons/sec. around 200 nm with 0.1 mm slit openings. The spectral distributions for two gratings measured by a conventional photomultiplyer are shown in Fig. 1. A second monochromator (Spex 270M) and a LN-cooled CCD detector (Princeton Inc.) are available for luminescence measurements, together with a liquid helium-flow type cryostat. To perform time-resolved experiments, a TAC system is also available.

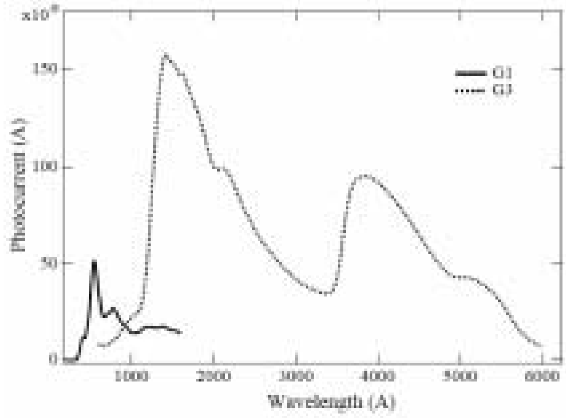


Fig. 1 Photocurrent at the sample position at BL1B.

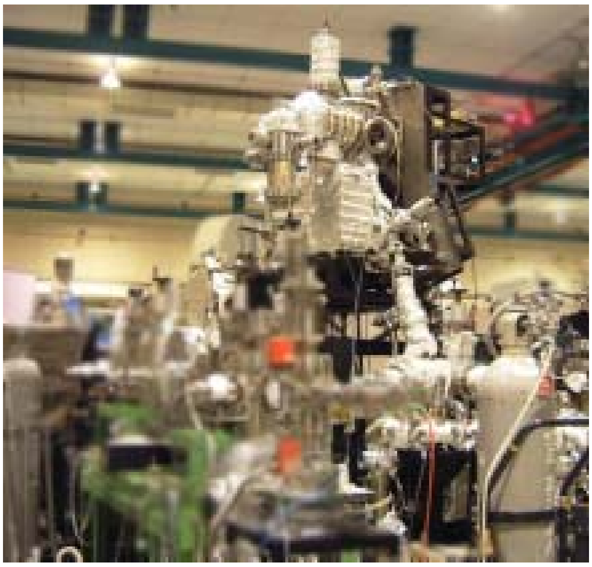


Fig. 2 Photo of BL1B.

Beamline Specifications

Monochromator	1-m Seya-Namioka type
Wavelength Range	40 to 600 nm (2-30 eV)
Resolution	E/ΔE~1000 at 100 nm (10 eV)
Experiment	Absorption, reflection, luminescence spectroscopy for solids

BL2B

Beamline for Gas Phase Photoionization and Reaction Dynamics

This beamline has been developed for the purpose of studying ionization, excitation and decay dynamics involving inner-valence electrons, 2*p* electrons of the third row atoms, and 4d electrons of the lanthanides. The monochromator is a spherical grating Dragon-type with 18-m focal length. High throughput (1×10^{10} photons s^{-1}) and high resolution ($E/\Delta E$ = 2000 - 8000) are achieved simultaneously under the condition of the ring current of 100 mA [1]. A second-order light of 7 % is contained at a photon energy of 45.6 eV (G3). The optical system consists of two prefocusing mirrors, an entrance slit, three spherical gratings (G1 - G3), two folding mirrors, a movable exit slit and a refocusing mirror [2]. The monochromator is designed to cover the energy range of 23 - 205 eV with the three gratings: G1 (2400 lines mm^{-1}, R = 18 m) at 80 - 205 eV; G2 (1200 lines mm^{-1}, R = 18 m) at 40 - 100 eV; G3 (2400 lines mm^{-1}, R = 9.25 m) at 23 - 50 eV.

We have been taking photoion yield curves of various fullerenes. Geometrical structures and electronic properties of fullerenes have attracted widespread attention because of their novel structures, novel reactivity, and novel catalytic behaviors as typical nanometer-size materials. However, spectroscopic information is very limited in the extreme UV region, which has been probably due to difficulties in acquiring enough amount of sample. This situation has been rapidly changed in these few years, since the techniques of syntheses, isolation, and purification have been advanced so rapidly that appreciable amount of fullerenes can be readily obtained.

[1] M. Ono *et al.*, Nucl. Instrum. Meth. Phys. Res. A **467-468**, 577 (2001).

[2] H. Yoshida and K. Mitsuke, J. Synchrotron Radiat. **5**, 774 (1998).

Beamline Specifications

Monochromator	18-m spherical grating Dragon-type
Wavelength Range	6 – 55 nm
Resolution	2000-8000
Experiment	Mass spectrometry; Photoelectron spectroscopy

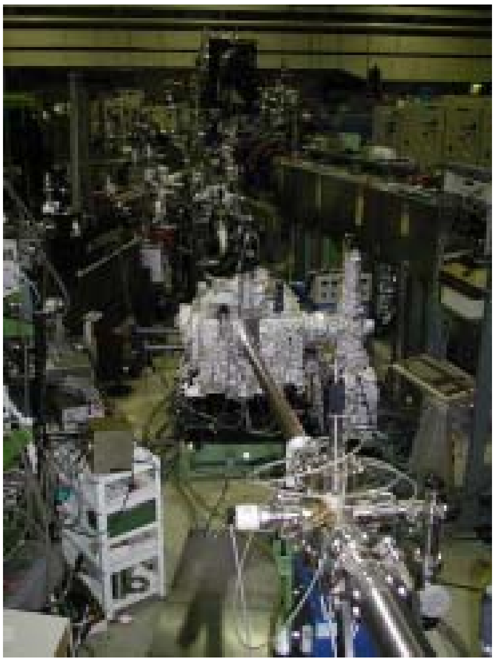


Fig. 1 18-m spherical grating monochromator installed at the Beamline 2B.

BL3U

Varied-Line-Spacing Plane Grating Monochromator for Molecular Soft X-Ray Spectroscopy

The beamline BL3U is equipped with an in-vaccum undulator composed of 50 periods of 3.8 cm period length. The emitted photons are monochromatized by the varied-line-spacing plane grating monochromator (VLS-PGM) designed for various spectroscopic investigations in the soft x-ray range including soft x-ray emission studies. Three holographically ruled laminar profile plane gratings are designed to cover the photon energy range from 60 eV to 800 eV. The beamline has two endstations, namely XES setup and Multi-purpose setup. The XES setup is used for soft x-ray emission spectroscopy. The beam is horizontally focused onto the sample position by plane-elliptical mirror, M2X. In the Multi-purpose setup, the beam is focused by the toroidal mirror M2. Between the sample position and M2, the differential pumping is placed.

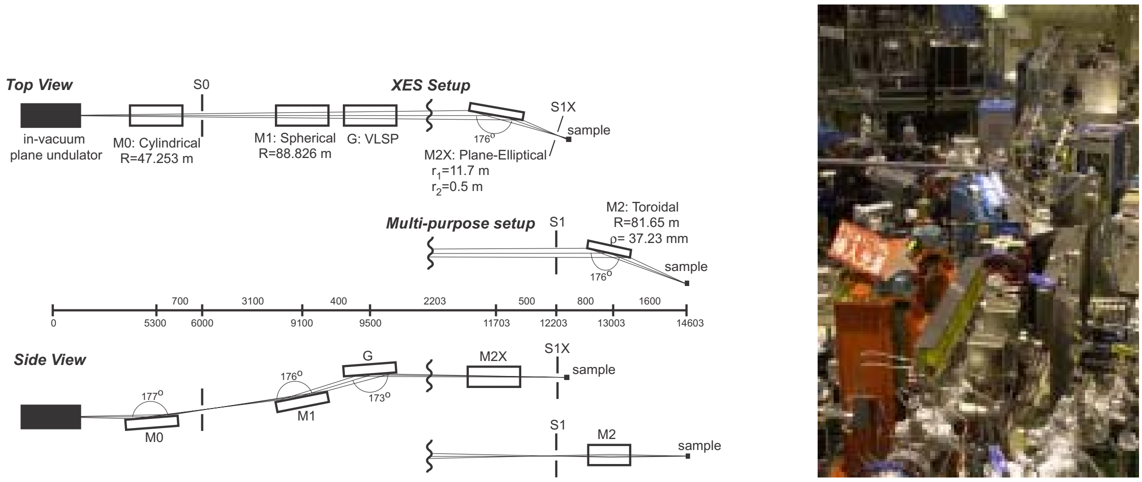


Fig. 1 Schematic layout (left) and the photography (right) of the BL3U. The distances along the beam from the center of the in-vacuum plane undulator are shown in mm. S1X and M2X can be replaced with the other exit slit S1 so that experiments can be carried out at either the XES or multi-purpose endstation. In the XES setup, the sample is placed at 5-10 mm downstream of S1X.

Beamline Specifications

Monochromator	Varied-line-spacing plane grating monochromator
Energy Range	60-800 eV
Resolution	E/ΔE > 7000
Experiment	Soft X-ray spectroscopy (XPS, XES, XAS)
Beam Size (XES Endstation)	Gaussian shape Vertical 5-20 μm; Horizontal 68 μm (FWHM)

BL3B

Beamline for Gas Phase Photoelectron Spectroscopy

This beam line is devoted to studies of elementary atomic and molecular processes induced by excitation of valence electrons. A monochromator is a vertically dispersed normal incidence type with 3m focal length and 10° angle between the incident and diffracted photon beams. The maximum wavelength resolution of 0.007nm is narrow enough to separate vibrational levels of excited states for various molecules. A main component in an experimental chamber is a spherical sector electrostatic energy analyzer which has been designed and setup for photoelectron spectroscopy. One can perform two-dimensional photoelectron spectroscopy with good resolution (≤ 30meV) in which the photoelectron yield is measured as a function of both photon energy and electron kinetic energy (binding energy). A two-dimensional spectrum, usually represented as a contour plot, contains rich information on photoionization dynamics and properties of superexcited states. A great variety of interesting high-lying states involved in autoionization have been studied [1-5].

[1] K. Mitsuke *et al.,* J. Electron Spectrosc. Rel. Phenom. **79**, 395 (1996).

[2] H. Hattori and K. Mitsuke, *ibid.* **80**, 1 (1996); H. Hattori *et al.*, J. Chem. Phys. **106**, 4902 (1997).

[3] Y. Hikosaka *et al.*, J. Chem. Phys. **105**, 6367 (1996); *ibid.* **107**, 2950 (1997); *ibid.* **110**, 335 (1999).

[4] K. Mitsuke *et al.*, J. Electron Spectrosc. Rel. Phenom. **112**, 137 (2000).

[5] Y. Hikosaka and K. Mitsuke, J. Phys. Chem. **105**, 8130 (2001); J. Chem. Phys. **121**, 792 (2004).

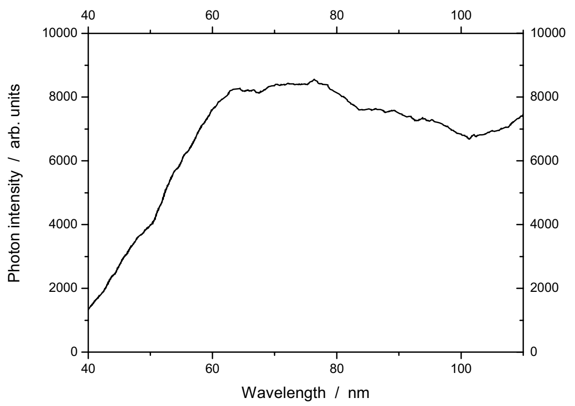


Fig. 1 Relative photon intensity at the sample point of BL3B.

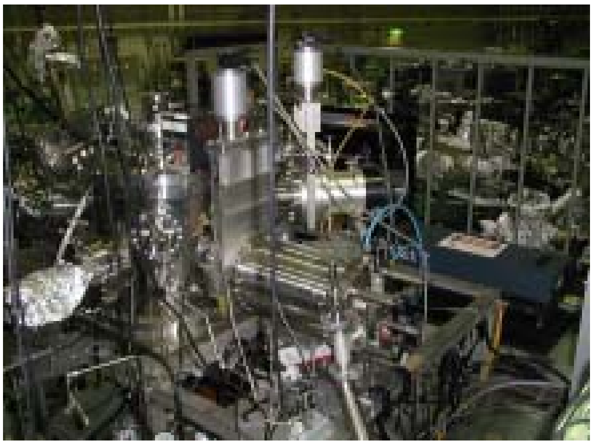


Fig. 2 Apparatus for gas-phase photoelectron spectroscopy at the Beamline 3B.

Beamline Specifications

Monochromator	3-m normal incidence
Wavelength Range	30 – 200 nm
Resolution	14000 at 100 nm
Experiment	Photoelectron Spectroscopy

BL4A1

SR-Induced Sputtering Deposition and Annealing Beamline

This beam line is used for synchrotron radiation (SR)-induced sputtering deposition and annealing onto substrates. The beam line has multilayered-mirror (MLM) monochromator. The beam line optics is optimized to obtain a high photon flux. Optimization concerning the reduction of the low energy background due to the total reflection has been made for the combination of the Mo/Si MLMs and the C filter. Mo/Si MLMs have a (normal incident) reflectivity of over 60% can be made for the energy region around 100 eV, which contains the core electron binding energies of Al and Si [1].

The SR-induced sputtering deposition and annealing chamber is connected to the beam line as shown in Fig. 1. The sample and deposition source can be easily introduced into the chamber, and the angle of them can be changed from outside.

[1] H. Mekaru *et al.*, Rev. Sci. Instrum. **70** (1999) 2601.

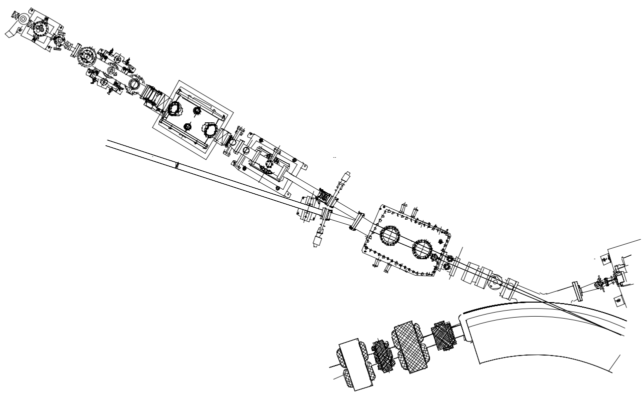


Fig. 1 Top view of BL4A1.

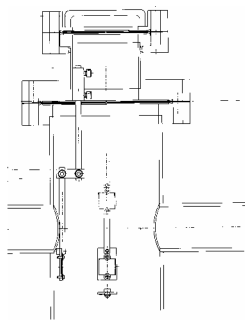


Fig. 2 Annealing chamber.

Beamline Specifications

Monochromator	Multilayered-mirror monochromator
Energy Range	50-95 eV
Resolution	5-9 eV (FWHM)
Experiments	Synchrotron radiation (SR)-induced sputtering deposition and annealing onto substrates

BL4A2

Beamline for Synchrotron Radiation Chemical Vapor Deposition

This beam line is used for synchrotron radiation chemical vapor deposition (SR-CVD) and photo-etching experiments. The beam line has no monochromator for high photon flux to irradiate and consists of only two mirrors. One is for focusing and the other is for branching. At the beam line, the gas supply and extinction system is equipped for using legally controlled high pressure gasses such as SiH_4, Si_2H_6 and GeH_4. They are commonly used to CVD of semiconductor crystals.

The SR-CVD and photo-etching chambers are connected to the beam line as shown in Fig. 1. In those chambers, infrared reflection absorption spectroscopy (IRRAS) system is installed to study the surface photochemistry on Si surfaces modified with various kinds of molecules.

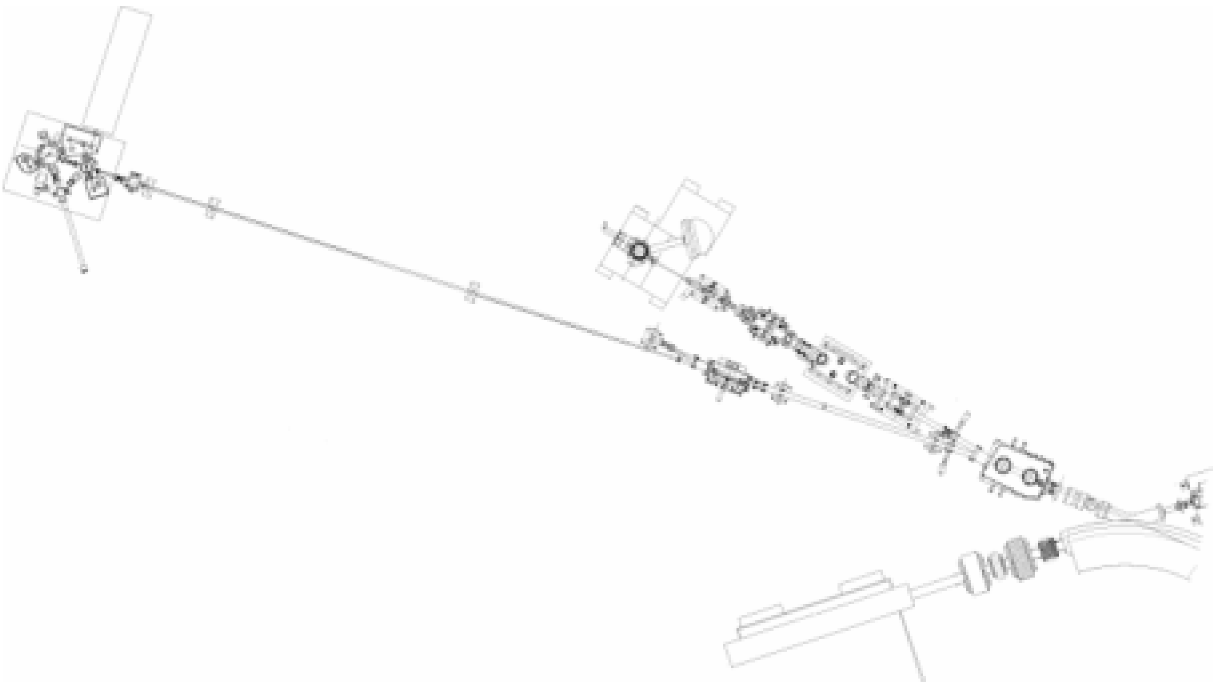


Fig. 1 Top view of BL4A2.

Beamline Specifications

Monochromator	None
Energy Range	The whole energy range of the synchrotron radiation
Resolution	—
Experiments	Synchrotron radiation chemical vapor deposition, and photo-etching experiments

BL4B

Varied-Line-Spacing Plane Grating Monochromator for Molecular Soft X-Ray Spectroscopy

The beamline BL4B equipped with a varied-line-spacing plane grating monochromator (VLS-PGM) was constructed for various spectroscopic investigations in a gas phase and/or on solids in the soft X-ray range. Two holographically ruled laminar profile plane gratings with SiO_2 substrates are designed to cover the photon energy range from 80 eV to 800 eV. The gratings with the groove densities of 267 and 800 l/mm cover the spectral ranges of 60-300 and 200-1000 eV, respectively, and are interchangeable without breaking the vacuum. Fig. 1 shows the absolute photon flux for each grating measured by a Si photodiode (IRD Inc.), with the entrance- and exit-slit openings set at 25 and 10 μm, respectively. Under this condition, the corresponding resolving power (E/ΔE) for the 800 l/mm grating is expected to be more than 8000 at 400 eV.

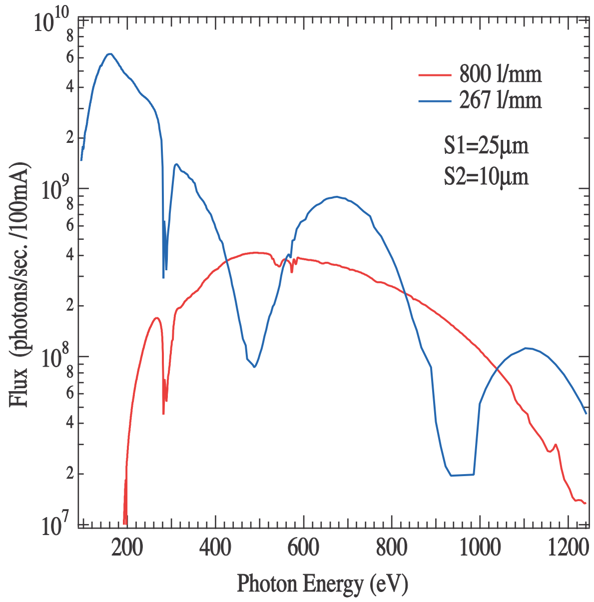


Fig. 1 Throughput from the VLS-PGM monochromator on BL4B.

Fig. 2 A photo of BL4B taken from the upper platform of BL3B.

Beamline Specifications

Monochromator	Varied-line-spacing Plane Grating Monochromator
Energy range	60-1000 eV
Resolution	E/ΔE > 5000 (at maximum)
Experiments	Soft X-ray spectroscopy (mainly, angle-resolved photoion spectroscopy for gaseous targets and photoelectron spectroscopy for gaseous and solid targets)

BL5U

Photoelectron Spectrometer for Solids and Surfaces

This beamline is designed for high-resolution angle-resolved photoemission study for solids and surfaces with the linearly and circularly polarized synchrotron radiation from a helical undulator. The beamline consists of a Spherical Grating Monochromator with Translational and Rotational Assembly Including a Normal incidence mount (SGM-TRAIN), and a high-resolution angle-resolved photoemission spectrometer.

The SGM-TRAIN is an improved version of a constant-length SGM to aim the following points; (1) wide energy range of 5-250 eV, (2) high resolving power, (3) use of linearly and circularly polarized light, (4) reduction of second-order light, and (5) two driving modes by a computer control. The second-order light is well suppressed by using laminar profile gratings and combinations of mirrors and gratings.

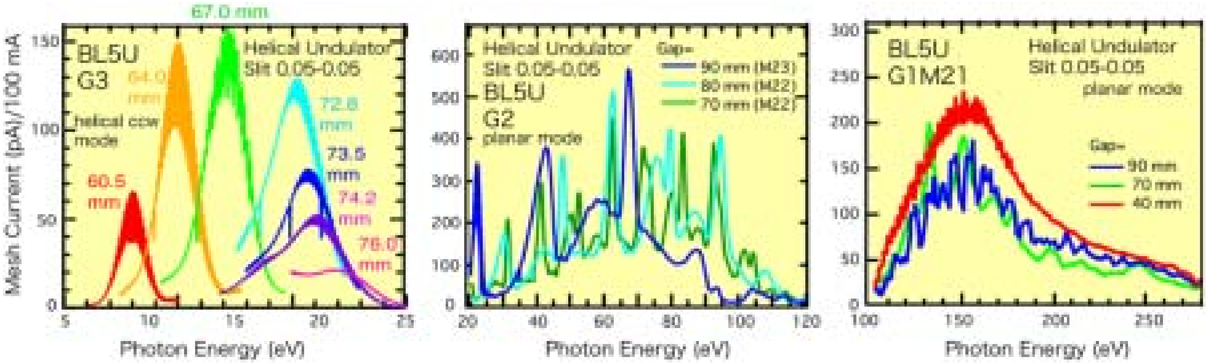


Fig. 1 Throughput spectra from the SGM-TRAIN monochromator on BL5U.

Beamline Specifications

Monochromator	SGM-TRAIN
Energy Range	5-250 eV
Resolution	0.5-80 meV (with slits width of 0.01 mm)
Experiment	ARPES, AIPES, XAS
Flux	1x 10^{12} photons/s for undulator radiation in MPW mode
Main Instruments	Hemispherical photoelectron analyzer (MBS-Toyama, A-1), LEED of reverse type (OMICRON), Liq-He flow cryostat (5 – 400 K)

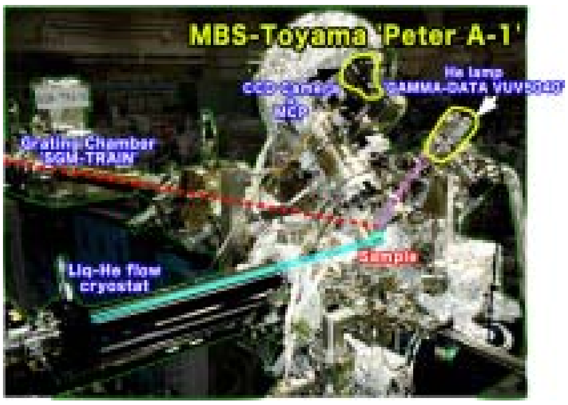


Fig. 2 High-resolution angle-resolved photoemission apparatus for BL5U.

BL5B

Calibration Apparatus for Optical Elements and Detectors

BL5B has been constructed to perform calibration measurements for optical elements and detectors. This beamline is composed of a plane grating monochromator (PGM) and three end stations in tandem. The most upstream station is used for calibration measurements of optical elements, the middle one for optical measurements for solids and the last for photo-stimulated desorption experiments. The experimental chamber at the most downstream station is sometimes changed to a chamber for photoemission spectroscopy.

The calibration chamber shown in Fig. 2 is equipped with a goniometer for the characterization of optical elements, which has six-degree-of-freedom; X-Y translation of a sample, and interchange of samples and filters. These are driven by pulse motors in vacuum. Since the polarization of synchrotron radiation is essential for such measurements, the rotation axis can be made in either horizontal or vertical direction (s- or p-polarization).

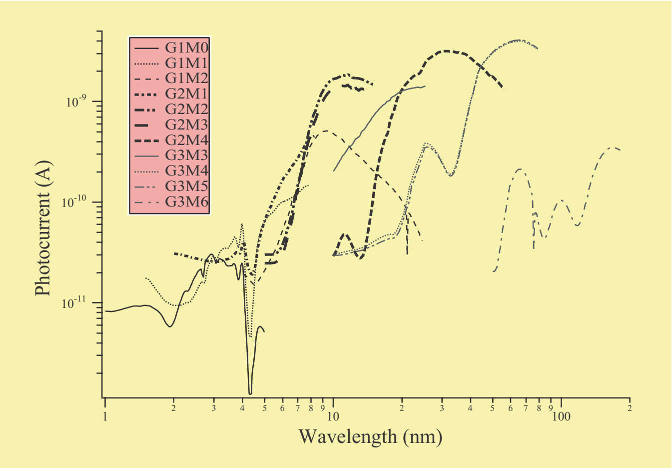


Fig. 1 Throughput spectra for possible combinations of gratings and mirrors at BL5B measured by a gold mesh.

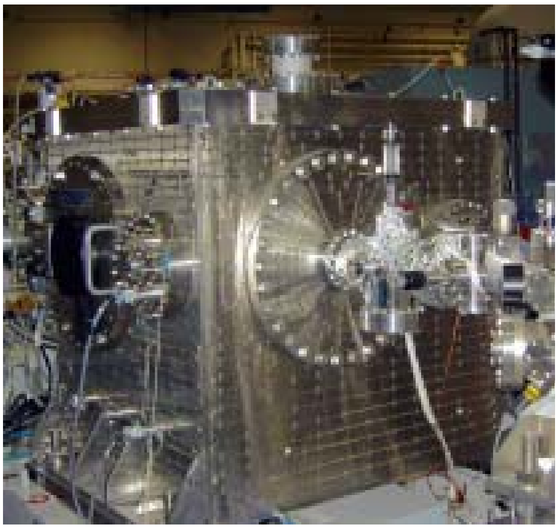


Fig. 2 A side view of the experimental chamber for calibration measurements.

Beamline Specifications

Monochromator	Plane Grating Monochromator
Energy range	6-600 eV (2-200 nm)
Resolution	E/ΔE ~ 500
Experiments	Calibration of optical elements, absorption of solids, photo-stimulated desorption from rare gas solids

BL6B (IR)

Infrared and Terahertz Spectroscopy of Solids

SR has a good performance (high brilliance and high flux) not only in VUV and SX regions but also in IR and terahertz regions. This beamline covers in the IR and terahertz regions. The previous beamline BL6A1 that has been constructed in 1985 is the pioneer of the infrared SR research. The beamline was upgraded in the spring of 2004 and the name was changed to be BL6B (IR). The front-end part including the bending duct #6 was replaced to a new one with higher acceptance angle using a magic mirror as shown in Fig. 1.

The beamline is equipped with two interferometers, one is Michelson-type (Bruker IFS-66v) and the other Martin-Puplett-type (JASCO FARIS-1), for the wide spectral region from several to 20,000 cm^{-1} ($h\nu$ = several 100 μeV – 2.5 eV) as shown in Fig. 2. The experimental chamber in which users bring can be equipped at the free port. In the near future, an IR microscope covering down to terahertz region will be set up.

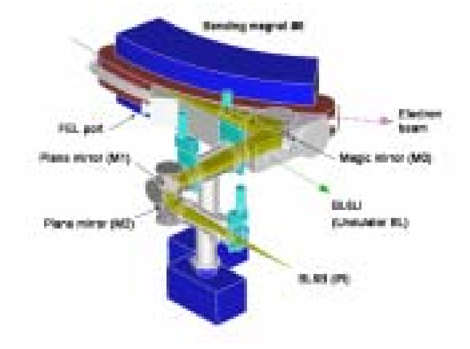


Fig. 1 The design of optics and front end of BL6B.

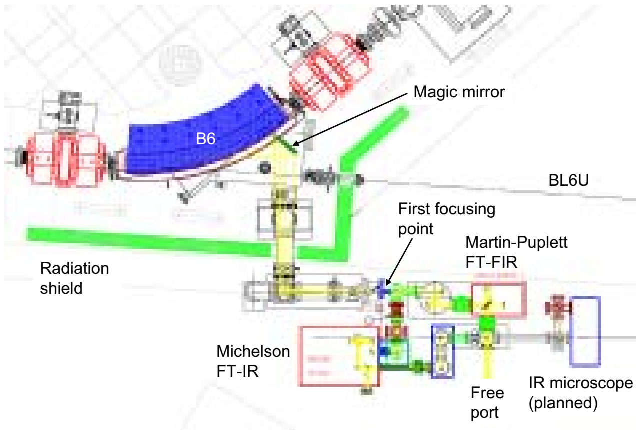


Fig. 2 Schematic figure of top view of BL6B.

Beamline Specifications

Interferometer	Michelson (Bruker IFS66v), Martin-Puplett (JASCO FARIS-1)
Wavenumber Range (Energy range)	several – 20,000 cm^{-1}, (several 100 μeV – 2.5 eV)
Resolution in cm^{-1}	0.1cm^{-1} for IFS66v, 0.25cm^{-1} for FARIS-1
Experiments	Reflectivity and transmission, Magneto-optics (Microspectroscopy)
Miscellaneous	Users can bring their experimental system in this beamline.

BL7U

Undulator Irradiation Beamline for STM Observation

This beamline has been constructed for STM observation of surface photochemical reactions stimulated by undulator irradiation. The schematic drawing of the BL7U is shown in Fig. 1. The undulator is in-vacuum type, of which the period is 36 mm and the number of the period is 26. The 1st harmonic is tuned from 70 eV to 140 eV [4]. Two Pt-coated cylindrical mirrors are used for the vertical and horizontal focusing. These two mirrors also suppress the higher harmonics of the undulator radiation into ~10% with respect to the first harmonic. The focus point is set at the point of 9100 mm downstream from the middle of the undulator. The spot size on the sample surface was 1.0 mm (H) x 0.4 mm (V) and the estimated photon flux density was 10^{18} photons (cm^2 sec 100 mA)$^{-1}$.

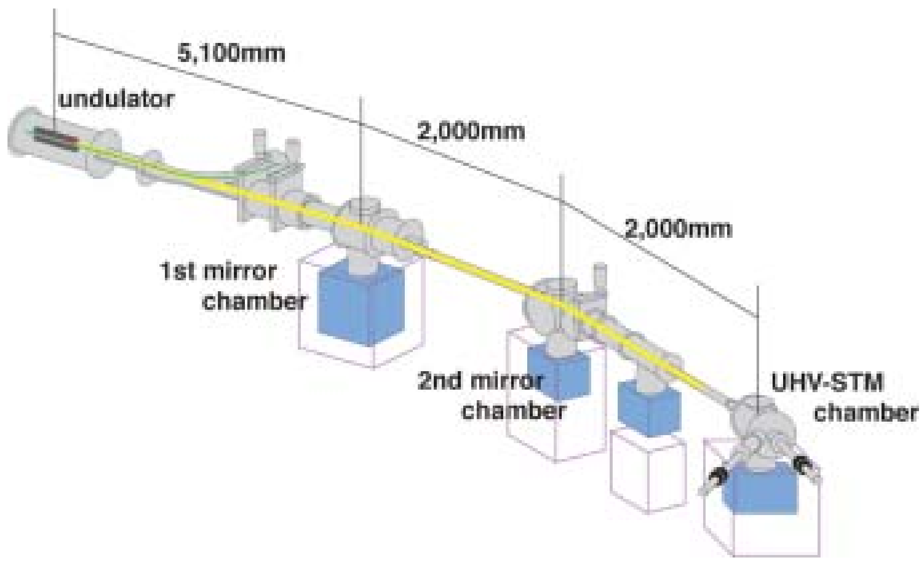


Fig. 1 Schematic drawing of BL7U.

Beamline Specifications

Monochromator	None
Wavelength Range	70 – 140 eV (1st harmonic)
Resolution	~10 -
Experiment	Undulator Irradiation and STM Observation
Miscellaneous	

BL7B

3-m Normal Incidence Monochromator for Solid-State Spectroscopy

BL7B has been constructed to provide sufficiently high resolution for conventional solid-state spectroscopy, enough intensity for luminescence measurements, a wide wavelength coverage for Kramers-Kronig analyses, and the minimum deformation to the polarization characteristic of the incident synchrotron radiation. This beamline consists of a 3-m normal incidence monochromator which covers the vacuum ultraviolet, ultraviolet, visible and infrared, *i.e.* the wavelength region of 40 -1000 nm, with three gratings (1200, 600, and 300 l/mm). Two interchangeable refocusing mirrors provide two different focusing positions. For the mirror with the longer focal length, an LiF or a MgF2 window valve can be installed in between the end valve of the beamline and the focusing position. Figure 1 shows absolute photon intensity for each grating with the entrance and exit slit openings of 0.5 mm. A silicon photodiode (AXUV-100, IRD Inc.) was utilized for measuring the photon intensity and the absolute photon flux was estimated, taking the quantum efficiency of the photodiode into account.

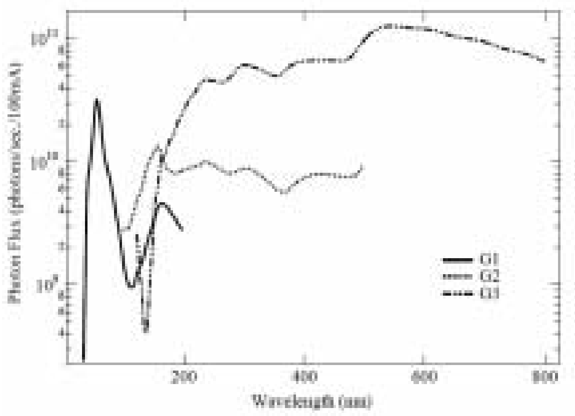


Fig. 1 Throughput spectra of BL7B measured by a silicon photodiode.

Fig. 2 Photo of BL7B.

Beamline Specifications

Monochromator	3-m Normal Incidence Monochromator
Wavelength Range	50 to 1000 nm (1.2 - 25 eV)
Resolution	$E/\Delta E$ = 4000 – 8000 for 0.01 mm slits
Experiment	absorption, reflection, fluorescence spectroscopy, mainly for solids

BL8A

Irradiation Beamline for Studies of Photochemical Reaction on Solids

The beamline BL8A was constructed for providing synchrotron radiation without monochromatizaion. The white synchrotron radiation is focused into a 3.5 mm × 2.5 mm size by use of a toroidal mirror. The focusing mirror can be removed for obtaining a bigger irradiation area. A differential pumping system with three stages is introduced, which enables users to perform experiments under a very low vacuum condition (<0.5 Torr). The intense white light available at this beamline is suitable for studies on photochemical reaction, chemical vapor deposition, photo-etching and irradiation damage effects. No standing experimental stations are placed at the beamline; users may install their own experimental chambers, while some standard chambers are arranged by UVSOR.

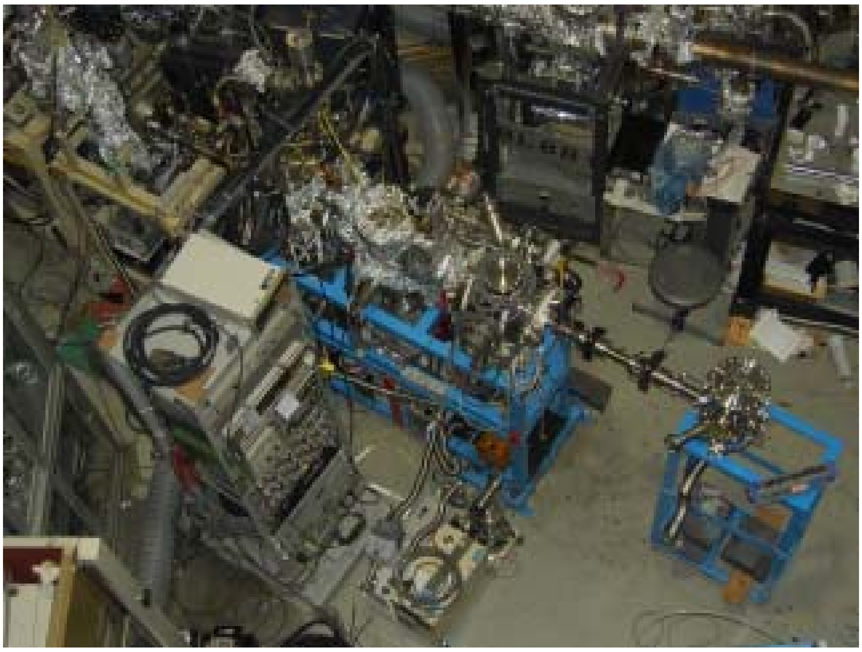


Fig. 1 A top-view photo of the beamline.

Beamline Specifications

Monochromator	None
Energy Range	The whole energy range of the synchrotron radiation
Resolution	—
Experiments	Photochemical reaction, chemical vapor deposition and photo-etching experiments
Miscellaneous	Beam spot size: (H)3.5 mm × (V)2.5 mm

BL8B1

Spherical Grating Monochromator for Soft X-Ray Spectroscopic Studies on Solids and Surfaces

The beamline BL8B1 equipped with a constant-deviation constant-length spherical grating monochromator [1] provides soft X-ray photons in the energy range 30-800 eV with medium energy resolution. The photon energy range is covered by using three gratings (R=15 m; 1080 l/mm, R=15 m; 540l/m, and R=7.5m; 360 l/mm) which are interchangeable in vacuum. Figure 1 shows a throughput spectrum measured with the entrance- and exit-slit openings of 10 μm. Under this condition, the achievable resolving power is about 4000 at 400 eV and 3000 at 245 eV, respectively.

An experimental chamber is equipped for conventional measurements of electron yield spectra, or pseudo-photoabsorption spectra, under a ~1×10^{-6} Torr vacuum condition.

[1] Hiraya *at al*, Rev. Sci. Instrum. **66**, 2104 (1995).

Fig. 1 Photo of the monochromator at BL8B1.

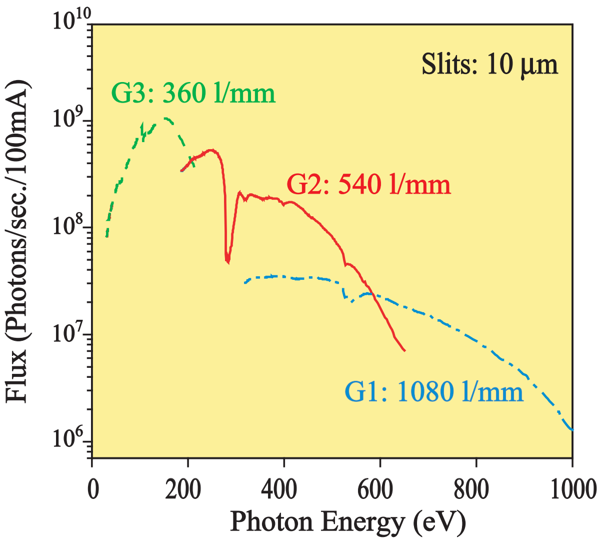


Fig. 2 Throughput of the monochromator at BL8B1.

Beamline Specifications

Monochromator	Constant-deviation constant-length spherical grating type
Energy range	30-800 eV
Resolution	E/ΔE = 4000 at 400 eV and 3000 at 245 eV
Experiments	Photoabsorption spectroscopy, electron spectroscopy and electron-ion coincidence spectroscopy for solids and surfaces

BL8B2

Angle-Resolved Ultraviolet Photoelectron Spectrometer for Solids

BL8B2 is a beamline for angle-resolved ultraviolet photoemission spectroscopy (ARUPS) system which is designed for measuring various organic solids such as molecular crystals, organic semiconductors, and conducting polymers. This beamline consists of a plane-grating monochromator (PGM), a sample preparation chamber with a fast entry Load-Lock chamber, a measurement chamber with an accurate for temperature dependence (base pressure 1×10^{-10}Torr), a cleaning chamber (base pressure 1×10^{-10}Torr), and a sample evaporation chamber (base pressure 3×10^{-10}Torr). The cleaning chamber is equipped with a back-view LEED/AUGER, an ion gun for Ar^+ sputtering, and an infrared heating unit. The PGM consists of premirrors, a plane grating, focusing mirror, and a post-mirror, with an exit slit. It covers the wide range from 2 to 150eV with exchanging two gratings (G1: 1200l/mm, G2: 450l/mm) and five cylindrical mirrors. The toroidal mirror focuses the divergent radiation onto the sample in the measurement chamber. The spot size of the zeroth-order visible light at the sample surface is about 1×1mm^2. Figure 1 shows the throughput spectra of PGM (slit=100μm). The energy resolution at a slit width of 100μm was found to be 0.004-0.3eV in the wavelength range from 2 to 130eV. A hemi-spherical electron energy analyzer of 75mm mean radius with an angular resolution less than 2° can be rotated around vertical and horizontal axes. The sample mounted on a manipulator can be also rotated around two axes.

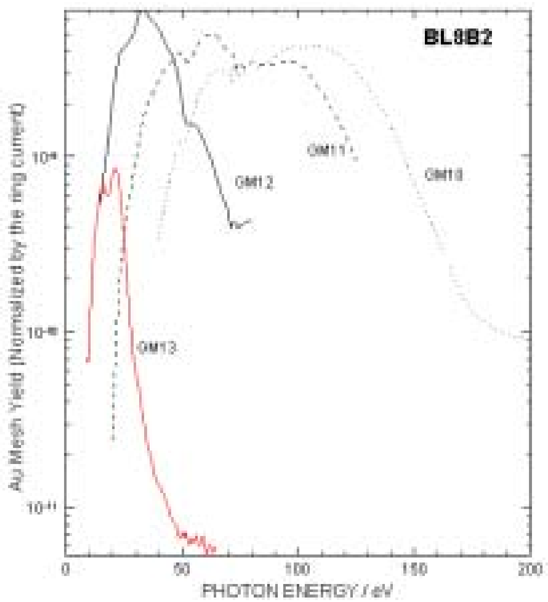


Fig. 1 Throughput spectra of plane-grating monochromator at BL8B2 (slit=100μm).

Fig. 2 A photo of BL8B2.

Beamline Specifications

Monochromator	Plane-grating monochromator
Wavelength Range	9- 600nm
Resolution	E/ΔE = 1000
Experiment	Angle-resolved ultraviolet photoemission spectroscopy