Light Source in 2005

Masahiro KATOH
UVSOR Facility, Institute for Molecular Science

1. Status of UVSOR-II

In the fiscal year 2005, we have operated the UVSOR-II accelerators from May ’05 to March ’06. We had two shut-down periods, in April ’05 and March ’06. The former was to install a new RF cavity [1]. The latter was to reinforce radiation shield of the storage ring. The new cavity has capability of producing the accelerating field three times stronger than before. We also stopped the operation for one week in September for maintenance works and for two weeks around the New Years day.

We had a few troubles on the accelerators during FY2005. 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 and a half. Same trouble happened last year. This power supply will be replaced in summer, 2006. The new one will have capability of increasing the maximum beam energy of the booster synchrotron from 600 MeV to 750 MeV, to realize the full-energy injection into the storage ring. We also had some minor troubles on the magnet power supplies of the storage ring, the RF amplifier of the linear accelerator and the power supply of the extraction kicker of the booster synchrotron. Fortunately, all of them could be recovered within several hours.

We had totally 38 weeks for the users operation, 36 weeks in multi-bunch mode and 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 and Saturday, the machine is operated for machine studies.

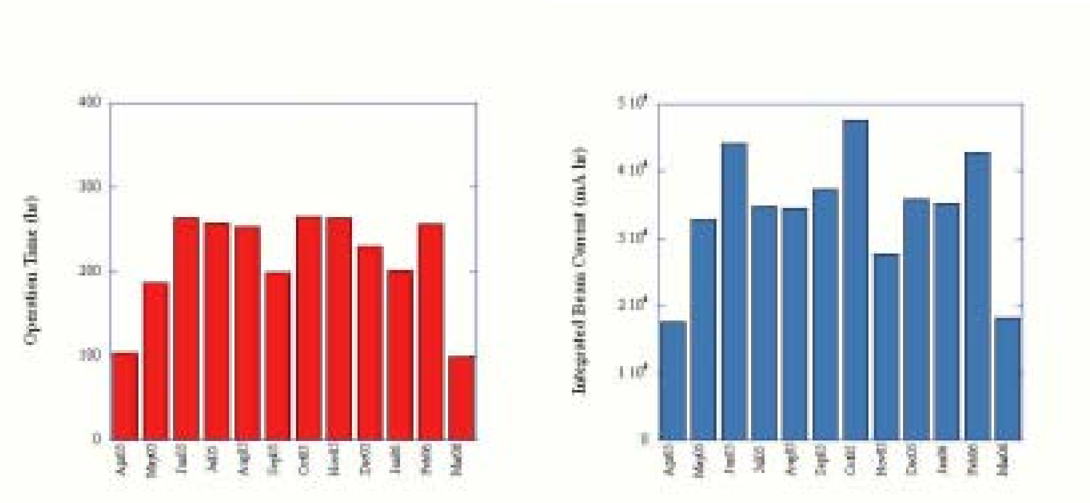


Fig. 1 Monthly statistics of the operation time (left) and of the integrated beam current (right).

2. Improvements

Operation with New RF Accelerating Cavity

The new RF accelerating cavity was installed in the ring, in March 2005. The cavity was successfully commissioned and the users operation with the new cavity was started in May. During the commissioning, it was proved that the new cavity could produce 150 kV accelerating voltage, which was the design goal [2]. However, it was also observed that the vacuum pressure started to rise when the accelerating voltage came closer to around 150 kV. Thus, we have decided to start the users operation with the accelerating voltage of 100 kV, which is still twice higher than before. Thanks to this higher voltage, the Touschek lifetime was improved. It was found that, even with the low emittance of 27 nm-rad, we could operate the storage ring with a sufficiently long lifetime, almost as long as that with the old cavity and with the moderately high emittance of 60 nm-rad.

Progress in Orbit Stabilization

The electron orbit of UVSOR-II shows drift motion of a few hundred microns with a time scale of hours. The orbit moves both in the horizontal and vertical planes. The origin of these motions is considered to be the temperature changes of the accelerator components and of the storage building itself. The machine is operated only for 12 hours a day. It was observed that the temperature of the accelerator components and the building were not stable. During night time, they are falling and, during day time, they are rising.

To suppress the orbit drift, a feedback system is under development. As the first step, a system has been constructed to correct the orbit displacement in the horizontal plane automatically by controlling the RF frequency [3]. This system has been successfully commissioned and the orbit drift in the horizontal plane is reduced significantly. The feedback system is now being upgraded to correct the orbit in both planes more precisely by using the correction magnets.

Replacement of Accelerator Control System

A control system based on the VAX computers and the CAMAC interfaces had been used for many years for the UVSOR accelerators [4]. The system itself was still reliable, however, it had been getting difficult to maintain the hardware, year by year. A few years ago, we started to replace the system, step by step, with more simple one based on PC's. Until the end of FY2005, all the system has been replaced.

Control of Undulators

A simple and reliable system based on PC was developed for controlling the undulators [5]. The system can correct the orbit displacement caused by the pole-gap changes automatically. The system was first introduced to the in-vacuum undulator (U07) and then to the second in-vacuum one (U03). This year, the system was introduced to the helical undulator/optical klystron (U05). This device produces significant betatron tune shift when the pole gap is narrow. The system corrects the tune shift as well as the orbit displacement. The users can change the pole gap anytime, although the polarization change is still limited to be done during the beam-injection time.

3. Researches and Developments

Design and Construction of a new Variably Polarized Undulator

A design work on the new undulator, which will be installed in the straight section between B6 and B7, has been finished. This undulator will provide VUV light of linear polarization in both horizontal and vertical planes. It can also provide circular polarized VUV light. The configuration of the magnet array is of APPLE-II type [6]. The main parameters are shown in Table 1. The undulator is now under construction and will be installed in the ring in autumn, 2006.

Table 1 Main parameters of the new undulator.

Configuration	APPLE-II
Polarization	Hor/Ver/Helical
Number of periods	38
Period length	76 mm
Total Length	2945 mm
Magnetic gap	24–200 mm
Deflection parameter (Horizontal mode)	max. 5.4 K
Deflection parameter (Vertical mode)	max. 3.6 K
Deflection parameter (Helical mode)	max. 3.0 K

Free Electron Laser

The shortest wavelength of the free electron laser at UVSOR had been 239 nm for many years, which was once the world record [7]. However, thanks to the smaller emittance realized by the upgrade of the accelerators in 2003 and to the higher peak current of the electron beam realized by the new RF cavity, it has come to be possible to oscillate the FEL in shorter wavelength with higher out-coupled power. We have succeeded in oscillating in deep UV region around 215 nm with an average power of a few hundred mW [8].

The UVSOR-FEL had been driven by the electron beam of 600 MeV for many years. The lower beam energy itself gives a higher FEL gain. In addition, the smaller emittance at the lower energy also contributes to the higher gain. However, thanks to the recent improvements in the quality of the electron beam as described above, even with the electron beam of 750 MeV, we can obtain a sufficient FEL gain for realizing oscillation. The laser oscillation at 215 nm was successfully demonstrated for the beam energy of 750 MeV [8]. We have found that the out-coupled power was higher than the case of 600 MeV. In addition, the beam lifetime was longer.

Laser Bunch Slicing

A TiSa laser, which can be synchronized with the RF system of the UVSOR-II accelerators, was installed in spring, 2005. The repetition rate is 1 kHz and the pulse energy is 2.5 mJ. This system can be used for laser bunch slicing for short SR pulses or for coherent terahertz pulses, and for coherent harmonic generation. A laser beam transport line was constructed in summer, 2005, under an international collaboration program, which involved a French group leaded by Dr. M. E. Couprie.

The laser pulses injected in the ring interact with the electron pulse in the undulator, whose fundamental wavelength is tuned to the laser wavelength. By the interaction, an energy modulation is created on the electron bunch. The laser system has a capability to produce an energy modulation on the electron beam, whose amplitude is comparable to the RF bucket height. During a series of the experiments in 2005, we have already obtained some preliminary results which clearly indicated the occurrence of the bunch slicing.

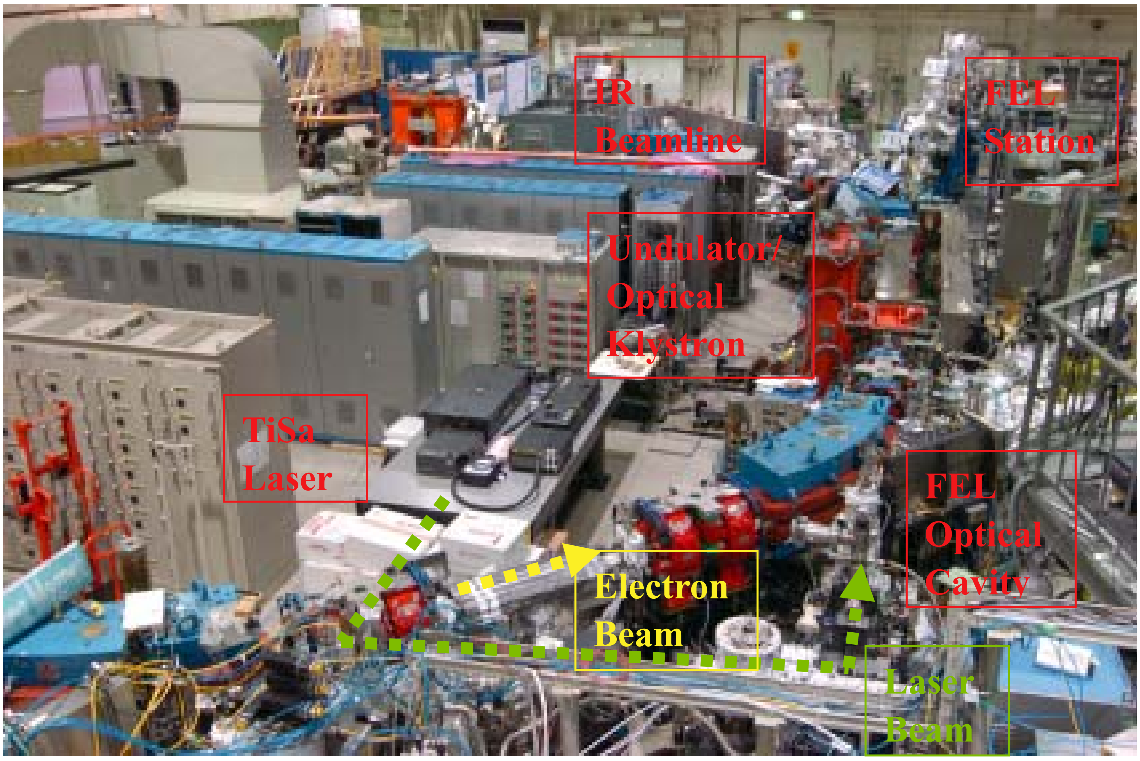


Fig. 2 Configuration of Laser Bunch Slicing Experiment.

[1] A. Mochihashi *et al.*, UVSOR Activity Report 2004 (2005) 35.

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

[3] Y. Suzumura *et al.*, in this report.

[4] N. Kanaya *et al.*, Nucl. Intr. Meth. A **352** (1994) 166.

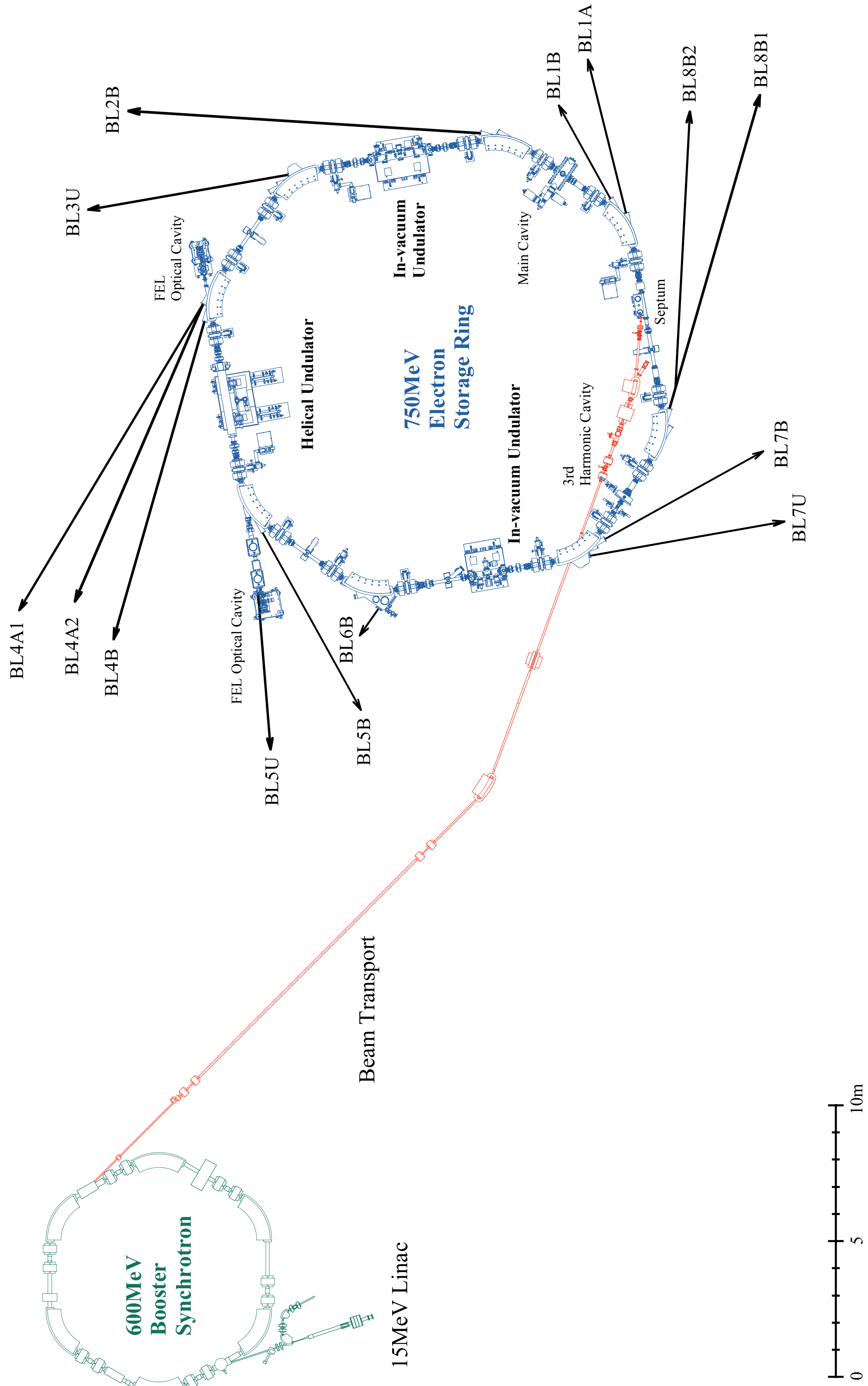
[5] K. Hayashi *et al.*, UVSOR Activity Report 2002 (2003) 50.

[6] S. Sasaki, Nucl. Instr. Meth. A**347** (1994) 83.

[7] H. Hama *et al.*, Proc. the 3rd Asian Free Electron Lasers and 5th Symp. on FEL Appl. (Hirakata, Osaka, 1997) 17.

[8] M. Hosaka, in this report.

UVSOR Accelerator Complex



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

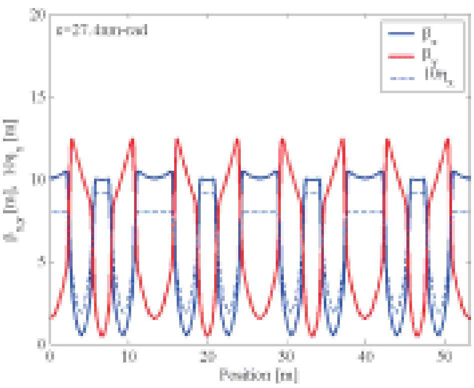
Parameters of Booster Synchrotron

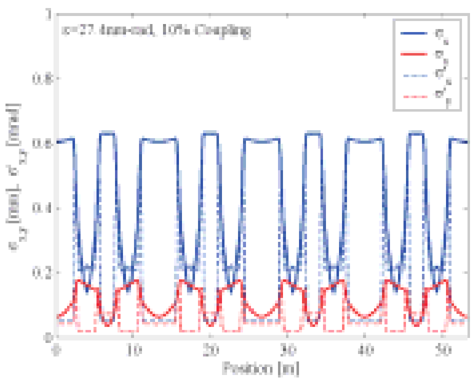
Energy	600 MeV
Injection Energy	15 MeV
Beam Current	32 mA (uniform filling)
Circumference	26.6 m
RF Frequency	90.1 MHz
Harmonic Number	8
Bending Radius	1.8 m
Lattice	FODO × 8
Betatron Tune	
Horizontal	2.25
Vertical	1.25
Momentum Compaction	0.138
Repetition Rate	2.6 Hz

Parameters of UVSOR-II Storage Ring

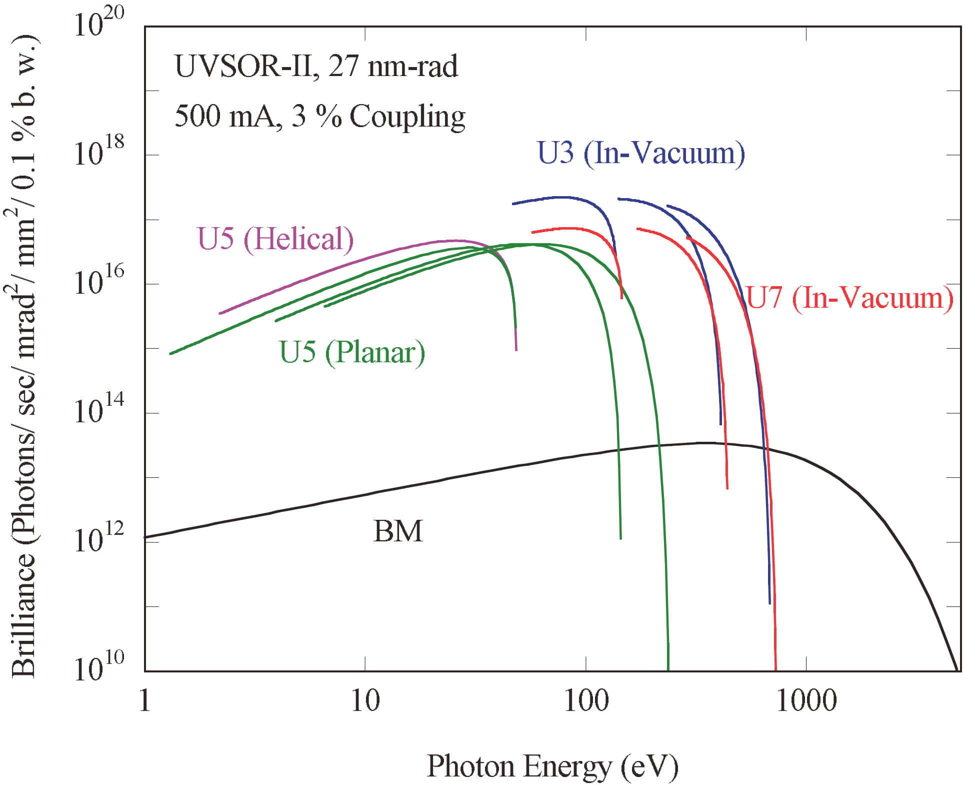
Energy	750 MeV
Injection Energy	600 MeV
Maximum Stored Current	500 mA (multi bunch) 100 mA (single bunch)
Natural Emittance	27.4 nm-rad
Circumference	53.2 m
RF Frequency	90.1 MHz
Harmonic Number	16
Bending Radius	2.2 m
Lattice	Extended DBA × 4
Straight Section	(4 m × 4) + (1.5 m × 4)
RF Voltage	100 kV
Betatron Tune	
Horizontal	3.75
Vertical	3.20
Momentum Compaction	0.028
Natural Chromaticity	
Horizontal	-8.1
Vertical	-7.3
Energy Spread	4.2×10^{-4}
Natural Bunch Length	108 ps

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



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	38 mm
Pole Length	1.9 m
Pole Gap	15~40mm
Deflection Parameter	2.00~0.24

BL7U In-vacuum Undulator

Number of Periods	26
Period Length	36 mm
Pole Length	0.94 m
Pole Gap	15~40 mm
Deflection Parameter	1.78~0.19

BL5U Helical Undulator / Optical Klystron

Number of Periods	21 / 9+9(Opt. Kly.)
Period Length	110mm
Pole Length	2.35 m
Pole Gap	30~150 mm
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 2005

Eiji SHIGEMASA
UVSOR Facility, Institute for Molecular Science

Eight bending magnets and three insertion devices are available for utilizing synchrotron radiation at UVSOR. There is a total of sixteen operational beamlines in 2005, which are classified into two categories. Nine 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 seven 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.

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. The new RF cavity has been installed to the short straight section between B01 and B02 before the end of March 2005. Keeping pace with the upgrade project, improvements and upgrades of the beamlines at UVSOR have been continuously discussed with users in a series of UVSOR workshops. From the viewpoint regarding radiation safety, the experiments carried out at the experimental stations on the second floor such as BL3B and BL7B, and the fine tunings of the laser system installed inside the shield walls during the machine study, seem to have become quite risky after introducing the so-called top-up operation of the UVSOR storage ring. Accordingly we have decided to put two old beamlines, BL8A and BL3B, out of service until the middle of March 2006. The experimental station for BL7B will be constructed at the vacant space after removing BL8A. All the beamline components have been completely removed from BL3B before the third week of March 2006, thanks to the efforts by Mitsuke’s group in Dep. VUV photoscience. The laser system will be moved to the corresponding empty lot of BL3B by the machine group. 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 there. The new beamline is planned to be constructed during the summer shutdown in 2006, and the beamline commissioning will be started after the installation of a new APPLE-II type undulator at the end of October 2006. 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 FY2005

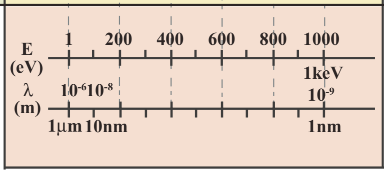
Beamline	Station Master	Sub Master	Supervisor
1A	N. Kondo	E. Shigemasa	E. Shigemasa
1B	M. Hasumoto	S. Kimura	S. Kimura
5U	T. Ito	S. Kimura	S. Kimura
5B	M. Hasumoto	E. Nakamura	E. Shigemasa
6B	S. Kimura	E. Nakamura	S. Kimura
7B	M. Hasumoto	S. Kimura	S. Kimura
8A	E. Nakamura	Y. Hikosaka	E. Shigemasa
8B1	Y. Hikosaka	E. Nakamura	E. Shigemasa
8B2	R. Sumii	E. Nakamura	S. Kimura

Representatives of In-House Beamlines in FY2005

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

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 (Dragon)	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
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)	25 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**	10m Normal Incidence (Modified Wadsworth)	6 eV 40 eV	Solid (Photoemission)	S. Kimura kimura@ims.ac.jp
7B	3m Normal Incidence	1.2 eV 30 eV	Solid (Reflection, Absorption)	M. Hasumoto hasumoto@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)	R. Sumii sumii@ims.ac.jp



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

** Under construction

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** (1992) 1264.

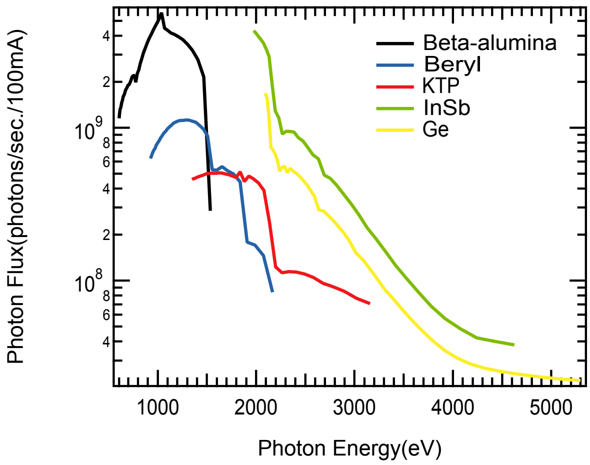


Fig. 1 Throughput spectra of the double crystal monochromator at BL1A.

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.

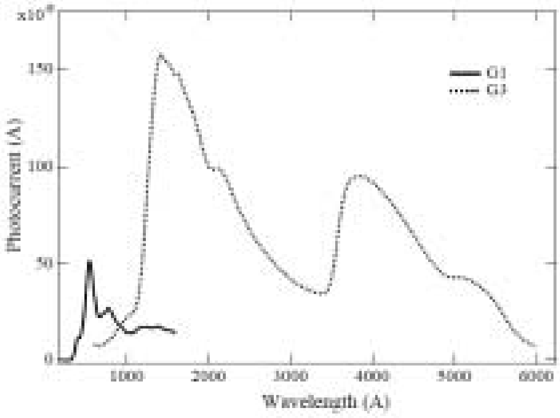


Fig. 1 Photocurrent at the sample position at BL1B.

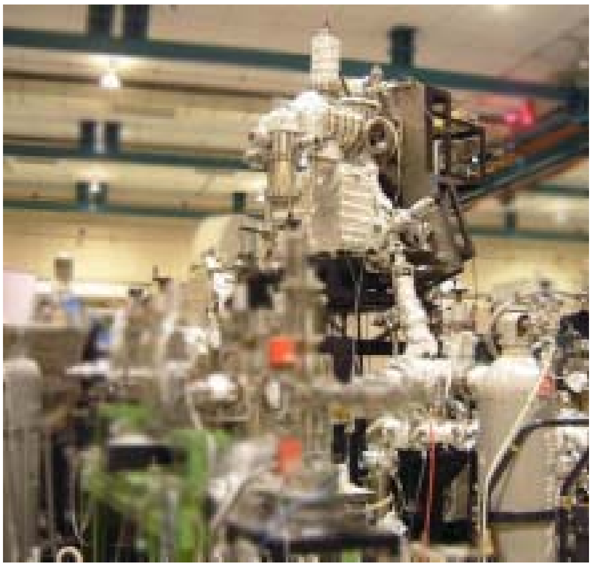


Fig. 2 Photo of BL1B.

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** (2001) 577.

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

Beamline Specifications

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

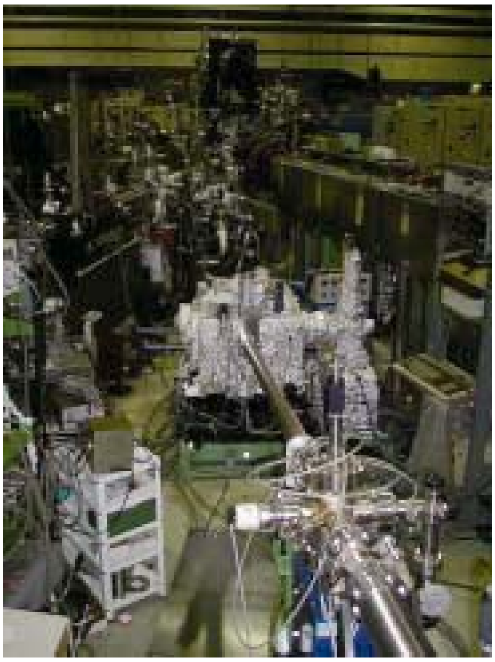


Fig. 1 18-m spherical grating monochromator installed at the Beamline 2B.

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.

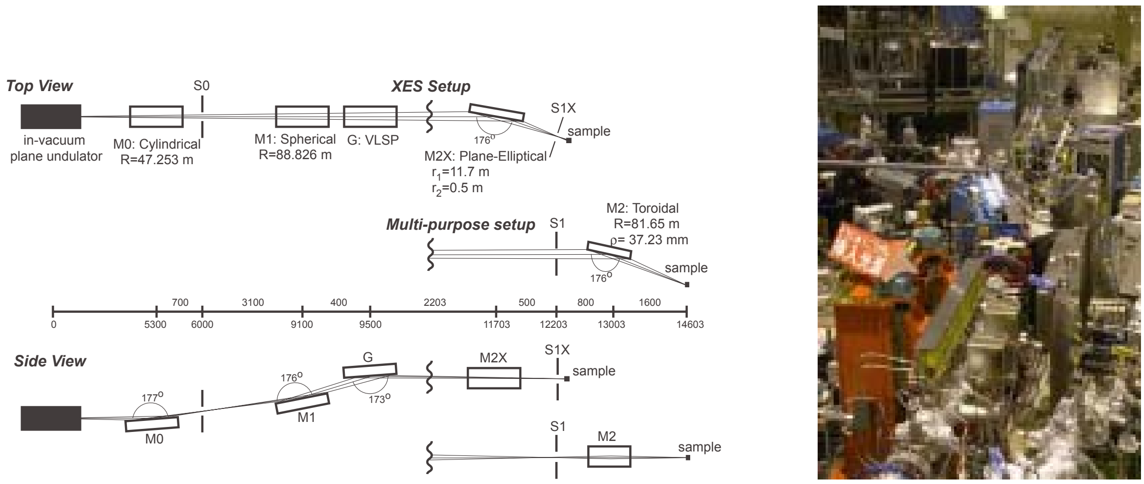


Fig. 1 Schematic layout (left) and the photography (right) of the BL3U. The distances along the beam from the center of the in-vacuum plane undulator are shown in mm. S1X and M2X can be replaced with the other exit slit S1 so that experiments can be carried out at either the XES or multi-purpose endstation.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

BL4A1

SR-Induced XeF_2 Etching Beamline

This beamline is used for synchrotron radiation (SR)-induced XeF_2 etching on SiO_2/Si substrates (Fig. 1). XeF2 is used for a high-rate and anisotropic etching, since XeF2 has high-etching rate of 600 nm/min even in a dry-etching condition.

A XeF_2-flow chamber with LiF window is installed in the beamline chamber (Fig. 2). The XeF_2-flow chamber is independently evacuated in order to avoid the damage to the chambers and evacuation instruments in the beamline. 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] Pt-coated plane mirrors will be installed to reduce the intensity of higher energy region, which will be absorbed to the LiF window.

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

Fig. 1 XeF_2 etching chamber in BL4A1.

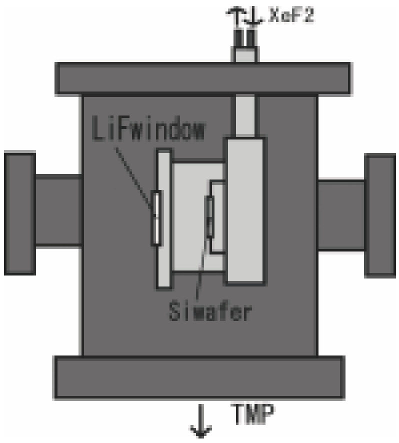


Fig. 2 Schematic drawing of the XeF_2 etching chamber.

Specifications

Monochromator	Multilayered-mirror monochromator
Wavelength range	13.3-22.5 nm
Resolution	5 - 9 eV (FWHM)

BL4A2

SR-Induced Photo Etching and CVD Beamline

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.

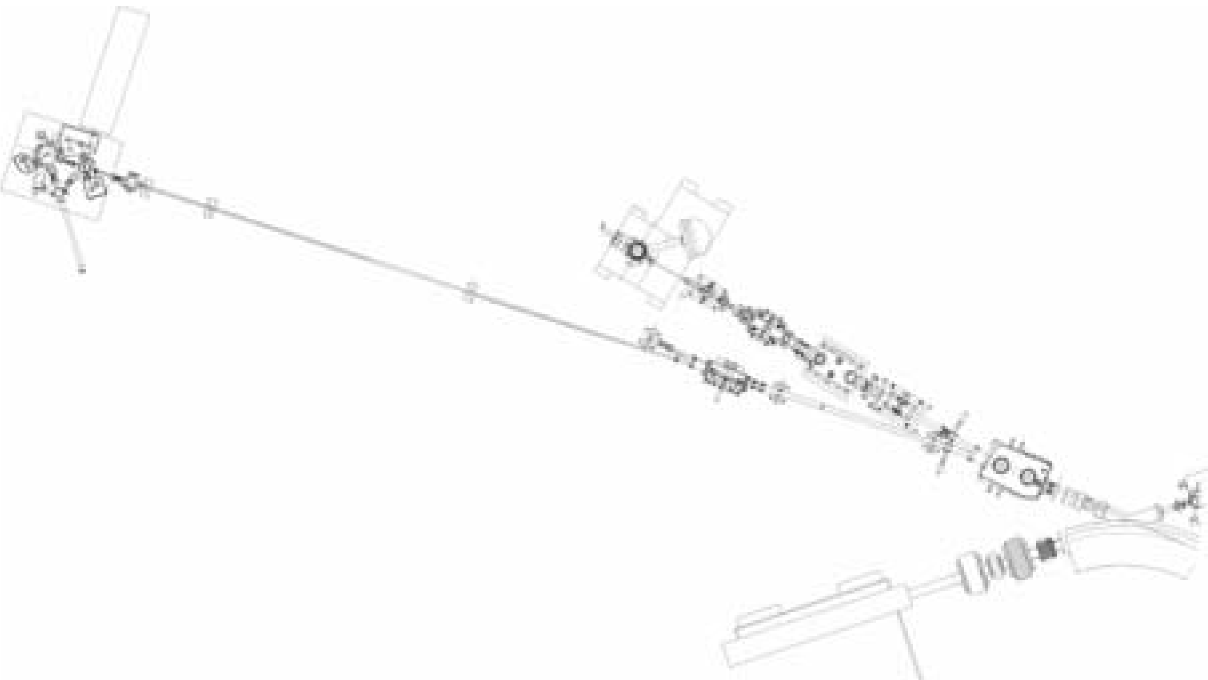


Fig. 1　Top view of BL4A2.

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. Three holographically ruled laminar profile plane gratings with SiO_2 substrates are designed to cover the photon energy range from 25 eV to 800 eV. The gratings with the groove densities of 100, 267, and 800 l/mm cover the spectral ranges of 25-100, 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 50 and 50 μm, respectively. The maximum resolving power (E/ΔE) achieved for each grating is more than 5000.

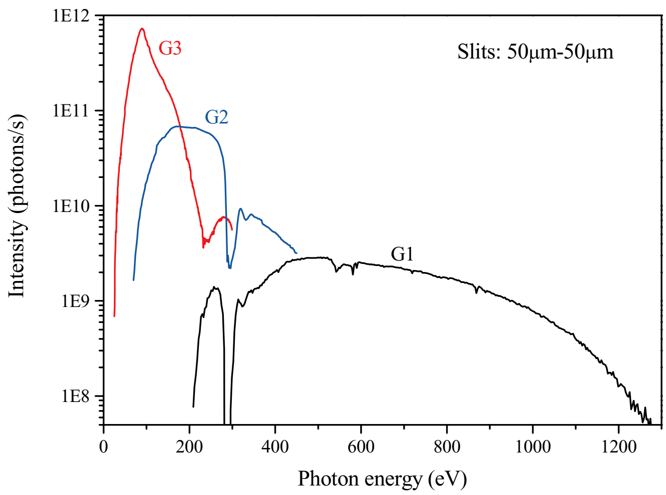


Fig. 1 Throughput from the VLS-PGM monochromator on BL4B.

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

Beamline Specifications

Monochromator	Varied-line-spacing Plane Grating Monochromator
Energy range	25-1000 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

Photoemission Spectroscopy of Solids and Surfaces

This beamline is designed for high-resolution angle-resolved photoemission study on solids and surfaces with the horizontal and circularly (CW, CCW) 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.

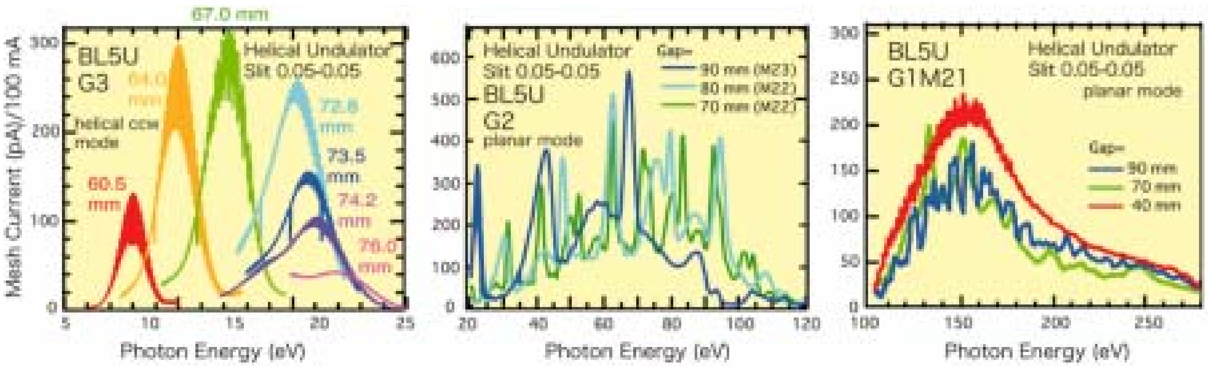


Fig. 1 Throughput from the SGM-TRAIN monochromator on BL5U.

Beamline Specifications

Monochromator	SGM-TRAIN
Energy Range	5-250 eV
Resolution	hν/ΔE >1000 for < 50μm slits
Experiment	ARPES, AIPES, XAS
Flux	$<10^{11}$ photons/s for < 50μm slits (at the sample position)
Main Instruments	Hemispherical photoelectron analyzer (MBS-Toyama 'Peter' A-1), LEED of reverse type (OMICRON), Liq-He flow cryostat (5 – 400 K)

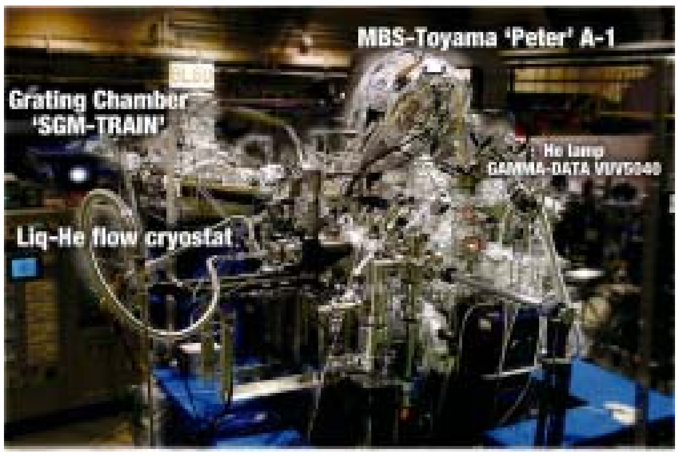


Fig. 2 High-resolution angle-resolved photoemission apparatus at BL5U.

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).

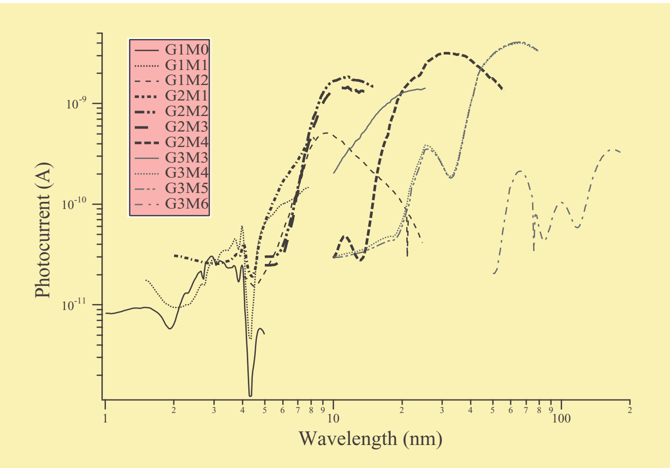


Fig. 1 Throughput spectra for possible combinations of gratings and mirrors at BL5B measured by a gold mesh.

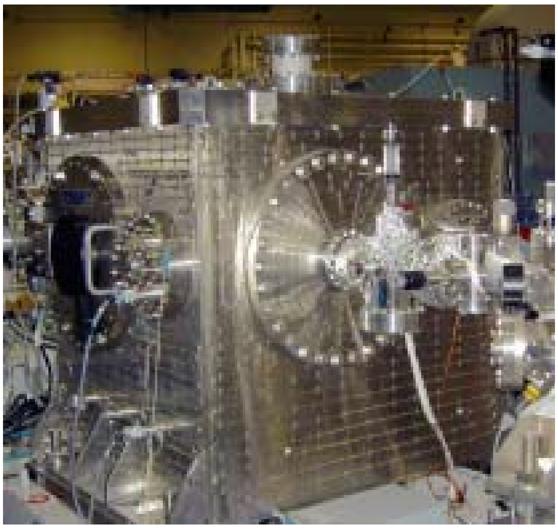


Fig. 2 A side view of the experimental chamber for calibration measurements.

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.

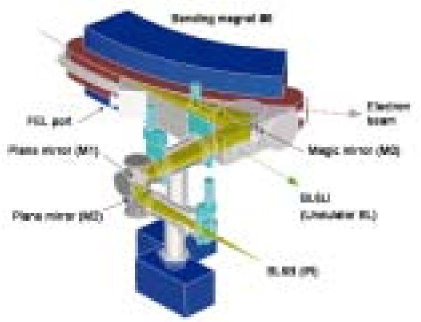


Fig. 1 The design of optics and front end of BL6B.

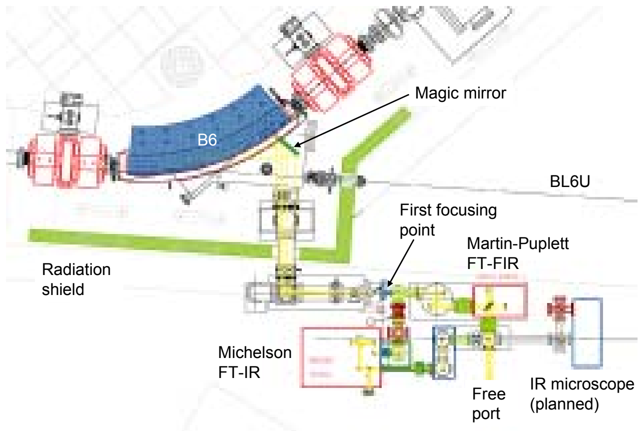


Fig. 2 Schematic figure of top view of BL6B.

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

High-Resolution Angle-Resolved Photoemission of Solids in VUV

The beamline BL7U is constructed to provide the photon flux with high energy resolution and high flux mainly for high-resolution angle-resolved photoemission spectroscopy of solids. The light source is an APPLE-II-type variable polarization undulator. The undulator light is monochromatized by the modified Wadsworth-type monochromator with three gratings (R=10 m; 1200, 2400 and 3600 lines/mm optimized at 10, 20, and 33 eV) is equipped. The monochromator has two normal-incident optics, one is a grating (G) and the other is a plane mirror (M1). The photon flux is strongly reduced at higher energy region. Then some multilayer coating mirrors with high reflection at special photon energies are equipped to M1. The beam size at the exit slit (S) position is reduced to 1/3 by the monochromator. After S, the light is focused on a sample by a troidal mirror (M3). The beam size is reduced to 1/2 by M3, then the beam size on the sample is 1/6 of the source size.

The beamline will be dedicated to users in 2007 autumn.

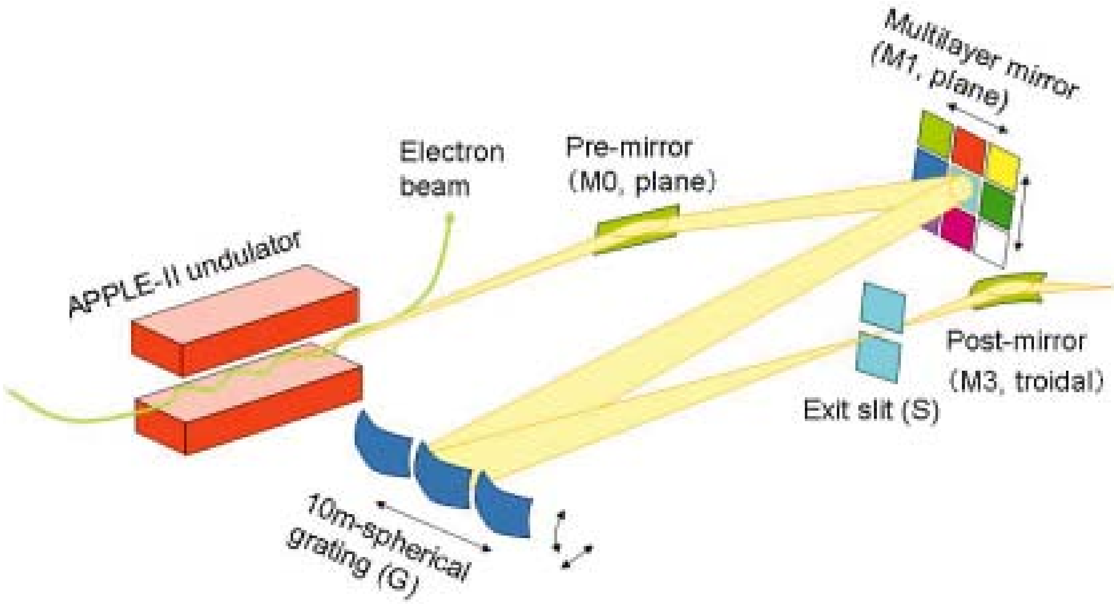


Fig. 1 Schematic figure of BL7U.

Beamline Specifications

Monochromator	10-m Normal Incidence Monochromator (modified Wadsworth-type)
Photon energy range	6 to 40 eV (λ = 30 - 200 nm)
Resolution	$E/\Delta E = 1\times10^4 \sim 5\times10^4$ (Expected)
Photon flux on sample	$\geq10^{12}$ ph/s (Expected)
Beam size on sample	100(H)×10(V) μm^2 (Expected)
Experiments	Angle-resolved photoemission of solids, photo-chemistry, VUV microscopy

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.

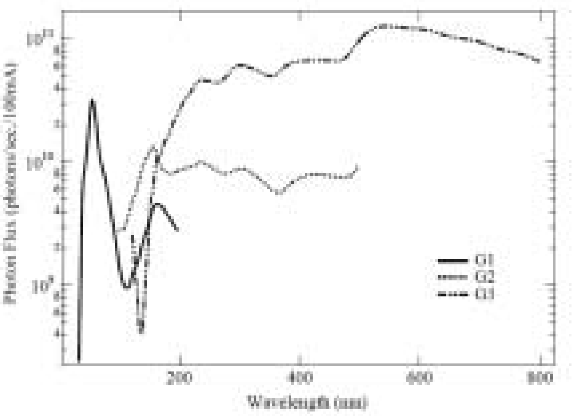


Fig. 1 Throughput spectra of BL7B measured by a silicon photodiode.

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

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 *et al.*, Rev. Sci. Instrum. **66** (1995) 2104.

Fig. 1 Photo of the monochromator at BL8B1.

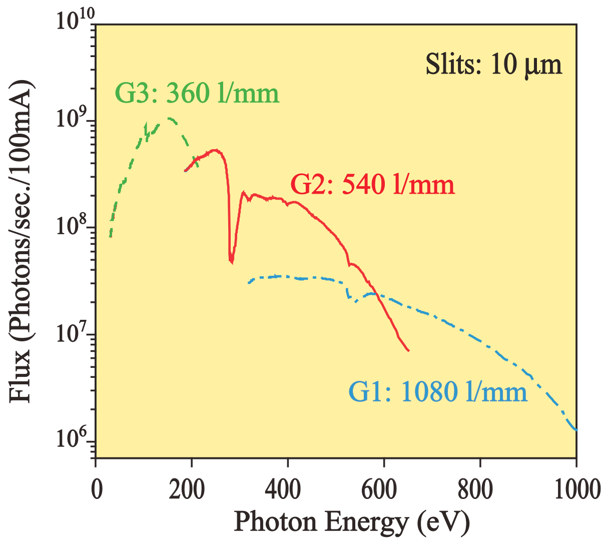


Fig. 2 Throughput of the monochromator at BL8B1.

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 130eV with exchanging two gratings (G1: 1200 l/mm, G2: 450 l/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 $1\times1mm^2$. Figure 1 shows the throughput spectra of PGM (slit=100 µm). The energy resolution at a slit width of 100 µm was found to be E/ΔE = 1000 in the wavelength range from 2 to 130 eV. A hemi-spherical electron energy analyzer of 75 mm 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.

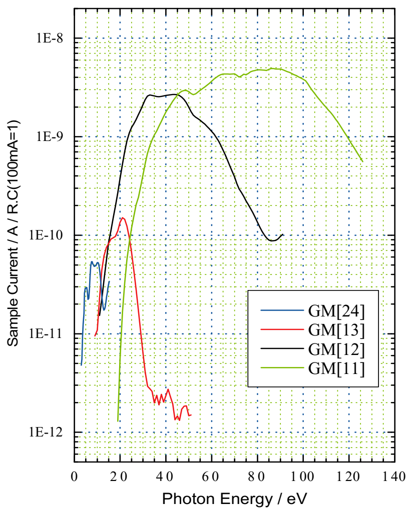


Fig. 1 Throughput spectra of plane-grating monochromator at BL8B2 (slit=100 µm).

Fig. 2 A photo of BL8B2.

Beamline Specifications

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