# Status of UVSOR

# The UVSOR Accelerator Complex in 1998

Hiroyuki HAMA, Masahito HOSAKA, Shigeru KOUDA, Jun-Ichiro YAMAZAKI, Toshio KINOSHITA

*UVSOR Facility, Institute for Molecular Science, Okazaki 444 Japan*

## 1. General

In 1998, the beam supply for user synchrotron radiation experiments was started on Jan-12 after the new year vacation. The statistics of the ring perfomance in1998 is shown in Table 1. Since the operation with the single-bunch mode was assigned for only two weeks, most of the user machine time was consumed with the multi-bunch mode with 12-bunch filled. The continuous beam delivery was interrupted by an accidental failure of the booster synchrotron in October. This most serious troubles encountered in the year was occurred on a high voltage unit of the synchrotron power supply. Large capacitance chemical condensers were exploded due to an irregular high voltage. Because there was no apparent malfunction discovered in the system, it took a very long time to fix the power supply. We have concluded a break of a balance resistance might provoke a spike of the irregular high voltage. After three-week unscheduled shut-off, the system was restored. Consequently we lost approximately 200 hours of the user beam time. In addition to this major trouble, a couple of minor troubles occurred on various devices such as misfire of the fast kicker for the beam extraction

Table. 1 1998 Ring Performance Statistics

| | Multi(12)-Bunch | Single-Bunch | R&D |
|---|---|---|---|
| Ave. fill Current | 248 mA | 73 mA | - |
| Ave. Lifetime | 5.2 hours@200mA | 1.8 hours@30mA | - |
| Int. Current | 200.1 A·hours | 2.2 A·hours | 43.4 A·hours |
| Total operation | 1578 hours | 100 hours | 886 hours |
| Ave. Beam current | 127 mA | 22 mA | 49 mA |

from the booster was frequently happened in May. These minor troubles were fortunately fixed very rapidly and a serious situation was kept away.

Monthly statistics of significant operational perfomance in the user machine time are presented in Fig. 1 through 4. The unscheduled shutdown due to the trouble of the booster mentioned above caused decreases of the operation time in October and November. Large portion of shorter operation times of March, April and August was the scheduled shut-off terms.

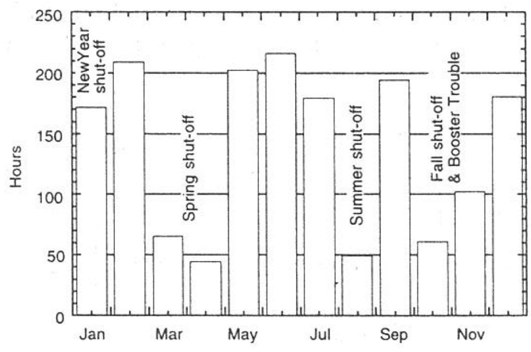



Fig. 1 The total integrated operation time for users accumulated each month.

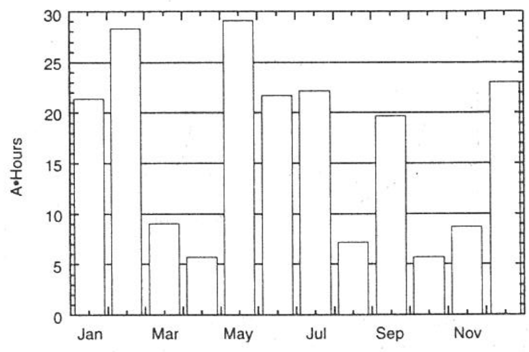



Fig. 2 The integrated beam current for users accumulated each month.

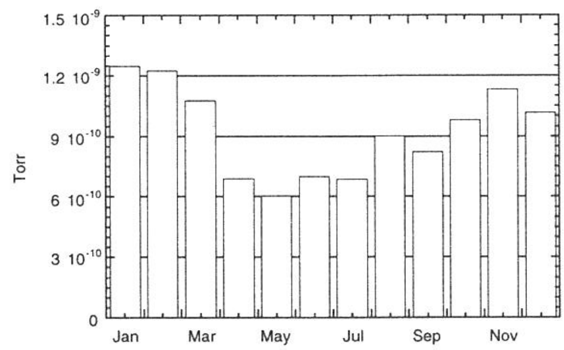



Fig. 3 The ring vacuum pressure at 200 mA beam current averaged over each month.

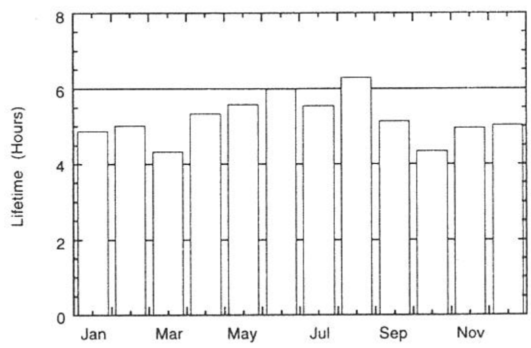



Fig. 4 The beam lifetime at 200 mA beam current with 12-bunch operation averaged over each month.

From April through Summer, good vacuum resulted from which the bake-out was done for a part of the ring vacuum chamber and all Ti sublimation pumps were maintained during the Spring shut-off term. From October, the higher vacuum resulted from the superconducting 4 T wiggler radiation, which was commissioned again after a long shut-down due to a malfunction of the 4 K refrigerator since the end of December, 1997.

## 2. Improvement

The lattice functions of the storage ring have been improved after the Spring shut-off term, then the operating point of betatron number was changed from (3.16, 2.64) to (3.16, 1.43) to expand the dynamic aperture. Furthermore the dispersion function on the straight sections for the insertions and the RF cavity has been reduced to be less than 7 3 cm (former value is approximately 30 cm). Since the vertical tune is kept away from the third order resonance, the beam handling became easier, so that the ramping (600 MeV to 750 MeV) speed was able to be two times faster than the pervious operation and it became possible to decelerate the beam from 750 MeV to 600 MeV without the beam lost, then the re-injection time has been greatly reduced because more than 130 mA beam current remains. After the beam re-injection and the energy ramping, the beam orbit is able to be corrected within an error of less than 30 μm (rms-value of 16 BPMs) from the default one .

This operating point became to be changed again after a shut-off term in October for the ring operation with the superconducting 4 T wiggler. Both operating points showing in Fig. 2(a) and (b) have no solution in case of introducing an additional focusing power of the 4 T wiggler at the beam injection energy, 600 MeV. Thus we had injected the beam with a 3 T excitation of the wiggler and the magnetic field had been increased up to 4 T by following the energy ramping so far. It was obviously inconvenient for a smooth beam injection procedure. The lattice function of Fig. 2(b) was modified to optimize for the 4 T wiggler by reducing

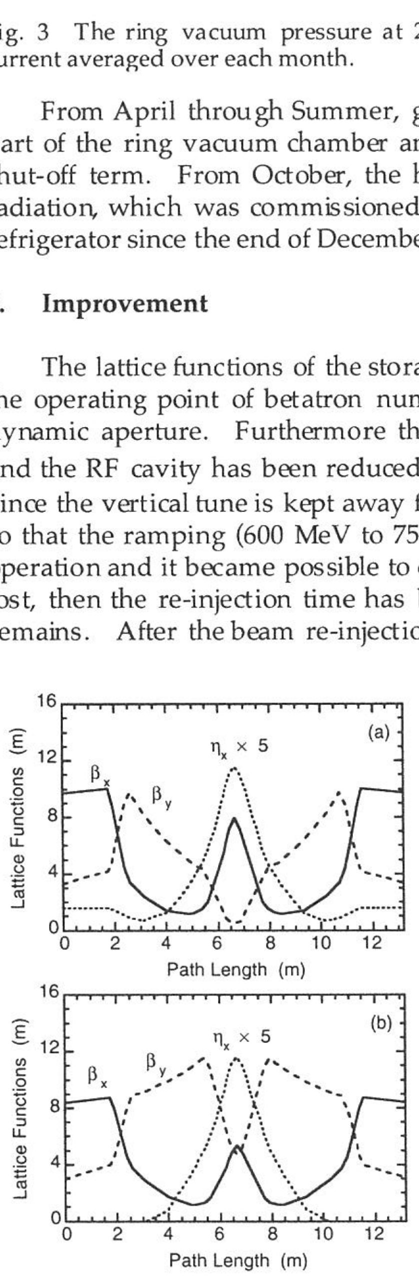



Fig. 5 (a)Pervious Lattice functions of the betatron numbers of (3.16. 2.64), and (b)developed Lattice functions of (3.16,1.43).

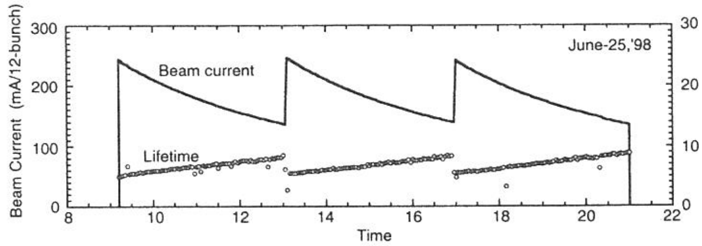



Fig. 6 Beam current and lifetime of a typical one-day operation.

the betatron length in the long straight section down to 1.7 m. Consequently the 600 MeV beam was able to be injected with the 4T excitation, and then the injection rate was not significantly reduced by completely correcting a closed orbit distortion due to the wiggler.

Power supplier and pulsers for the bump magnets in the booster synchrotron which had been used for more than 15 years were replaced. New ones employs IGBTs for fast switching of discharge, and the charging voltages of all three pulsers can be changed proportionately. It is apparently working well. However the pulse width is a bit longer than old one because of internal impedance of the IGBT, and then the beam current injected from the linac has decreased to approximately 60 % of the pervious current. The pulse width should be improved along with the beam injection scheme between the synchrotron and the linac.

An additional feedback system for the third harmonic RF cavity (HCV) used for suppression of the coupled-bunch instability was installed. In the HCV, the RF voltage should be kept at approximately one-third of that in the main RF cavity (MCV). Moreover the phase between the HCV and the MCV should be kept at a certain angle so as to introduce the Landau damping. Because the induced RF field due to the beam current is so large that the resonant frequency of the HCV should be widely detuned from the third harmonic of the main RF frequency to reduce the induced field and create the appropriate phase (approximately $\pi/2$ of the main RF). The external current is fed to keep a constant RF voltage in the HCV with the same phase of the beam induced field. This operation is not complete passive or active mode, and then called "semi-active" mode. In this mode, as the beam current decreases the external current must be increased to keep the RF voltage. However, because of the large detuning of the HCV and the finite output power of the power amplifier, most of the fed external power is usually reflected and it becomes impossible to keep the RF voltage. Therefore, as the beam current decreased the resonant frequency of the HCV had to be a bit tuned by manually moving the plunger in order to increase the RF voltage. Normally there are two feedback system required for the RF cavity. One is a power or RF voltage feedback applying to the power amplifier (or a low level circuit), and another is a phase or resonant frequency feedback applying to the plunger. In this case, a forward power feedback of the external current should be applied to the plunger. As a result of the new feedback system of which the external forward power level controls a phase shifter of the third harmonic oscillator, the bunches has been stabilized at a wide range from the fill current through a few tens mA and operators was released from an annoying plunger control.

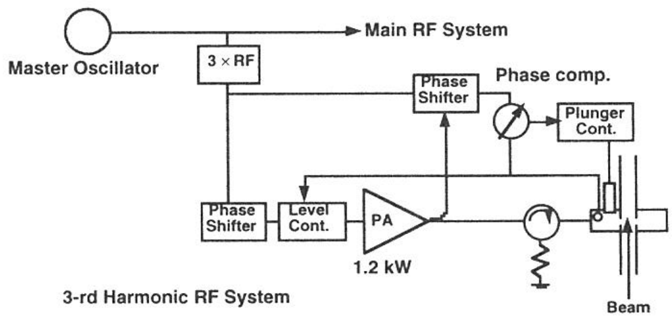
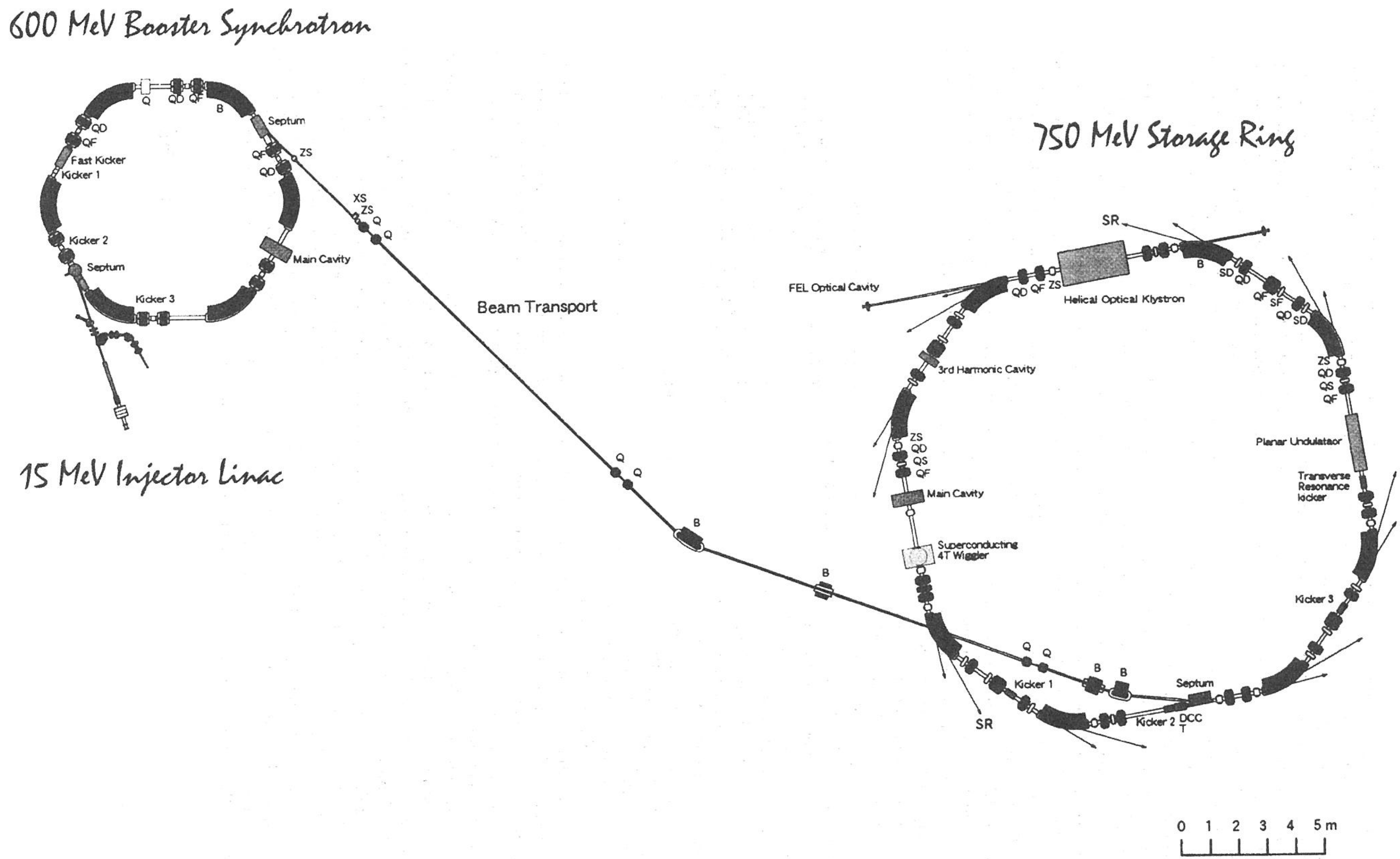



Fig. 7 Feedback loops of the third harmonic RF cavity system.

A new aluminum beam pipe for the storage ring has been testing by the accelerator group. Recent experimental studies of the ring impedance showed an evidence of which the inductive impedance dominates the bunch lengthening and the single-bunch instabilities. Estimated normalized broad-band inductive impedance has been 3 ~ 4 Ω which may resulted from many discontinuities of the beam pipe. In order to reduce the ring impedance, a new beam pipe has been designed. In addition, the vacuum system is also getting older and new one has been highly desired. The new beam pipe equips lumped NEG pumps containing 6 NEG modules, which has a pumping speed of more than 3000 $l/s$ for the hydrogen gas. By using an appropriate auxiliary pump with a pumping speed 2 ~ 3 $l$ / for inert gases and the methane gas, an excellent vacuum of less than $10^{-8}$ Pa was able to be achieved without baking of the beam pipe. Although the whole system is still under designing, the ring vacuum will be greatly improved in near future.




The UVSOR Accelerator Complex

# ACCELERATOR COMPLEX

## Injection Linac

| | |
|---|---|
| Energy | 15 MeV |
| Energy Spread | ~ 1.6 MeV |
| Frequency | S-band 2856 MHz |
| Acceleration | 2π/3 Traveling Wave |
| Length | 2.5 m |
| Klystron Power | 1.8 MW |
| Repetition Rate | 2.6 Hz |

## Booster Synchrotron

| | |
|---|---|
| Lattice Type | FODO |
| Energy | 600 MeV |
| Beam Current | 32 mA ( 8-bunch filled ) |
| Circumference | 26.6 m |
| Super Cell | 6 |
| Bending Radius | 1.8 m |
| Betatron Tune | 2.25 ( horizontal )<br>1.25 ( vertical ) |
| Momentum Compaction | 0.138 |
| Harmonics | 8 |
| RF Frequency | 90.115 MHz |
| Repetition Rate | 2.6 Hz |

## Storage Ring

| | |
|---|---|
| Lattice Type | Chasman-Green |
| Energy | 750 MeV |
| Critical Energy | 425 eV |
| Super Cell | 4 |
| Bending Radius | 2.2 m |
| Betatron Tune | 3.16 ( horizontal )<br>1.43 ( vertical ) |
| Momentum Compaction | 0.0264 |
| Emittance | 164 nm rad ( horizontal ) |
| RF Frequency | 90.115 MHz |
| Harmonics | 16 |
| Beam Current | Multi-Bunch 200 mA<br>Single-Bunch 70 mA |
| Life Time | 4 h at 200 mA |

## Additional Equipment

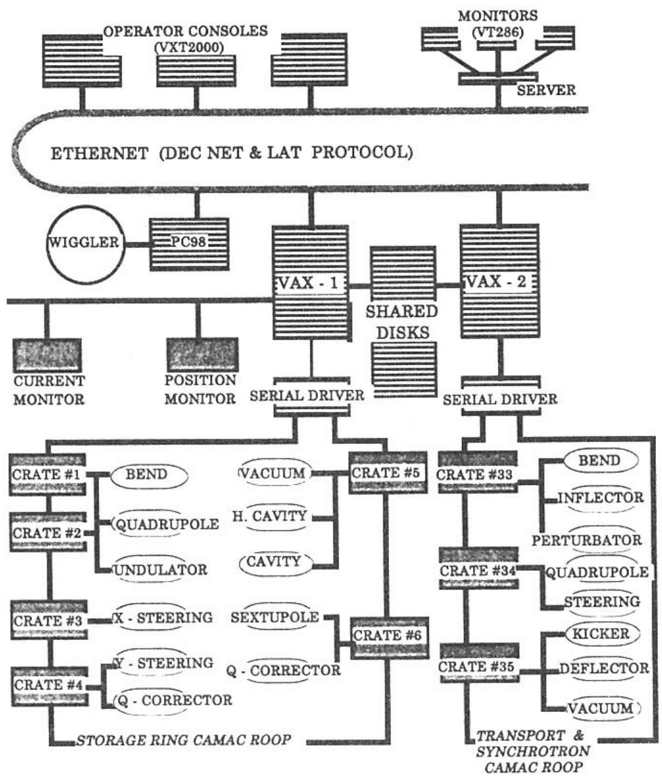
| | |
|---|---|
| Higher - Harmonic Cavity | 3 × 90.115 Mhz |
| Superconducting Wiggler | 4 T (maximum) |
| Undulator | for SR |
| Helical Optical Klystron | for FEL |

## Control System

Preface: Based on Dual-Host system with CAMAC loop and friendly man-machine interface

Architecture

| | |
|---|---|
| CPU | VAX4000 (× 2) |
| OS | VMS |
| Connection | DECNET & Local Cluster |
| Operator Console | X - Servers (VXT200 × 3) |
| Status Monitors | VT286s + Macintosh |
| Interfaces | CAMAC serial loop |
| | GPIB for Beam Monitors |
| | RS232C for Host CPU of Wiggler |
| Languages | FORTRAN, C, Pascal |




**Scheme of Accelerator Control System "UCOSS"**

# Beam Lines in 1998

Masao KAMADA
*UVSOR Facility, Institute for Molecular Science*

About one third of beam lines has been upgraded in recent years. In May, we had a beer party to celebrate the commissioning of a 3-m normal-incidence monochromator at BL7B for solid-state researches. Before the party, each active working member had reported an initial planning, expected performance, ray tracing calculation, budget, troubles at test stages, and reason for delay in schedule. Also the future schedule was discussed in details during the party. In July, we had another beer party to celebrate the commissioning of a multi-layer monochromator at BL4A for photochemical reaction. The members in the Urisu group reported the initial calculation, construction procedures, and test experimental results. All of us joined them to expect future scientific achievements with these monochromators. In December, the Mitsuke group had announced the good high-resolution spectrum obtained by the Dragon-type monochromator at BL2B2, where the old Seya-Namioka monochromator was scrapped to expand the wavelength region and to achieve high-resolution for gaseous experiments in VUV and EUV ranges. In December, the new mirror system at BL7A was commissioned by Prof. T. Kinoshita. This mirror system is useful to change spectral range between soft and hard x-ray regions with 4T-superconducting wiggler.

Besides them, a 15-m SGM monochromator at BL8B1 was operational mainly for gaseous experiments in EUV region with a TOF-Mass spectrometer, besides the use for solid-state spectroscopy. A Bruker FT-IR interferometer and an old FT-FIR of a Martin-Puplett type at beam line 6A1 were used for solid-state experiments in the wide wavelength range from near infrared to millimeter wave. A SGM-TRAIN monochromator at beam line 5A, which has been constructed for the use of circularly polarized light from the helical undulator, was operational for photoemission experiments in EUV range. On the other hand, the photoelectron spectroscopy system at BL8B2 is under replacement by the Ueno group to achieve higher-resolution of angle-resolved UPS for organic materials.

Therefore, sixteen experimental stations excluding BL2B2, 4A, 7B, and 8B2 were operational in 1998. The UVSOR facility will soon have twenty stations operational; two soft-x-ray stations equipped with a double-crystal monochromator, eight extreme ultraviolet stations with a glancing incidence or a plane-grating monochromator, four vacuum-ultraviolet stations with a Seya-Namioka-type or a normal incidence-type monochromator, two (far) infrared stations equipped with a FT interferometer, a multi-layer monochromator, and three white-light stations without any monochromator.

In 1998, many and interesting results were obtained at UVSOR beam lines. For examples, combination experiments with SR and lasers were successfully carried out at BL1B, BL3A2, and BL6A2 for gaseous and solid/surface researches. New experiments with an electron-ion coincidence (EICO) method to investigate SR-induced desorption on solid surfaces were actively conducted at beam line 2B1. Resonant photoelectron experiments on organic and transition-metal compounds were carried out at BL1A, BL5B, and BL7A. Photoelectron microscopy experiments were also conducted at BL5B, and BL7A. Photoelectron experiments on semiconductor and metallic surfaces were conducted at BL2B2 and 5A. Two-dimensional photoemission experiments for solid and gaseous molecules at BL1A and BL3B, respectively. Photochemical reaction experiments on semiconductors and organic compounds were carried out at BL3A1, 4B, and 8A. Infrared reflection at high pressure and magnetic circular dichroism in high magnetic field were successfully studied with FT-IR and FT-FIR at BL6A1.

There were lots of troubles as usual in old facilities in the world. In August, a transformer of FT-IR at BL4B was burned, and a switching system at BL2A had electric leakage. In October, a rotary pump at BL8B1 was suddenly fired. These accidents pushed us to install a new alarm system for watching electric troubles in the experimental hall. Also, we did an evacuation drill for our security in November.

The UVSOR facility strongly asks all users to conduct their experimental procedures according to the beam line manuals and the guidebook. The persons who want to use the open and the in-house beam lines are recommended to contact with the following station master or supervisor and the representative, respectively. The persons who want to know updated information of the UVSOR facility are recommended to open http://www.uvsor.ims.ac.jp/.

Table I. Station masters and supervisors of open beam lines in 1998

| Beam Line | Station Master | Sub Master | Supervisor |
|---|---|---|---|
| 1B | M. Hasumoto | M. Kamada | M. Kamada |
| 2B1 | S. Tanaka | M. Kamada | M. Kamada |
| 3A1 | M. Kamada | K. Hayashi | M. Kamada |
| 3A2 | N. Kondo | T. Gejo | T. Kinoshita |
| 5A | S. Tanaka | M. Hasumoto | M. Kamada |
| 5B | M. Hasumoto | K. Hayashi | T. Kinoshita |
| 6A1 | K. Hayashi | O. Matsudo | M. Kamada |
| 7A | T. Kinoshita | O. Matsudo | T. Kinoshita |
| 7B | T. Kinoshita | M. Hasumoto | T. Kinoshita |
| 8A | T. Gejo | N. Kondo | T. Kinoshita |
| 8B1 | T. Gejo | N. Kondo | T. Kinoshita |

Table II. Representatives of in-house beam lines in 1998.

| Beam Line | Representative | Department/Facility |
|---|---|---|
| 1A | N. Kosugi | VUV Photo Science |
| 2A | N. Kosugi | UVSOR |
| 2B2 | K. Mitsuke | VUV Photo Science |
| 3B | K. Mitsuke | VUV Photo Science |
| 4A | T. Urisu | VUV Photo Science |
| 4B | T. Urisu | VUV Photo Science |
| 6A2 | M. Kamada | UVSOR |
| 6B | K. Yakushi | Molecular Assemblies |
| 8B2 | N. Ueno | VUV Photo Science |

# *BL1A*

## Soft X-Ray Beamline for Photoelectron-Photoabsorption Spectroscopy

BL1A is a soft x-ray beamline for photoelectron-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 range from 585 to 4000 eV by using several kind of crystals such as β-alumina, beryl, quartz, InSb and Si crystals. The throughput spectra of the beryl ($10\bar{1}0$) and InSb (111) crystals are shown in Fig.1. Typical energy resolution ($E/\Delta E_{h\nu}$) of the monochromator is about 1500 when we use a pair of beryl or InSb crystals.

For photoelectron-photoabsorption spectroscopy, an ultra-high-vacuum (UHV) apparatus is connected. The top view of the apparatus is shown in Fig. 2. It is equipped with a high-performance electron analyzer (SES-200, SCIENTA Co.). The pass energy ($E_P$) can be varied between 1 and 500 eV and typical resolving power ($E_P/\Delta E_{elec.}$) is more than 1000. Using the apparatus, resonant photoelectron spectra for solid samples can be obtained with the total energy resolution ($\Delta E_{total}$) of ~0.7 eV around hν=1000 eV.

**Reference**

[1] A.Hiraya et al., Rev. Sci. Instrum.,63 (1992) 1264.

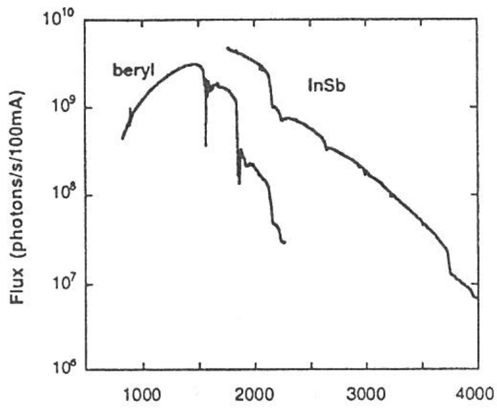



Figure 1. Throughput spectra of the double crystal monochromator at the BL1A.

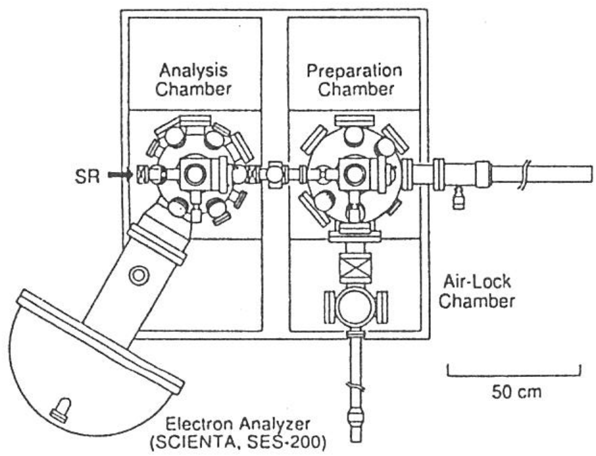



Figure 2. Top view of the UHV apparatus for photoemission-photoabsorption spectroscopy.

### Specification

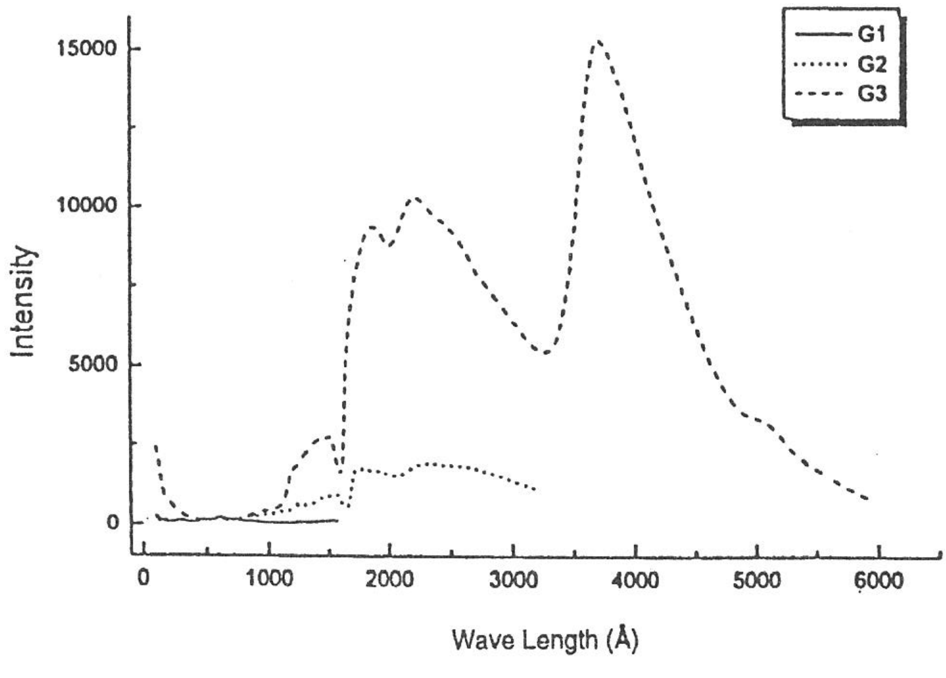
| | |
|---|---|
| Monochromator | : double crystal monochromator ($\theta_B$=70-20°) |
| Monochromator crystals (2d value, energy range) | : β-alumina (22.53Å, 585-1609eV), beryl (15.965Å, 826-2271eV), quartz (8.512Å, 1550-4000eV), InSb (7.481Å, 1764-4000eV), Si (6.271Å, 2104-4000eV) |
| Resolution | : E/ΔE=1500 for beryl and InSb |
| Experiment | : photoelectron-photoabsorption spectroscopy for solid |

# *BL1B*

## Seya-Namioka Monochromator for General Purpose in VUV Region

The beam line 1B has been used for many experiments such as absorption, reflectivity, photo-ionization, and luminescence in condensed phase. The system consists of a pre-mirror, a 1-m Seya-Namioka type monochromator, and a post-mirror. Three gratings with 600, 1200, and 2400 gr/mm can cover the wavelength range from 40 nm to 650 nm, and two post mirror make it possible to change the focus point. A long-focus mirror is usually used with a LiF window to separate a main chamber for spectroscopy in liquids and biospecimens, while a short-focus mirror is suited to solid-state spectroscopy. The output flux from this monochromator is about $10^{10}$ phs/s around 200 nm with 0.1 mm slits. The spectral distributions obtained with three gratings are shown in the figure, although they are not the best data because of the contamination of the mirrors and gratings due to the recent careless accident.

A second monochromator (Spex 270M) and a LN-cooled CCD detector (Princeton Inc.) are available for luminescence experiments, together with a liquid helium-flow type cryostat. A time-resolved system to observe luminescence and excitation spectra with three time-gates is also possible. The decay measurement is one of the highlights of this station. A couple of weeks are supplied for the decay measurements under single bunch operation. A TAC system is therefore one of the standard instruments at this beam line.



# *BL2A*

## Gas Phase Photoabsorption and Fluorescence Spectroscopy

Photoabsorption cross section and fluorescence excitation spectra of gaseous sample are simultaneously measured in a vacuum cell or effusive jet condition. The primary photons in the 30-400 nm region are dispersed by a 1-m Seya monochromator. Higher order light in the 80-120 nm range is suppressed by using a long channel with a cross section 2.5 × 5.0 × 170 mm long filled with argon gas at a pressure ≅0.3 Torr as shown in fig. 1. No filter is used between 30 and 80 nm since the photon flux at λ<40 nm is very weak (see fig. 1). The gas filter and cell are placed in a main chamber which is evacuated by a 5000 *l*/s diffusion pump (Varian, Model VHS10). A LiF window is used for the measurement at the 105<λ<210 nm range as usual. Thus, the total photoabsorption cross section and fluorescence excitation spectra are available in the wide wavelength region 30-210 nm without or with little contamination by the higher order light.

Dispersed fluorescence and polarity of emission from the excited fragment are also measurable in addition to the total photoabsorption and emission cross sections. In the single bunch operation of synchrotron radiation with the period of 178 ns, a radiative life time can be measured.

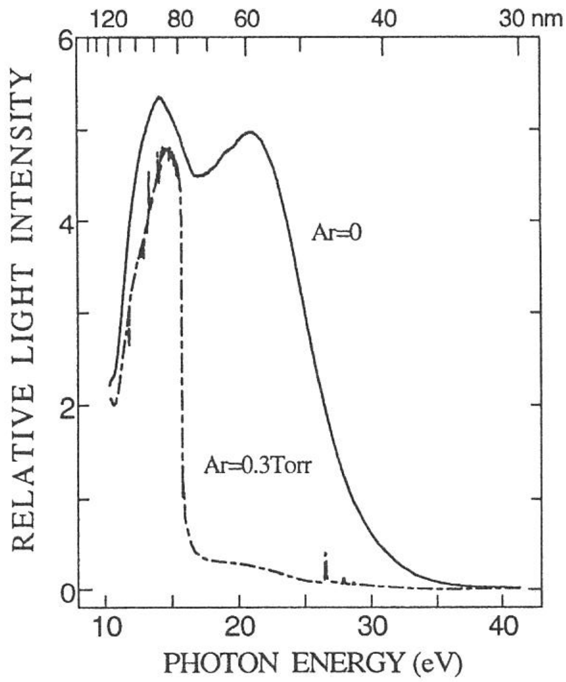



**Fig. 1. Transmitted $I_0$ intensity with and without an Ar gas filter.**

### Specification

Monochromator : 1-m Seya
Wavelength range : 30-400 nm
Resolution : $\Delta E/E \cong 10^{-3}$ at 100 nm
Grating : 1200 *l*/mm blazed at 96 nm
Experiments :

- Vacuum cell or effusive jet
- Total photoabsorption cross section
- Fluorescence cross section
- Dispersed fluorescence
- Radiative lifetime
- Emission polarity

# *BL2B1*

## Soft-X ray beamline for solids and solid surfaces

BL2B1 is a beamline in order to study solids and solid surfaces by the use of photoabsorption and photoelectron spectroscopy. A 2-meter grazing incidence monochromator ('Grasshopper' type, Mark XV; Baker Manufacturing Co.) is installed. A 2400 l/mm grating has been installed since April 1994, and was replaced by a 1800 l/mm grating at March 1997. The resolving power is better than 600 at C-K edge (about 290 eV). Figure 1 shows the photoelectron yield from the Au mesh (10%-transmission) located near the position of a sample by the use of the 1800/mm grating. The dip around 300 eV is due to carbon contamination of optical elements.

The analyzing chamber is installed at the focusing point of the monochromized light. The pressure is less than $1x10^{-10}$ Torr. A double-pass CMA, a LEED optics, an ion-gun for sputtering, and a sample holder which can be cooled with liquid nitrogen and heated, etc. are equipped for the 'in-situ' measurements. The photoelectron spectroscopy including CIS (Constant initial state spectroscopy), CFS (Constant final state spectroscopy) can be measured using CMA, which is controlled by a personal computer. Samples can be transferred to the analyzing chamber from the air, through the preparation chamber in which sample treatments (e.g. cleaving, filing, and deposition) can be made.

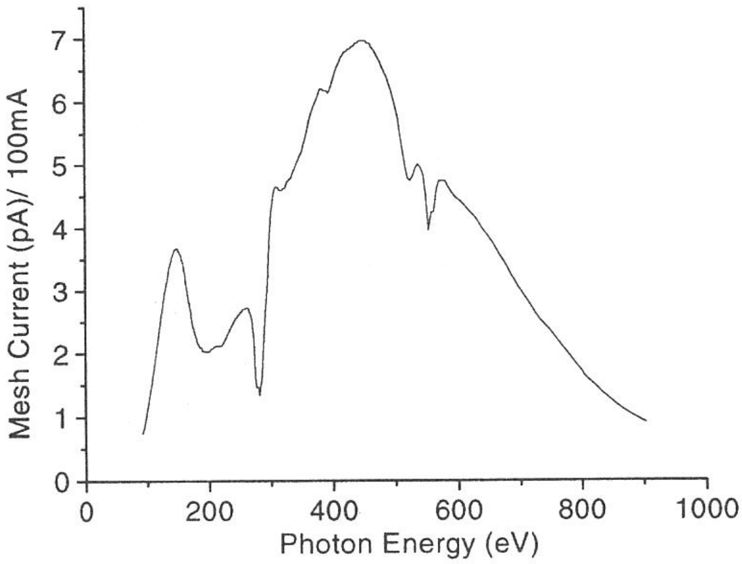



*Figure 1. Photoelectron yield measured by the use of the Au mesh*

**Specification**

| | |
|---|---|
| Monochromator | :2m grasshopper type |
| Energy range | :95-1000 eV ( 1800 l/mm) |
| Resolution of photon | :<0.4eV at 300eV (1800 l/mm) |
| Resolution of photoelectron | :<0.3eV (hv=150eV) |

Experiment : Photoelectron spectroscopy, X-ray absorption spectroscopy,

# *BL3A1*

## Irradiation Port with Undulator Radiation

The beam line 3A1 has been used for various kinds of experiments need intense undulator radiation. In recent years, photo-desorption, photo-chemical reaction, SR-CVD, photo-etching, irradiation damage effects in condensed phase, light amplification induced by core-level excitation, and so on have been carried out at this beam line. The luminescence from High-Tc superconductors and fullerens, the fluorescence yield of which is not high enough at beam lines for bending radiation, has been observed. A combination experiment with undulator radiation and a diode laser has been successfully conducted for time-response measurement of SR-induced desoprtion.

A planar-type undulator installed in a long straight section of the UVSOR storage ring provides an intense quasi-monochromatic radiation to beam lines 3A1 or 3A2. The undulator consists of 24 sets of magnets, a period length of which is 80 mm. The photon-energy range from 8 to 52 eV can be covered by the fundamentals with a K-value from 0.62 to 3.6, although higher harmonics are mixed into the spectral distribution in case of high K-values.

The beam line 3A1 has no monochromator between the undulator and a sample chamber. The radiation is introduced by a toroidal focusing mirror into sample chamber through a pinhole of 1 mm in diameter and metallic filter (Al, Sn, and In). A gold mesh is always installed in the sample chamber to monitor the incident photons. A typical spectrum distribution measured by the monochromator at BL 3A2 is shown in the figure, where the undulator gap is 60 mm and the photon flux is estimated to be about $10^{14}$-$10^{15}$ phs/s on the samples.

A differential pumping system can be provided for the users who want to use gaseous materials. A second monochromator (Jobin-Yvon HR-320), another VUV monochromator ( home-made one of normal-incident type), and a helium storage-type cryostat are available for luminescence experiments. A TAC system is also one of the standard instruments of this beam line. For liquid- or gaseous-phase experiments, $MgF_2$ windows can be installed to separate the sample chamber from the beam line.

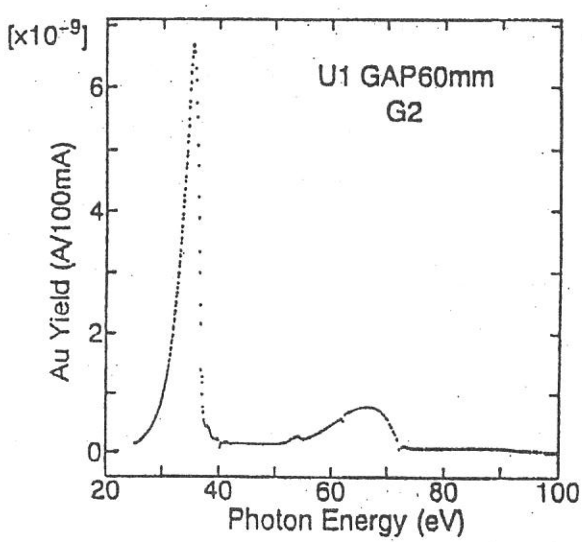
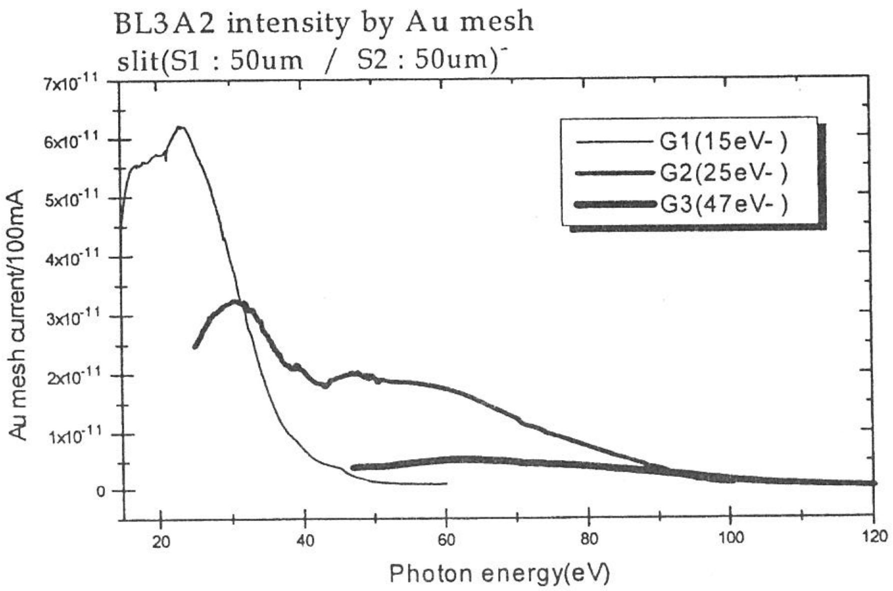



Fig. 2 Typical spectrum of undulator

# *BL3A2*

## Gas-Phase Dissociative Photoionization Apparatus

This machine has been constructed to study the formation of multiply-charged ions and their dissociation processes. The monochromator is constant-deviation grazing-incidence type with 2.2m focal length and covers wide wavelength region(10-100nm) where many kinds of molecules and multiply-charged ions are effectively measured. High intensity photon beam is available by introducing the radiation emitted from the undulator to the monochromator. The apparatus contains an angle-resolved time-of-flight mass spectrometer (TOFM) equipped with automatic data acquisition system for photoion-photoion coincidence measurements. For full understanding of dissociative multiple photoionization, we detect the coincidence signals of two fragment ions produced from a parent ion, evaluate the kinetic energy release in "Coulomb explosion", and measure the angular distributions for the fragment ions. The sensitivity with respect to high-speed ions (several tens of electron volts) is much improved in comparison with commercial TOFMS.




**Specifications**

| | | |
|---|---|---|
| monochromator | : | 2.2m Constant-Deviation Grazing-incidence |
| Spectral range | : | 10 - 100nm (15eV - 120eV) |
| Resolution | : | 550 - 800 (0.03eV - 0.18eV) |
| Mass spectrometer | : | 300 |
| Length of the drift tube | : | 0.2 - 1m |
| Rotatable angle | : | 0 - 90° with respect to the photon beam |

# BL3B

## Beam Line for Gas Phase Two-Dimensional 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 (*e.g.* Fig. 1), 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 as follows: (1) a bound valence state of nitric oxide whose autoionization gives rise to a number of irregularly spaced peaks in its photoionization efficiency curve,[1)] (2) the $(3\sigma_g)^{-1}(3\sigma_u)^1$ valence state of acetylene which dominates photoionization cross section and leads to strong vibrational excitation,[2)] (3) Rydberg states of nitric oxide which undergo dissociation into N** + $O(^1D^e, {}^3P^e)$ followed by autoionizing transitions of the superexcited nitrogen atoms,[3)] and (4) multiple-electron-excited Rydberg states of carbonyl sulfide which are primarily produced by conversion from the Rydberg states converging to $OCS^+(B^2\Sigma^+)$ and subsequently dissociate into S** + $CO(X^1\Sigma^+)$ giving rise to autoionizing transitions of the superexcited sulfur atoms.[4)]


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.*, *ibid.* **105**, 6367 (1996).
4) Y. Hikosaka *et al.*, *ibid.* **107**, 2950 (1997).

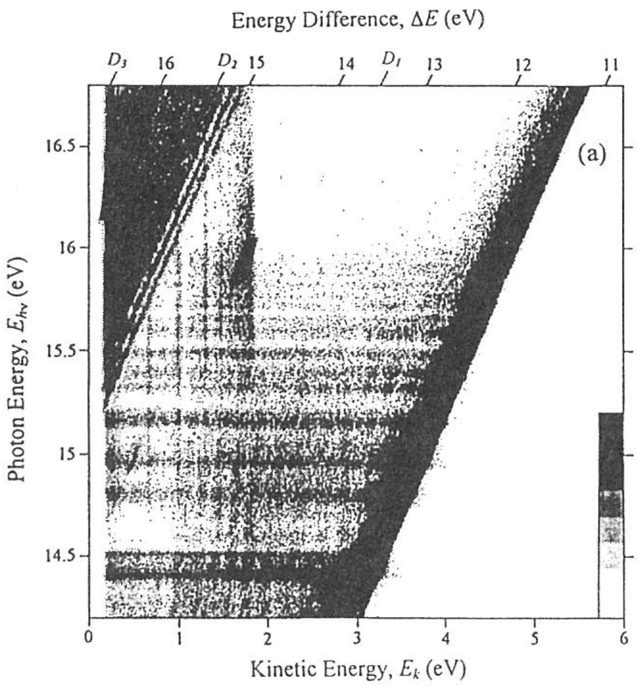




**Figure 1.** Two-dimensional photoelectron spectrum of OCS taken at the photon energy range from 14.2 to 16.8eV. The electron yield is presented by the plots with eight tones from light to dark on a linear scale.[4)]

### Specification

Monochromator : 3 m normal incidence
Wavelength range : 30 - 200 nm
Resolution : 0.007 nm at 100 nm

# *BL4A*

## Multi-Layered Mirror Monochromator Beam Line for Synchrotron Radiation Stimulated Processing Study

This beam line is now under construction. Synchrotron radiation stimulated reaction has been studied actively during the last decade. The excitation energy dependence of the reaction, however, is a difficult data to obtain, due to that it requires a large number of monochromatised photons which is not supplied by the conventional monochromator beam lines. This beam line is designed to supply $10^{13}$ to $10^{14}$ monochromatised tunable photons/s with 3–5 % resolutions, by using a double crystal type multi-layered mirror monochromator. The multi-layered mirrors now considered are Mo/Si for 50–90 eV and Mo/C or Mo/$B_4$C for 90–150 eV ranges. The calculated reflectivities for a Mo/Si mirror is shown in Fig. 1. The background photons of the lower energy region can be removed by a metal thin film filter.The beam spot size at the focussed point (sample surface in the reaction chamber) is about 2x3 $mm^2$. For the energy range of 200–500 eV which is covered by this beam line, however, the reflectivity of the multi-layered mirror is generally low, and development of the high efficiency mirror is required.

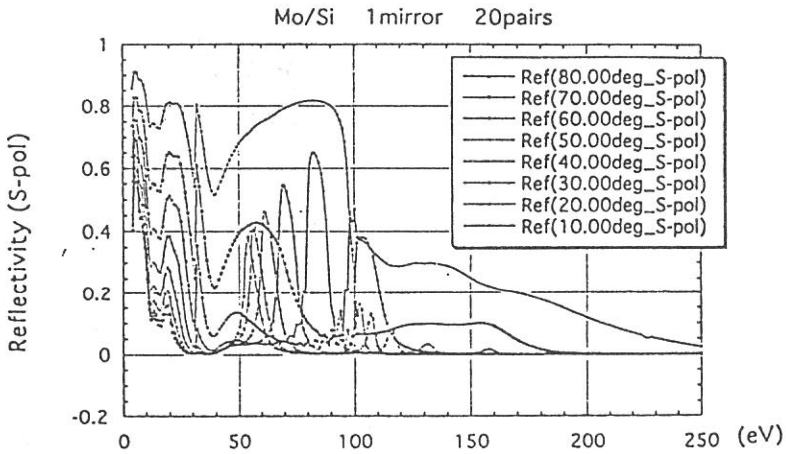



Fig. 1 Calculated reflectivities of the Mo/C multi-layered mirror.

### Specifications

| | |
|---|---|
| Monochromator | :Multi-layered mirror monochromator |
| Wavelength range | :50–150 eV |
| Resolution | :3–5 % |
| Experiments | :Excitation energy dependence of the SR processing |

# *BL4B*

## Synchrotron Radiation Stimulated Processing Beam Line

Several kinds of synchrotron radiation stimulated processing experiments can be conducted using this beam line. The reaction gases up to about 0.1 torr can be used by the differential vacuum pumping. Reaction apparatus shown in Fig. 1 is consisted of four ultra high vacuum chambers, which is used for etching and chemical vapor deposition (CVD) experiments, Si gas source molecular beam epitaxy (MBE) experiments, sample storage, and air-locked sample introduction. The infrared reflection absorption spectrum measurement system is equipped to the reaction chambers to monitor the surface reaction *in situ*. The SR stimulated chemical reaction of surface submonolayer hydrogen on Si(100) have been successfully monitored recently [1].

[1] A.Yoshigoe, K.Mase, Y Tsusaka, T.Urisu, Y.Kobayashi, and T.Ogino, Appl. Phys. Lett. 67 (1995) 2364.

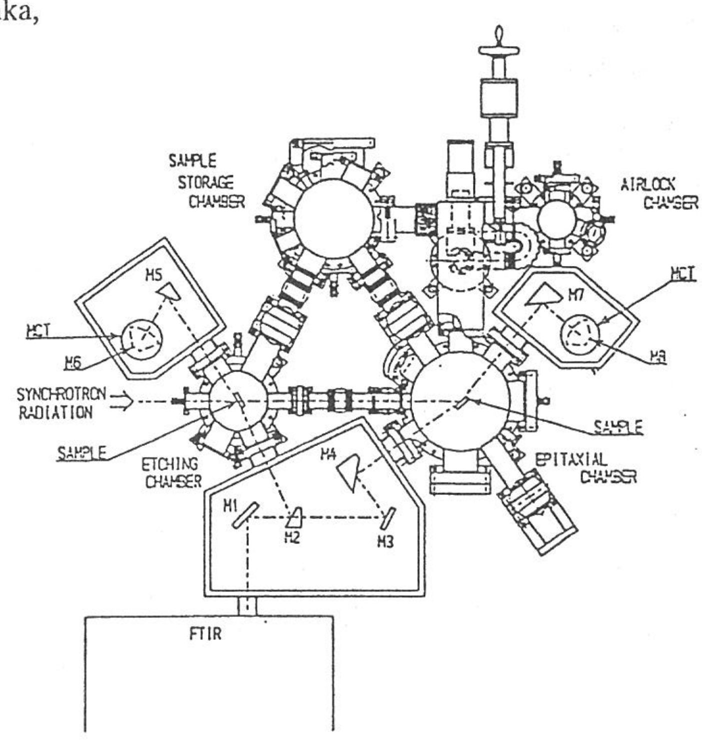



Figure 1. Reaction apparatus

### Specification

| | |
|---|---|
| Monochromater | : white beam reflected by bent-cylindrical mirror with grazing incidence angle of 2 degrees. |
| Wavelength range | : 1–100nm |
| Experiments | : SR-stimulated processing |

# *BL 5A*

## Photoelectron Spectrometer for Solids and Surfaces

The beamline 5A is designed for spin- and angle-resolved photoelectron experiments for solids and surfaces with the circularly polarized synchrotron radiation from a helical undulator and for high-resolution photoelectron experiments with bending magnet radiation. The beamline consists of a Spherical Grating Monochromator with Translational and Rotational Assembly Including a Normal incidence mount (SGM-TRAIN), a spin- and angle-resolved photoelectron spectrometer, and a high-resolution photoelectron 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 linear and circular polarization, (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.

### Specifications

*1)Monochromator*

Type:SGM-TRAIN
(two glancing-incidence and one normal-incidence)
Energy Range: 5-250 eV
Resolution: 0.5-80 meV with slits of 0.01mm
Flux: $3x10^{10}$ phs/sec at 120 eV with slits of 0.1 mm
(for bending manget radiation)

*2) Main Instruments*

Two-levels UHV chamber ($1x10^{-10}$ Torr)
Hemi-spherical electron-energy analyzer
(OMICRON HR-125)
Spin- and Angle-resolved spectrometer
(low-energy diffused scattering type)
LEED of reverse type (OMICRON)
Ion-gun (ULVAC-Phi)
He-lamp for UPS
Low-temperature cryostat (>30 K)

*3)Helical Undulator (Optical Klystron)*

| | |
|---|---|
| Number of periods | 18 |
| Period length, □u | 110 mm |
| Length of dispersive part | 302.5 mm |
| Total length | 2351.2 mm |
| Deflection parameter, Kx,y | 0.07-4.6 (helical mode) |
| Deflection parameter, K | 0.15-8.5 (planar mode) |
| Fundamentals | 2-45 eV (Circular polarization) |

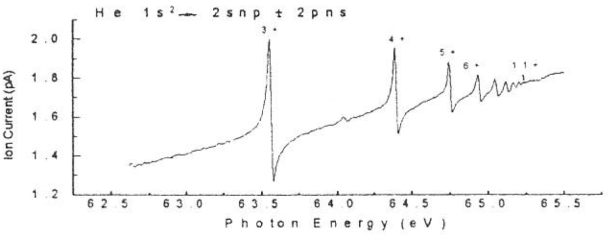



Fig. 1 He ionization spectrum

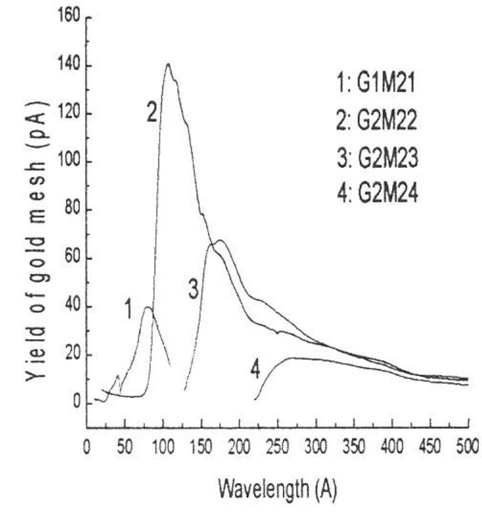



Fig. 2 Typical spectral distribution

*Refs: M. Kamada et al., Rev. Sci. Instrum. 66, 1537 (1995), N. Takahashi et al., Jpn. J. Appl. Phys. 35, 6314 (1996).*

# *BL5B*

## Calibration Apparatus of Optical Elements

BL5B has been constructed to calibrate optical elements. The beam line consists of a plane grating monochromator (PGM) and three chambers (Fig. 1). The chamber A is used for calibration of optical elements, the camber B for optical measurements of solids and the chamber C for photo-stimulated desorption (PSD) experiments. The chamber C is sometimes changed to a chamber for photoemission microscopy.

The calibration chamber is equipped with a goniometer. The goniometer, which was installed for the characterization of optical components, has six degrees for freedom; X-Y translation of a sample, and interchange of samples and filters. They are driven by vacuum pulse motors. Since the polarization of SR is essential for such measurement, axis of the rotation can be made in either horizontal or vertical direction (s- or p-polarization).

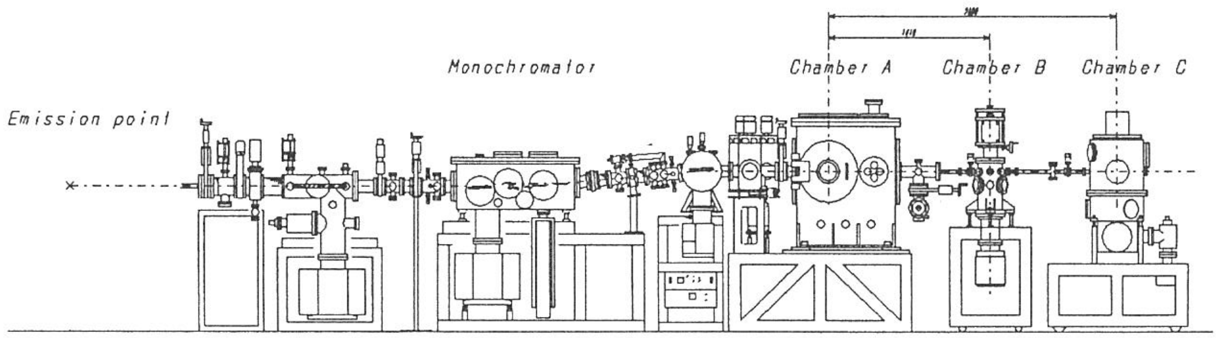



**Figure 1.** Schematic figure of BL5B spectrometer system.

### Specification

Monochromator: Plane grating
Wavelength range: 2 - 200 nm (Fig. 2)
Resolution: $\lambda / \Delta\lambda = 300 \sim 500$
Experiments: Calibration of optical elements, absorption of solids, photo-stimulated desorption from rare gase solids, photoelectron microscopy.

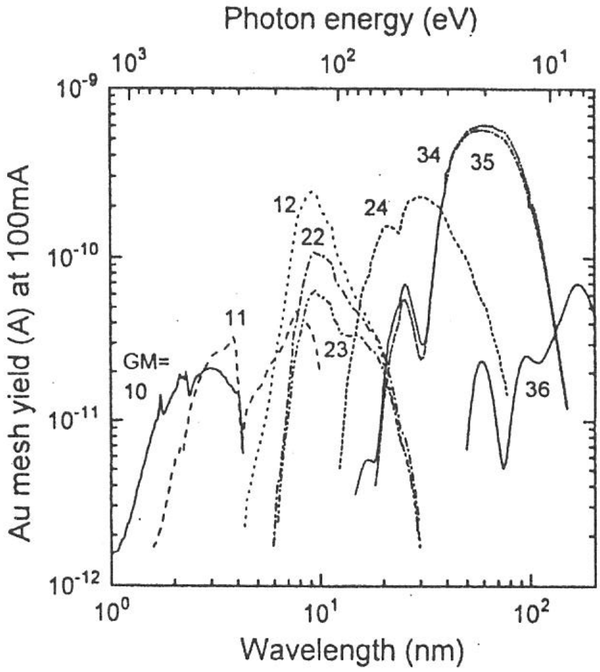



**Figure 2.** Throughput spectra of BL5B detected by a gold mesh (84% transmission).

# BL6A1

## Fourier-Transform Middle- and Far- Infrared spectrometers for solids

Synchrotron radiation of UVSOR covers a very wide energy region from soft-X ray to millimeter wave. BL6A1 was constructed in order to cover a long wavelength part in the spectral distribution from near infrared to millimeter wave. The beamline is composed of two kinds of interferometers, a Martin Puplett type and a Michelson type (Fig.1). The spectrum from 0.7 um to 2 mm is measureable by changing three kinds of detectors; MCT, Si-bolometer and InSb hot electron detector (Fig.2). Owing to the high brightness of the SR, the present spectroscopic system is especially favorable to the transmission and reflection measurements on tiny specimens.

In summer 1998, the control system for the Martin-Puplett type interferometer ( SPECAC ) was replaced owing to its lots of troubles. Most of the components in the control system were newly installed except the chopper controller and the PC. After some correction, the system is now under use regularly.

We have also installed new beamsplitters in the rapid scan type interferometer (Bruker IFS66V): Quartz( II ) and myler( 23 micron ). It expands the measurable region.

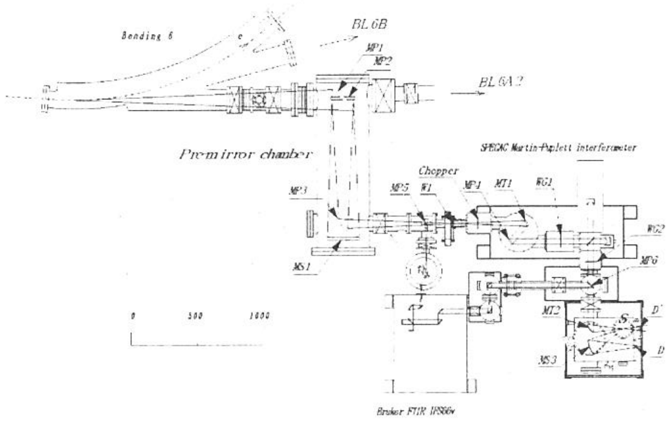



Fig.1 Top view of BL6A1.

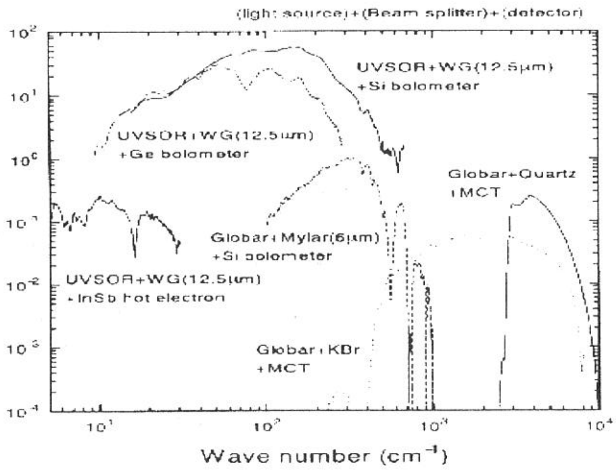



Fig.2 Throughput spectra of BL6A1.

**Specification**

Interferometers: a Martin-Puplett type and a Michelson type

Detectors: Si bolometer ( 20-1000 cm-1 )

Ge bolometer ( with polyethylene window, 30-300 cm-1 )

Ge bolometer ( with quartz window, 10-200 cm-1 )

InSb bolometer ( 5-50 cm-1 )

MCT ( 400-10,000 cm-1 )

Photovoltaic type MCT ( 400-4000 cm-1, time response: 10 nsec )

Wavelength range: 5~300 cm-1 by the Martin-Puplett type interferometer

40~28,000 cm-1 by Michelson type interferometer

Experiments: Temperature dependence of reflectivity and transmission spectra, absorption under high pressure ( up to 20 GPa ), reflectivity under magnetic field ( up to 8 T ) and time-resolved spectroscopy.

# *BL6A2*

## Photoelectron Spectrometer for Solids and Surfaces

A Plane Grating Monochromator (PGM) consists of pre-mirrors, a plane grating, focusing mirror, and a post-mirror, with an exit slit only. It covers the wide spectral range from 2 to 130 eV with exchanging two gratings and 5 focusing mirrors. A typical spectral distribution is shown in the figure, where the numbering indicates the combination of the grating and the mirror. A typical photon flux is about $10^{11}$ phs/s/100 mA at 90 eV with a resolving power of 700. Angle-integrated and angle-resolved photoelectron spectrometers are available. The overall resolution of the integrated type analyzer is about 0.3 eV, while the angle-resolved hemispherical analyzer has a resolving power of 100 with an angular resolution of 1.1° in two axes. The optical system including an ICCD detector can be installed. The standard instruments for surface analysis such as Auger, LEED, Ion gun, and gas doser are installed in the analyzing chamber, the base pressure of which is $1.2 \times 10^{-10}$ Torr. The samples are transferred from an air-lock chamber to the analyzing chamber through a preparation chamber.

**Specifications**

1) Monochromator

Type: Plane Grating Monochromator (no entrance slit)

Range: 2-130 eV

Resolution: 0.015-0.3 eV with slit of 0.3 mm

Flux: $10^{11}$ phs/s/100 mA at 90 eV with 0.1mm slit

2) Main Instruments

Angle-integrated Cylindrical Analyzer

(home made, ΔE=0.3 eV)

Angle-Resolved Hemi-Spherical Analyzer

(home made, E/ΔE=100 Δθ=1.1° Two-axes)

Second Monochromator (Jobin-Yvon HR-320)

ICCD (Princeton Instrum.)

Preparation Chamber

Air-lock chamber for quick insertion

LEED of Reverse type (OMICRON)

Ion-gun of Differential type (ULVAC-Phi)

Auger (ULVAC-Phi)

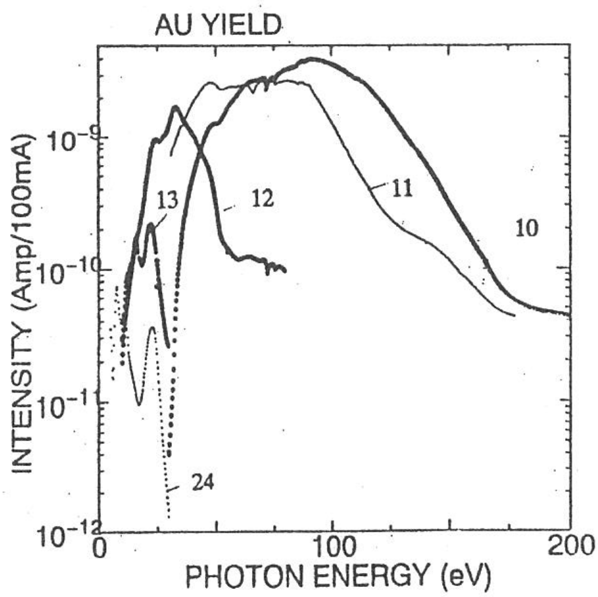



Fig. 1 Typical spectral distribution

# *BL7A*

## Soft X-ray Spectrometer for Solids

The beam line BL7A equipped with a double crystal monochromator (DXM) was constructed for the spectroscopic research of solids in the soft X-ray region, where both the bending magnet radiation and the 4T wiggler radiation are provided. Reconstruction of the beam line, such as installation of the focusing mirror system and the new software, improvement of the pumping system etc., has been almost completed. The focussing mirror system was installed between the front-end of the BL7A and the monochromator chamber to obtain the higher performance. The detail of the mirror system is described in this activity report (by Kinoshita et al.). By using the mirror system, procedure of the movement of the beamline between the wiggler line and the bending line has not become necessary. The schematic drawing of the beam line is shown in Figure 1. When we use the relatively lower photon energy light (less than 1.7keV), we use the pair of Si mirrors whereas the pair of Cr mirrors is used for higher energy experiments. The beamline covers the photon energy range from 0.8-5.5keV, by using several pairs of monochromator crystals.

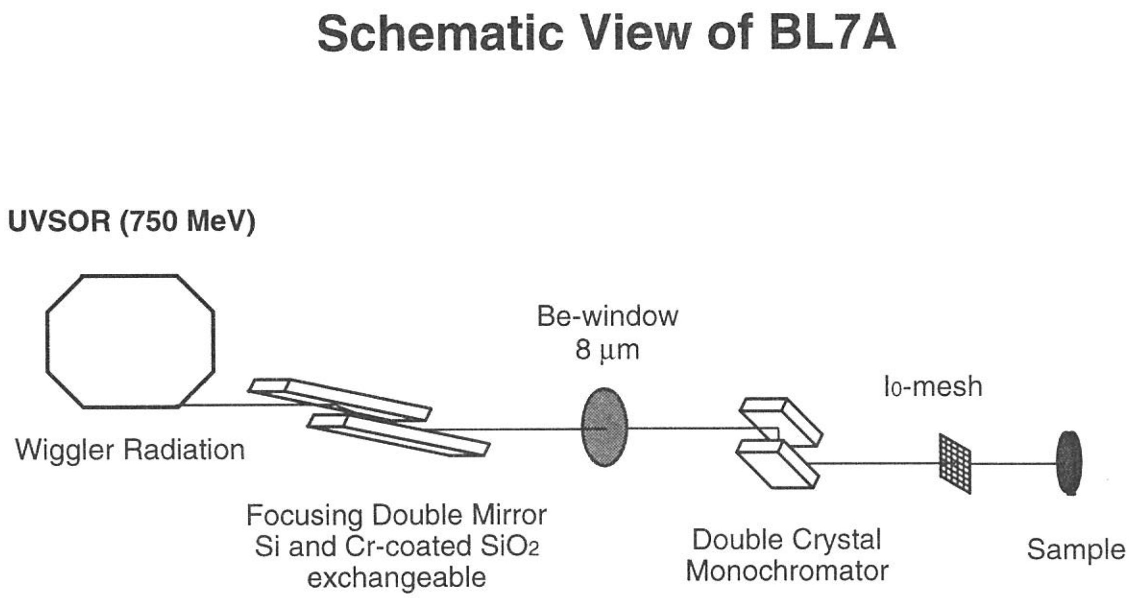



**Figure 1.** The schematic drawings of the beam line BL7A. The mirror system and the monochromator are located in the straight line downstream of the wiggler.

**Specification**
Monochromator : Double Crystal Monochromator
Monochromator crystals and covered photon energy:

Beryl($(10\bar{1}0)$) (0.82-2.27keV), $YB_{66}$(400) (1.12-3.08keV), Quartz-Y($(10\bar{1}0)$) (1.53-4.26keV),

InSb(111) (1.74-4.85keV), Ge(111) (2.00-5.55keV).
Typical resolution: 0.46eV (Beryl Crystal, E=860eV)
Experiments : X-ray absorption spectroscopy (by photoelectron total yield and/or fluorescence)

# *BL7B*

## 3m Normal Incidence Monochromator for UV, VIS and IR Spectroscopy of Solids

The reconstruction of the beamline BL7B has been almost completed. The 1m Seya-Namioka type monochromator was replaced to the 3m normal incidence monochromator (3m NIM; McPherson upgrade model of 2253) for the extended researches of the highest level with the higher resolution and intensity, the wider wave-length region available and so on. It will be also possible to utilize the linear and circular polarization inherent in synchrotron radiation (SR) and to realize some combined experimental systems, for example, with the synchronized laser to SR pulse or with the extended field. The outline of the new beamline is shown in Figure 1. The main parts of the system are a pre-mirror focusing system, a 3-m NIM and a post-mirror focusing system. The light from 50 to 1000 nm wavelength region is covered by changing three gratings *in situ*. Each spherical grating is original laminar type fabricated on $SiO_2$ and has effective grooved area of 120x40mm$^2$. The 2 focusing positions are available for the experiments. At the position between 2 positions, LiF or MgF2 window valve is installed. Therefore, the measurements for the organic materials, liquid and biochemical ones are possible at the 2nd focal position.

This beamline is used for absorption, reflection and fluorescence measurements on various materials with higher performance (high energy resolution, high intensity, well-polarized light, short repetitive pulse light) not only in the VUV region but also in the near UV, VIS and near IR region. The perfoemance of the beamline is presented in this activity report (by Fukui et al.). The beamline will be opened to the users from April, 1999.

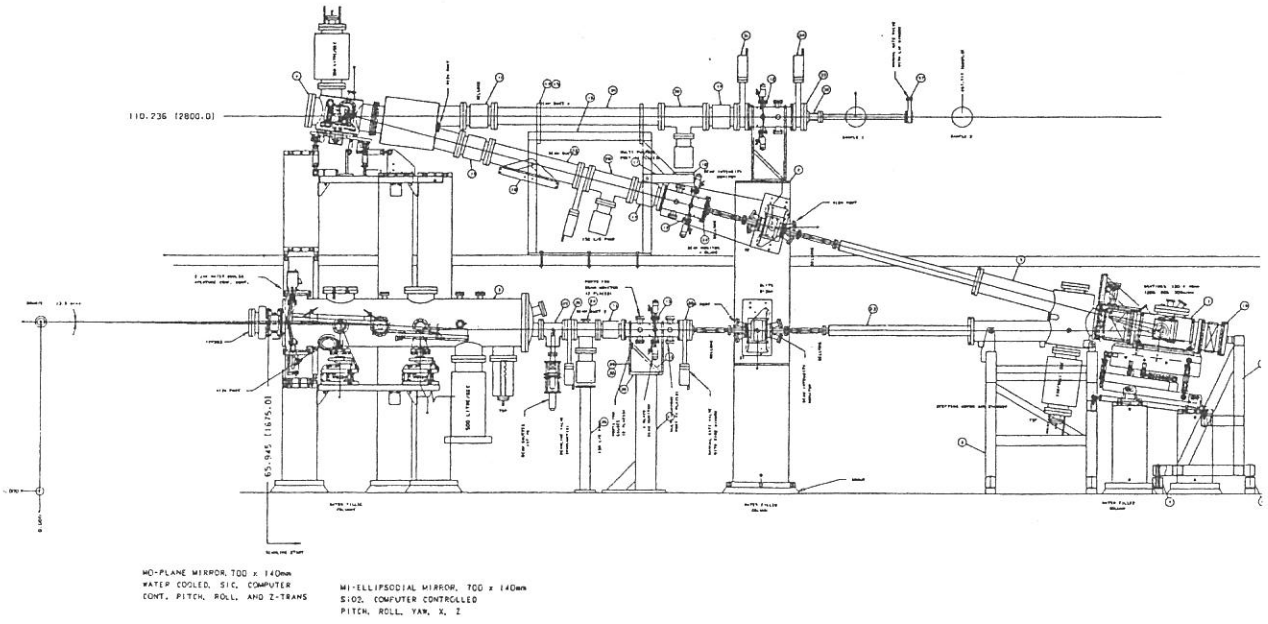



Figure 1. The outline of the side view of the new beamline BL7B.

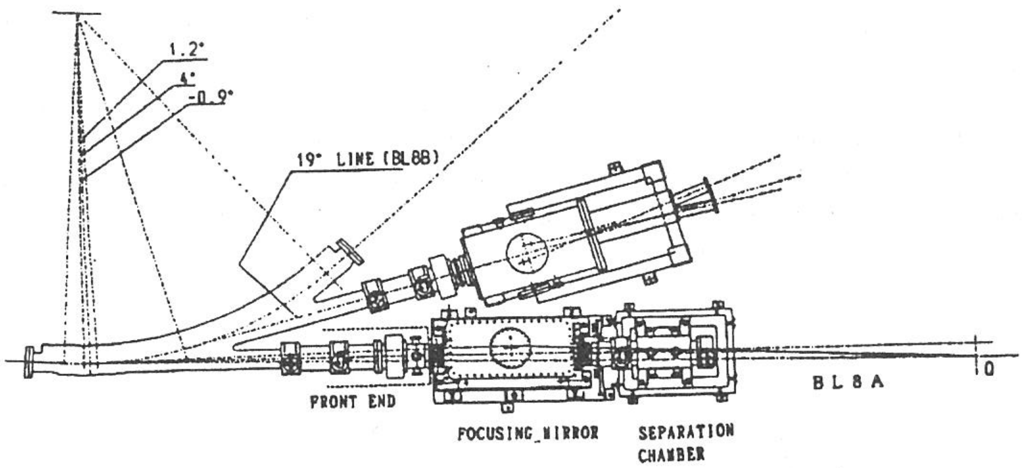
### Specification

| | |
|---|---|
| Monochromator | : 3m Normal Incidence Monochromator |
| Wavelength range | : 50nm-1000nm |
| Typical resolution | : E/ΔE=4000-23000 for 0.01mm slit |
| Experiments | : Absorption, reflection, fluorescence spectroscopy mainly for solids |

# *BL8A*

## Free Port

This beamline was constructed as a free port to which user can connect their own instruments. The beamline consists of a front end, a focusing premirror chamber and a separation chamber. Both focused and unfocussed beam can be used. A general purpose reaction chamber and a two (or three) stage differential pumping system are available for the experiments that use gas samples without window. With using three stage differential pumping system, gas pressure at the reaction chamber upto 0.5 torr can be used while keeping ultra high vacuum at the premirror chamber.




|← 2500mm →|← 2807mm →|

UP VEW OF BL8A

**Specification**

Spectral range : whole range of synchrotron radiation from UVSOR

Acceptance angle

Unfocused beam : 25 mrad (horizontal) × 8 mrad (vertical)
0.6 mrad (horizontal) × 0.6 mrad (vertical)
(with $\phi$ 3 mm aperture before sample)

Focused beam : 7.7 mrad (horizontal) × 8 mrad (vertical)

Beam spot size at focu : 3 mm (horizontal) × 2 mm (vertical)

Source - mirror distance : 2500 mm

Mirror - focus distance : 2807 mm

# *BL8B1*

## Photoabsorption and Photoionization Spectrometer

Last year a new beam line BL8B1 was constructed for observation of high resolution photoabsorption and photoionization experiments in the photon energy range from 30 to 800 eV, which includes the 1s core excitation energy of C, N and O atoms. For high resolution measurement among these energy, a constant-deviation constant-length spherical grating monochromator (CDCL-SGM) with three gratings (G1: R = 15 m; 1080 l/mm, G2: R = 15 m 540 l/mm, G3: R = 7.5 m; 360 l/mm) has been employed, whose entrance and exit slit positions and directions of incident and exit photon beams do not change during its scan. Consequently, it provides us with an resolution (E/ΔE) of 4000 at 400 eV and of 3000 at 245 eV. A drain current of gold foil reveals the absolute photon flux normalized by an ring current when two slit widths are 10 μm (Fig. 1).

Being Equipped at the downstream of the mono - chrometer, an chamber with a time-of-flight ion detector and a photoelectron detector allows us to measure photoelectron - photoion coincidence (PEPICO) and photoion - photoion coincidence (PIPICO) spectra. Measurements of absorption, electron yield and emission spectra of solid samples are also available.

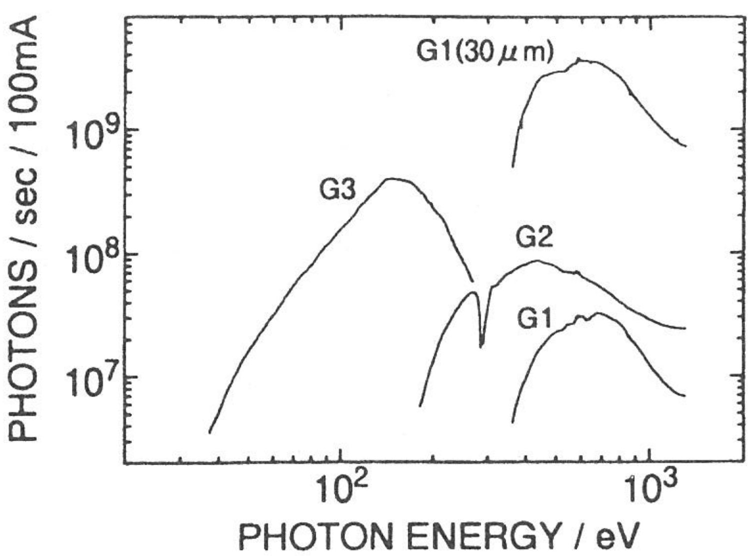



**Figure 1.** Absolute photon fluxes measured by a drain current of gold foil

**Specification**

| | |
|---|---|
| Monochrometer | : 2.2 m constant-deviation grazing incidence |
| Wavelength range | : 30 to 800 eV |
| Resolution | : E/ΔE = 4000 at 400 eV and 3000 at 245 eV |
| Available Experiments | : Measurement of photoabsorption and photoionization spectra for gas and solid sample |

# *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 solid such as molecular crystals, organic semiconductor, and conducting polymers. The 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 manipulator for temperature dependence (base pressure $3\times10^{-10}$ Torr), a cleaning chamber (base pressure $2\times10^{-10}$ Torr), and a sample evaporation chamber (base pressure $3\times10^{-10}$ Torr). The cleaning chamber is equipped with back-view LEED/AUGER, $Ar^+$ gun and an infrared heating units. The PGM consists of pre-mirrors, a plane grating, focusing mirror, and a post-mirror, with an exit slit. It covers the wide range from 2 to 150 eV 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 $1\times1mm^2$. The energy resolution at a slit width of 100 μm was found to be 0.004 - 0.3 eV in the wavelength range from 2 to 130 eV. A hemispherical electron energy analyzer of 25 mm mean radius with an angular resolution of 2° can be rotated around vertical and horizontal axes. The sample mounted on a manipulator can be also rotated around two axes.

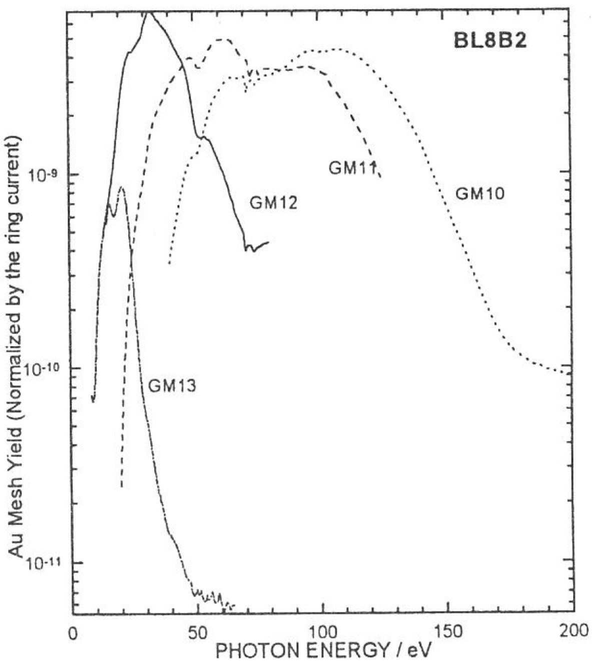
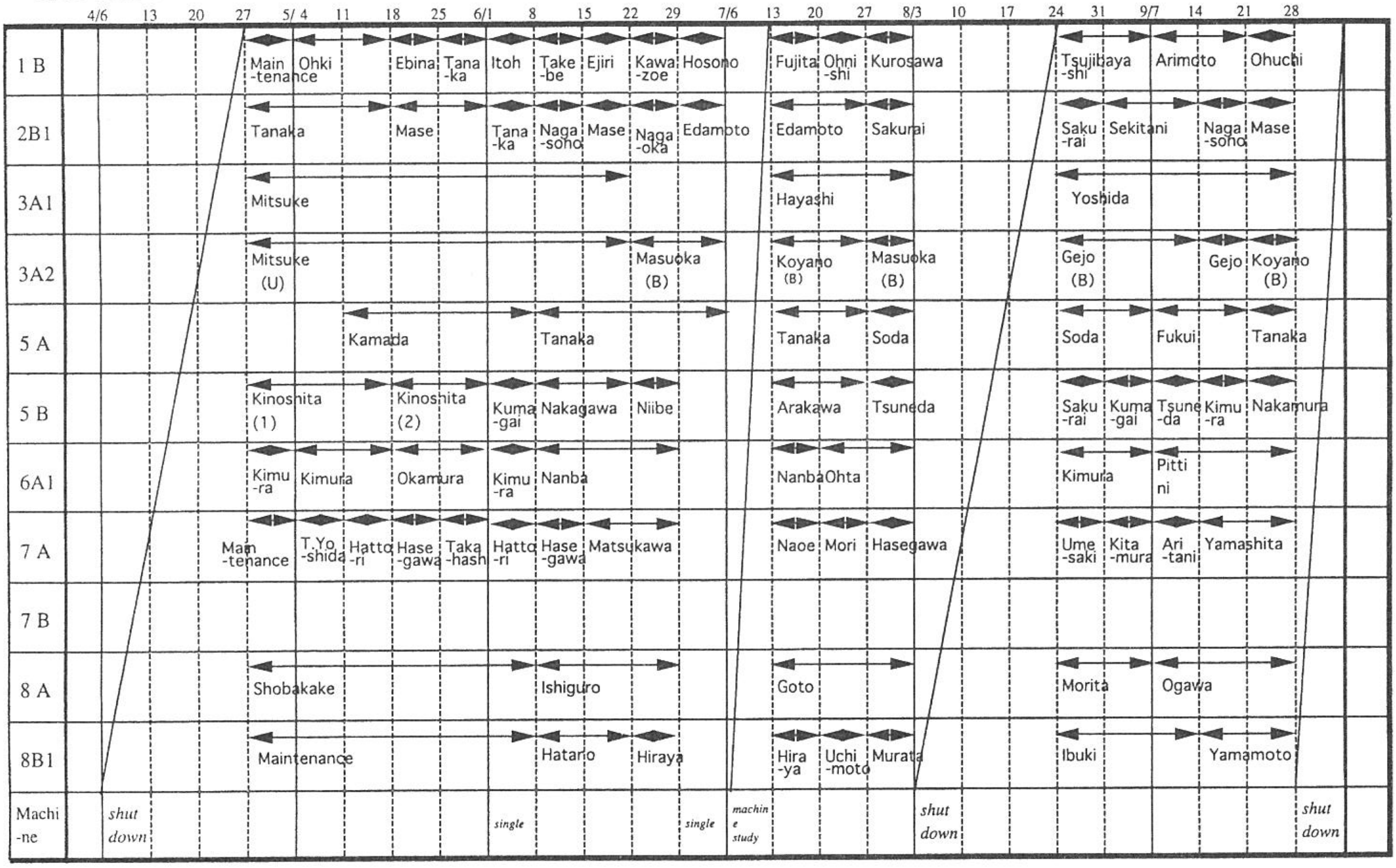


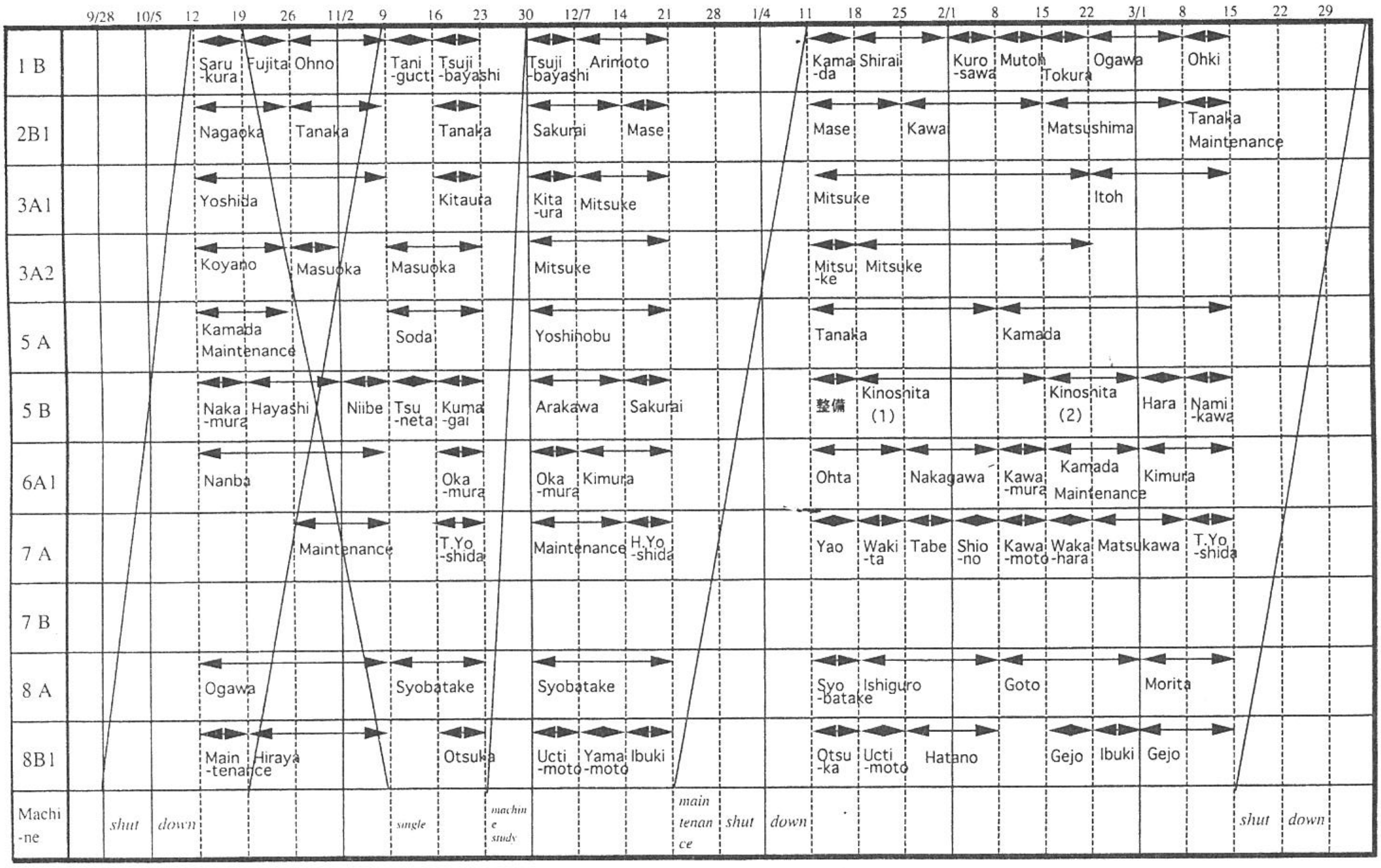

Figure Throughput spectra of plane-grating monochromator at BL8B2 with 100 μm exit slit.

### Specification

| | |
|---|---|
| Monochromator | : plane grating monochromator |
| Spectral range | : 2 - 130 eV |
| Resolution | : 0.25 eV at 40 eV, as determined by the Fermi edge of gold. |
| Experiment | : Ultraviolet Photoelectron Spectroscopy for various organic solids |
| Polarization | : 85~91 % at 5000 Å |

Open beam lines



In-house beam lines