Instruments Developments

(BL2B2)

First performance test of the 18m Spherical Grating Monochromator

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An 18 m spherical grating monochromator (18 m SGM) with high resolution and high photon flux has been constructed at the bending-magnet beamline BL2B2 of the UVSOR [1]. The monochromator is designed to cover the energy range of 20–200 eV with the three gratings: G1 (2400 lines mm^{-1}, R = 18 m) at 80–200 eV , G2 (1200 lines mm^{-1}, R = 18 m) at 40–100 eV and G3 (2400 lines mm^{-1}, R = 9.25 m) at 20–50 eV. A resolving power of 5000 and photon flux of more than 10^{10} photons s^{-1} are expected at a 100 mA ring current. The including angles are 160° for G1 and G2. A small including angle of 140° is adopted for G3 and two plane mirrors coated with aluminium are located between G3 and the exit slit as optical filters. These geometrical devices may contribute significantly to reduction of the high-order lights.

Figure 1 shows a doubly excitation spectrum of He obtained by using G2. Sample gas was introduced as an effusive jet into the reaction chamber with a pressure of 3×10^{-6} Torr. The spectrum was obtained by extracting ions from the interaction region by applying a highly negative voltage to the cathode of a microchannel plate detector. Entrance and exit slit widths are set to 100 μm and the position of the exit slit is fixed at 4230 mm away from the center of the grating, which is close to the focusing length of the diffracted light with the energy of 60 eV. A series of the Rydberg states up to n = 9+ are clearly observed. The observed full width of the 9+ Rydberg transition is about 27 meV. The resolving power is thus estimated to be more than 2400 at 65 eV with the slit widths of 100 μm.

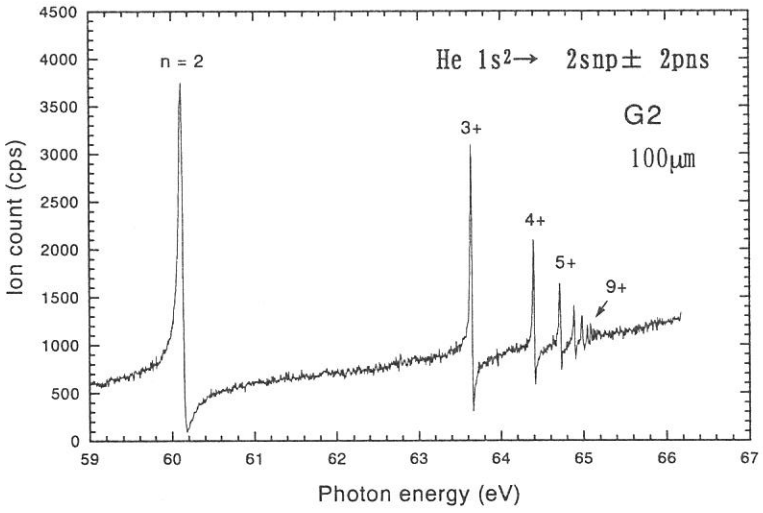

Fig. 1 Doubly excitation spectrum of He obtained by using G2 with slit widths of 100 μm.

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(BL1B)

Construction of Nonlinear Spectroscopic System using CW Mode-Locked Ti:Sapphire Laser Synchronized with Synchrotron Radiation

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We have newly developed a spectroscopic system combining cw mode-locked Ti:Sapphire laser with synchrotron radiation (SR), in which the laser pulse is synchronized with SR pulse. The present system has advantages of the peak power, repetition rate and time resolution in the visible/UV region derived from cw mode-locked laser as well as that of wide spectral range of photon energy in the VUV region derived from SR. These features are especially suited for nonlinear spectroscopy such as two-photon spectroscopy and pump-probe spectroscopy focused on inner-shell electronic states of solids. In this report we concentrate on a description of the measurement system. Physical aspects of the measured data obtained with our system will be reported elsewhere.

The present system was constructed at BL1B of UVSOR facility. We set up two types of measurement configuration. The first configuration is for two-photon spectroscopy, and its schematic diagram is shown in Figure 1. This configuration resembles the experimental set up reported earlier[1, 2]. The laser is a cw mode-locked Ti:Sapphire laser (Coherent Mira 900-F/P) pumped by a diode-pumped frequency-doubled Nd:Vanadate laser (Coherent Verdi, cw power 5 W). The tuning range, average power, pulse width, and repetition rate of this Mira 900 laser is 720-820 nm (with short wave optics set), 500 mW, 160 fsec, and 90 MHz, respectively, in the femtosecond configuration. The second and third harmonics of the laser output can be obtained by a harmonic generator (Coherent 5-140 UltraFast Harmonic Generator), generating average powers of 390 mW in second harmonics, and 260 mW in third harmonics. The synchronization of the laser and SR pulses is achieved by a phase-lock loop circuit (Coherent Mira Synchro-lock 9300). We used the 90-MHz RF from the UVSOR master oscillator as a reference frequency to which the laser pulse is synchronized.

We investigated the timing jitters between the laser and SR pulses by using a MCP-type photomultiplier and TAC-MCA system. The result showed that the jitter is well below a few tens of picosecond, which is the time resolution of the measurement system employed. We adopted an external voltage-controlled phase shifter (R&K PS-3 90 MHz) to make an arbitrary time delay between the two light pulses. The Synchro-lock system also has an internal voltage-controlled phase shifter. However, a quick phase change with the internal shifter, for example by 180 degrees (5.5 nsec) in 1 msec, resulted in a failure of phase locking loop.

In two-photon spectroscopy experiment we detected luminescence under two-photon excitation of the samples by photon counting method. To distinguish this signal from the background we used phase modulation method. In the first duration (e.g. 1 sec) the phase shifter is set so that the laser and the SR pulses reach the sample at the same time, and the photon numbers detected are accumulated in counter channel 1. In the next 1 sec, the phase shifter is set so that the two pulses does not overlap in time, and the photon numbers detected are accumulated in counter channel 2. After proper accumulation time, subtracting the count in channel 2 from that in channel 1 gives the nonlinear part of the emission signals.

We also tried an ON/OFF method for extracting desired signals. In the first duration an electronically controlled mechanical shutter

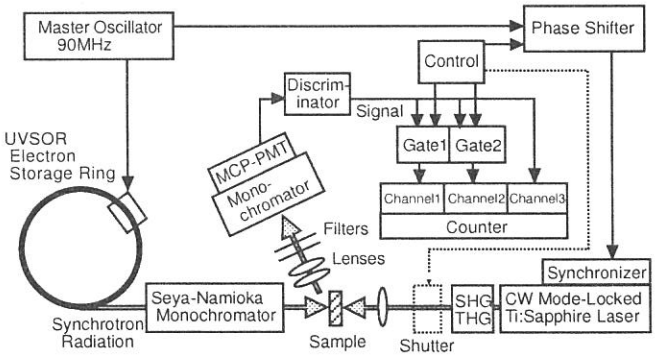

Figure 1. Schematic diagram of experimental system for two-photon spectroscopy.

for the laser is open, while in the second duration the shutter is closed. Thus the difference between the counts of the two channels gives desired signals, provided that the scattering from the laser alone can be neglected. The latter method is not suitable to the case where there exists a thermal effect due to heating of the sample by the laser, but also has a merit that it can reveal a relatively slow time dependence of the emission signals.

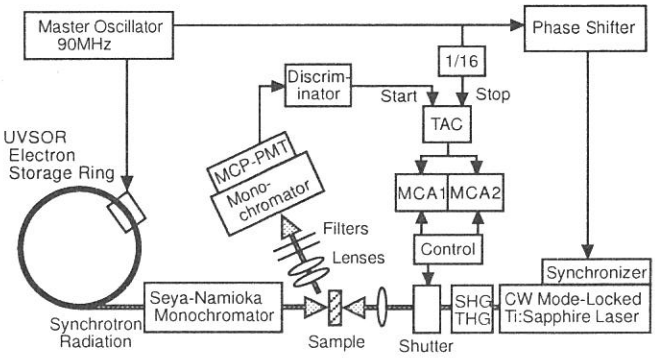

Figure 2. Schematic diagram of experimental system for measurement of laser induced emission change.

In addition to two-photon spectroscopy we performed laser-induced emission experiment. In this experiment we measured a variation of the emission intensity induced by laser irradiation under constant excitation of SR. Since the emission from the sample was expected to have a short lifetime and a low yield, we adopted dual TAC-MCA configuration (Figure 2). The pulse timing was adjusted so that the laser pulse (width 160 fsec) was at the center of the SR pulse (width 1 nsec). We used a mechanical shutter for the laser in the same way as in the above. The emission was detected by a MCP-type photomultiplier and time-to-amplitude-converted signals were fed to MCA 1 in the first duration and to MCA 2 in the second duration. By subtracting the accumulated count in MCA 2 from that in MCA 1, we obtained a time resolved emission change induced by the laser.

During the above experiment we noticed that there exist dark counts synchronized with the SR pulses. We found that they are caused by circulating electron bunches in the storage ring, having an electromagnetic nature, and are neither removed by repositioning electronics nor by adjusting the discrimination level. Fortunately since several empty bunches existed in the 16 bunch positions under the multi-bunch operation of UVSOR, we could find a low noise area of about 40 nsec within a single period of 176 nsec.

In conclusion we have developed an experimental system for nonlinear spectroscopy, which is based on the combined use of cw mode-locked Ti:Sapphire laser and SR. The synchronization of the pulses has been found satisfactory. Several measurement techniques have been developed and performed for this system to investigate inner-shell electronic states of solids. There were an electromagnetic noise from the electron storage ring, which should be carefully avoided in measuring very low level photon signals.

The present work was supported by Grant-in-Aid for Scientific Research from the Ministry of Education, Sports and Culture.

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(BL4A1)

Construction of the Multilayered-mirror monochromator and the beam line BL4A1

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We proposed to use a multilayered-mirror (MLM) monochromator which is expected to provide an energy-tunable, high-photon-flux monochromatized light. A practical MLM monochromator has never been developed so far for the low energy region (decades to hundreds eV) that is especially important for SR process experiments. When considering a MLM monochromator for use in SR stimulated processes, technical problem is to remove the background existing in the low energy region caused by the total reflection.

Our focus in this work is on the energy region of 60 - 120 eV, in which fairly high reflectivity is known to be obtainable, for example, by Mo/Si and Mo/C MLMs. This energy region covers the core electron binding energy of Al (2s: 118.6 eV, 2p: 80.9 eV) and Si (2s: 150.8 eV, 2p: 108.2 eV), important materials in semiconductor processes. As mentioned above, it is important to reduce the background at the low energy region (<40 eV) caused by the total reflection and that at the high energy region caused by the higher order photons. In the present case, the C filter (120±24 nm thick) is used to reduce the low energy background. It is also effective to use MLMs at low incident angles in reducing this background because the total reflection component decreases as the incident angle to the MLM decreases. Use of two MLMs is effective not only in keeping the output beam position constant, but also in reducing the intensity of the higher order photons. The Mo/Si MLM structures were designed by assuming that a high reflectivity and a symmetric reflectivity curve would be obtained, and synthesized by sputter deposition techniques. The transmission electron microscope (TEM) cross-sectional image of the Mo/Si MLM fabricated for the present monochromator is shown in Fig. 1.

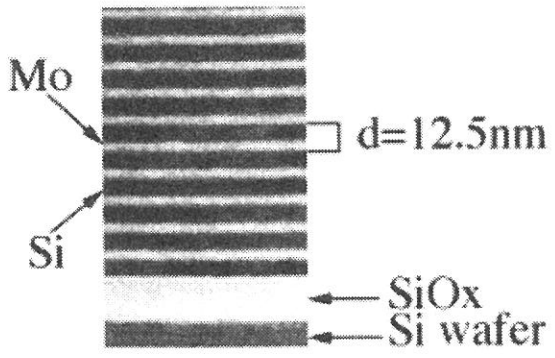

Fig. 1. Cross-Sectional TEM image of one of the Mo/Si MLMs fabricated for the present experiments (number of layers: 20, thickness ratio: Mo/Si = 3.75 nm/8.75 nm).

Figure 2 shows a schematic diagram to explain the mechanism of the mirror driving system. The rotating centers of the first and the second MLMs (A and B in Fig. 2, respectively) are set on the XY and YZ lines which form a rigid right angle XYZ with the first MLM parallel to the XY line and the second MLM perpendicular to the YZ line, as shown in Fig. 2. The pulse motor drive slides the rotational axis (A) of the first mirror parallel to the incident beam axis on the linear motion stage, with the rotational axis (B) position of the second mirror fixed. The first and the second mirrors are mechanically linked to each other and slide on the XY and YZ bars of the right angle XYZ, respectively, so that the apex Y translates in parallel with the linear motion of the first mirror. It is designed so that two kinds of mirror pairs can be exchanged with each other in the ultra high vacuum (UHV) by rotating half the mirror holders using ultrasonic motors. The driving system fabricated in this work has the feature that it covers the wide MLM beam incident angle (θ) range of 10 - 80 degrees. Fine adjustment of the first mirror is made in atmosphere and that of the second mirror can be made in the UHV by piezoelectric actuators. These adjustments suppress the horizontal and vertical shakinesses of the output beam axis, respectively, less than 0.4 mrad and 1.7 mrad over the full scanning range. The monochromator chamber is evacuated to 5.0×10^{-10} Torr by a 300-L/s turbo molecular pump.

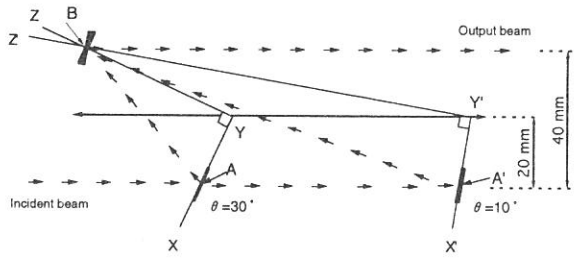

Fig. 2. The mirror driving mechanism of the MLM monochromator. The distance between the sliding surfaces of axis A and the apex Y is 20 mm, and that between the sliding surfaces of axis A and axis B is 40 mm.

Figure 3 shows the drawings of BL4A1, which consists of a pre-mirror chamber, a double crystal type MLM monochromator, a white beam chamber, a filter chamber, a detector chamber, and an X-ray photoelectron spectrometer (XPS) chamber. The pre-mirror is an elliptically-bent cylindrical quartz mirror with a Pt coating on its surface. (The radius of the cylindrical curvature is 236.2 mm and the longer and shorter radii of the elliptical curvature are, respectively, 2111 mm and 132 mm.) It is set at 2.35 m downstream from the light source point of the bending magnet with a grazing incident angle of 4 degrees. The horizontal and vertical acceptance angles of the pre-mirror are, respectively, 16.56 mrad and 12.79 mrad.

The reflected beam is focused at a point 6.1 m downstream from the center of the pre-mirror and has an elliptical spot size of about 5 mm×2 mm. When the MLM is not used, the SR beam is reflected by a pair of Pt coated plane mirrors with grazing incident angles of 2 degrees in the white beam chamber to keep the output beam at the same height as that of output beam from the MLM monochromator. Two filters, one consisting of a thin film of C and the other consisting of a thin film of Al, are set in the filter chamber, and a Au vapor-deposited detector and a Si photodiode detector (International Radiation Detectors Inc., AXUV-100) are set in the detector chamber to measure photo-current. A differential pumping system is set at the end of the beamline to maintain a high vacuum in the white beam chamber during the experiments using reaction gases in the XPS chamber.

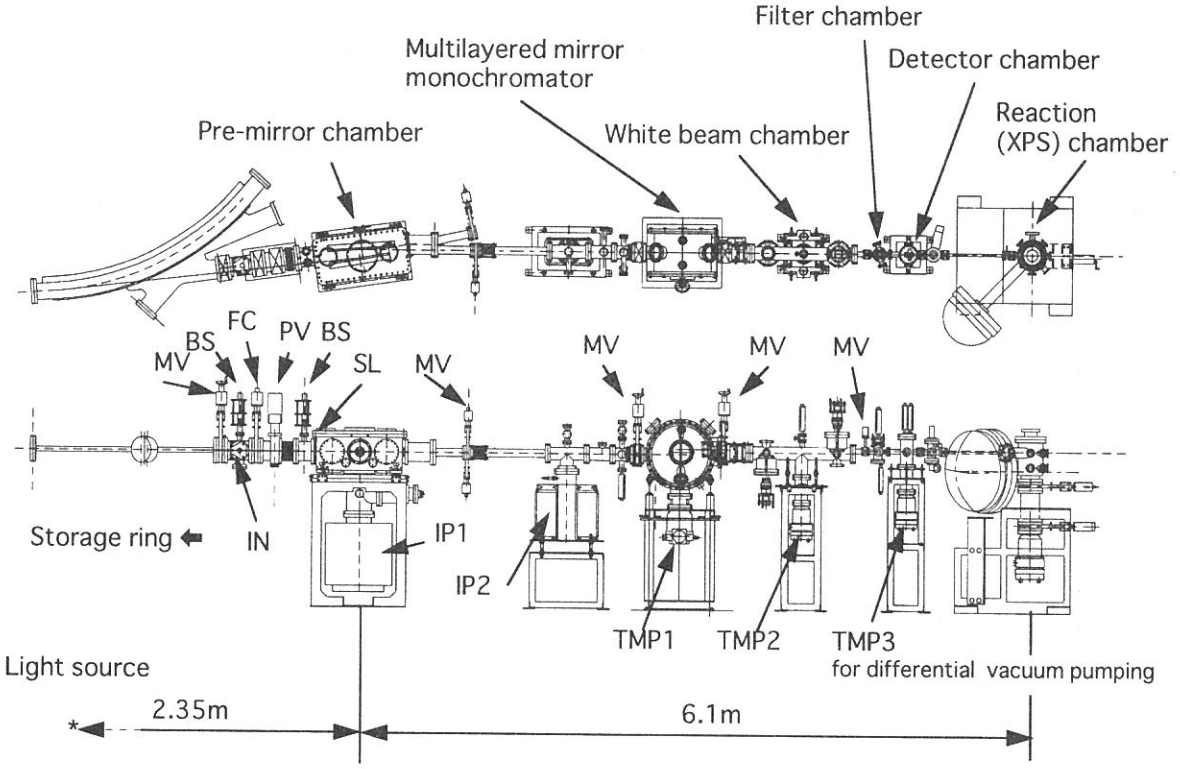

Fig. 3. Top and side views of the MLM monochromator beamline (BL4A1) constructed at the UVSOR facility in the IMS. MV: manual valve, IN: insulator pipe, FC: fast closing valve, PV: pneumatic valve, BS: beamline shutter, SL: slit, IP1: 400-L/s ion pump, IP2: 150-L/s ion pump, TMP1: 300-L/s turbo molecular pump, TMP2: 340-L/s turbo molecular pump, TMP3: 150-L/s turbo molecular pump.

(BL5A)

Measurements at the BL5A

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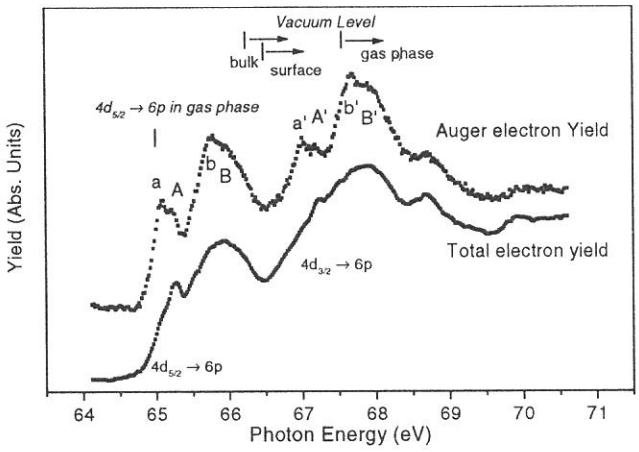
The beam line 5A has been constructed in order to measure the electronic structure of solid and solid surfaces, and consists of a monochromator for the synchrotron radiation and electron spectrometers for the photoelectron spectroscopy. It was constructed so that the radiation from a bending magnet and a helical undulator can be used for the monochromator (SGM-TRAIN[1]). However, the operation of the helical undulator interfere with the electron motion in the bending magnet at other beamlines of UVSOR, and the radiation from the bending magnet is mainly used currently. For the photoelectron spectroscopy, two kinds of electron spectrometers are installed. One is angle- and spin- resolved photoelectron spectrometer[2] for spin-resolved photoelectron spectrometer. It consists of electron lenses, an energy selector and spin detector. Electron lenses and the energy selector are commercial one (VSW HA54), and the spin detector of diffused scattering type is home-made. The other one is Omicron EA-125 analyzer, and used for conventional photoelectron spectroscopy without spin resolving. The performance of these apparatus has been presented in previous UVSOR activity reports.

The monochromator (SGM-TRAIN) is controlled by a PC with a home-made program written in Visual Basic (Microsoft) of 16-bit version on the windows 3.1. The EA-125 electron spectrometer is controlled by another PC with a commercial program written in Borland Pascal (DOS). The spin resolved electron spectrometer is controlled by the other PC with a home-made program written in Visual Basic of 32-bit version on the windows 95. Three computers are connected via the RS-232 cables, and the photon energy of the monochromator can be set according to the request of the program for the electron spectrometer. This system enables us to measure the constant initial state spectroscopy, in which the photon energy and the electron energy are changed simultaneously to keep the difference of them to be constant. It also enables the constant final state spectroscopy, in which the photon energy is changed and the electron energy was kept to be constant.

An upper curve in the figure bellow shows an example of the spectrum measured in the constant final state spectroscopy mode. The sample was Xe film depsosited at 30K. The kinetic energy of the photoelectron was fixed to be corresponding to the Xe-NOO Auger electron. The short escape depth of the Auger electron enabled us to detect the surface core exciton (a and a') at the Xe-4d edge, which were not observed in the ordinal total electron yield spectrum (lower curve).



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(BL6A1)

Replacement of the control system for a Martin-Puplett type interferometer at BL6A1

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BL6A1 was constructed for spectroscopy in infrared region. We have two interferometers at BL6A1: a Martin-Puplett type (SPECAC Co.) and a Michelson type (Bruker IFS66V). The Martin-Puplett type interferometer has gone through with various experiments for more than fifteen years. We replaced the control system for the Martin-Puplett type interferometer (SPECAC) because of repeated troubles.

A new control system for SPECAC is schematically drawn in Fig.1. A control box outputs digital signals to a stepping motor and manages the limiter (photointerrupter) signals. A lock-in amplifier extracts the signals from the detectors which is synchronous with a chopper. Both of the control box and the lock-in amplifier are controlled by a PC/AT compatible computer. Most of the components for the control system, including the control software, were newly installed excepting the chopper controller and the PC.

We utilized the programming language LabVIEW for the control software. The readily-made instrument drivers (VIs) save time of programming and the easy-to-follow nature of the "graphical programming" seems to improve the re-productivity of the software. The top window of the SPECAC control software is shown in Fig.2. The software consists of three routines: "Main" (configuration, data acquisition and display), "ZPD"(adjustment of zero path difference position) and "FFT"(fast Fourier transform of the interferogram data). To fulfill the specification, the wait time before data acquisition and the elimination way for back rush of the lead screw were carefully implemented.

After the installation of the system, we carried out several tests for total reliability. For example, the interferometer was scanned for ten times and the aberration of the position of the ZPD peak was compared. One of the results is shown in Fig.3. It is clear that the motor slip did not occur and the position error was less than 1 micron.

After debugging of the software, the system has been adopted to the user time regularly. We will continuously improve its function for users' convenience.

The preparation time needed for both of the hardware and the software was about two month.

We are very grateful to all of the UVSOR staff for their kind support.

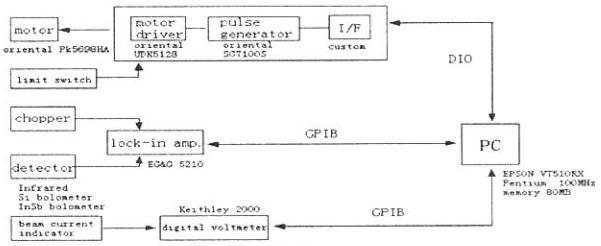

Fig.1 Diagram of the SPECAC control system.

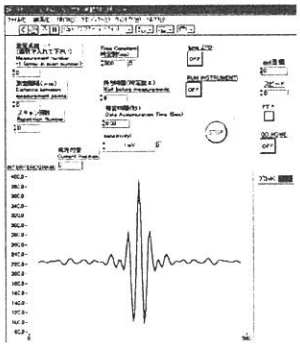

Fig.2 Top windows of the SPECAC control system.

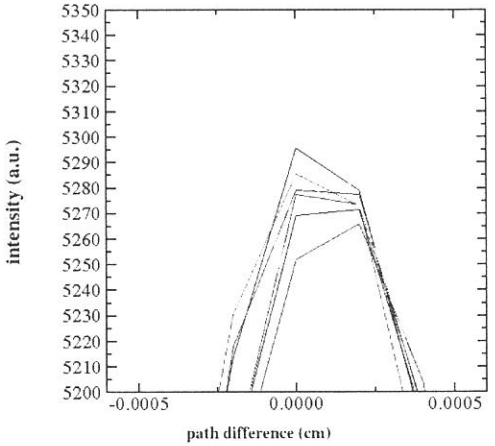

Fig.3 A result of tests for mirror movement.

(BL7A)

Performance of the focussing mirror system for the double crystal monochromator beamline BL7A

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As described in the UVSOR Activity report in 1997, the reconstruction of the soft X-ray beamline BL7A, such as installation of the focusing mirror system and the new software, improvement of the pumping system etc., has been performed [1]. The focussing mirror system was installed between the front-end of the BL7A and the monochromator chamber to obtain the higher performance. The design detail of the mirror system was described previously [1]. By using the mirror system, we may not need to move the beamline from the wiggler line to the bending line. Although the bending magnet radiation is still available, this is for only the case when a trouble of the wiggler occurs. When we use the relatively lower photon energy light (less than 1.7keV), the pair of Si mirrors is used to prevent the radiation damage of the crystal owing to higher energy photons whereas the pair of Cr mirrors is used for higher energy experiments. In this activity report, we report the performance of the system.

Figure 1 shows the picture of the X-ray spot observed at the end station of the beamline, where the fluorescent screen with MCP (micro-channel plate) was attached. This is the spot obtained in the combination of Cr mirrors and the InSb monochromator crystals. The width of the spot is about 7mm and the height is 5mm. The spot size is larger than that expected from the ray tracing results presented in Fig. 2 of ref.1. This may be due to the slope error of the mirrors and the small misalignment of the mirror holder. By reducing the width of the (horizontal) diaphragms located in the upstream of the mirror, the small spot size of less than 1mm ϕ can be achieved.

Figure 2 shows the throughput of the BL7A for the several combinations of the focussing mirrors and the monochromator crystals. It is noted from the comparison with the previous result [2] that the intensity in all energy regions becomes stronger. Especially, due to the high cut Si mirrors, the wiggler radiation becomes available even in lower energy region, which may not damage the beryl and/or quartz crystals. As a result, the throughput from the beryl crystals becomes about 300 times than the previous one without the mirror system. It is also noticed that the glitches for YB_{66}(400) reflection around 1.4keV can be reduced by using the Si mirrors. The use of the focussing mirror system gives us a lot of advantages for performing the soft X-ray spectroscopy.

References

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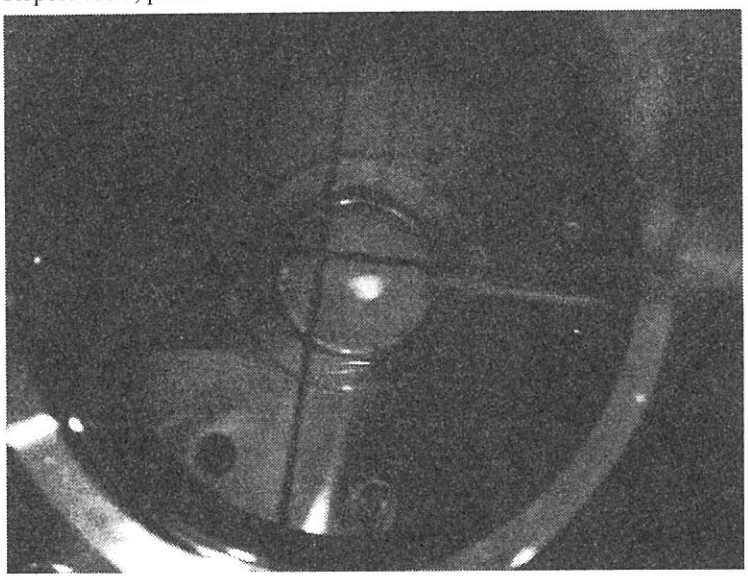

Figure 1. Observed light spot at the end station of BL7A. The acceptance angle of the beamline was set at about 4.5mrad.

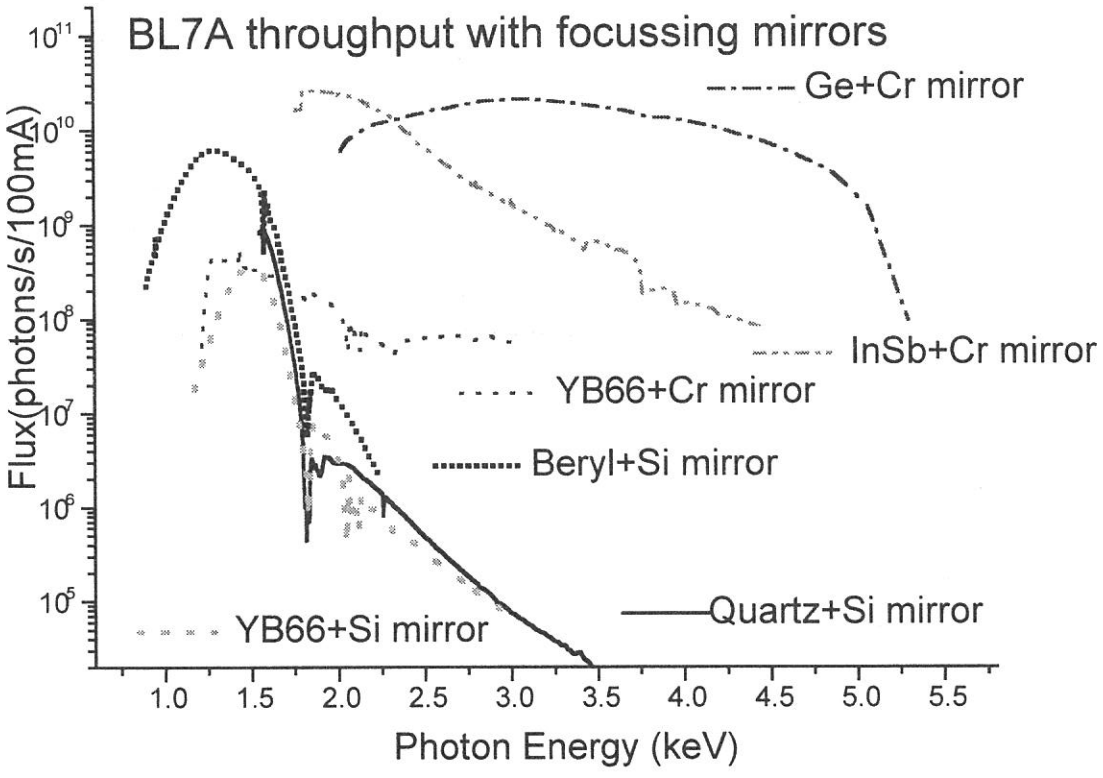

Figure 2. Throughput of the BL7A for the several combinations of the focussing mirrors and the monochromator crystals. 4T wiggler radiation is used as a light source.

(BL7B)

Present Performance of BL7B 3m Normal Incidence Monochromator

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The reconstruction of the beamline BL7B has been almost completed. The 1m Seya-Namioka type monochoromator was replaced to the 3m normal incidence monochromator (3m NIM) for the extended researches of the highest level with the higher resolution and intensity, the wider wavelength region available and so on. It will be also possible to utilize the linear and circular polarization inherent in SR and to realize some combined experimental systems, for example, with the synchronized laser to SR pulse or with the extended field.

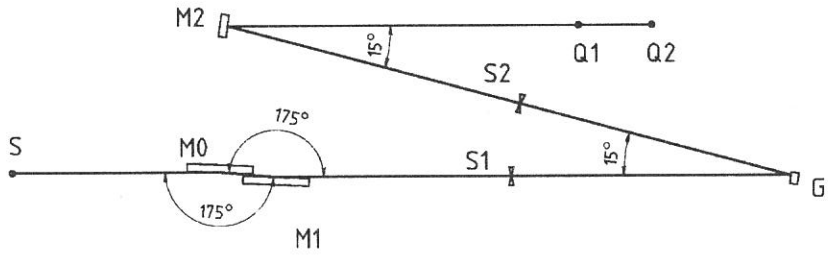

Fig. 1

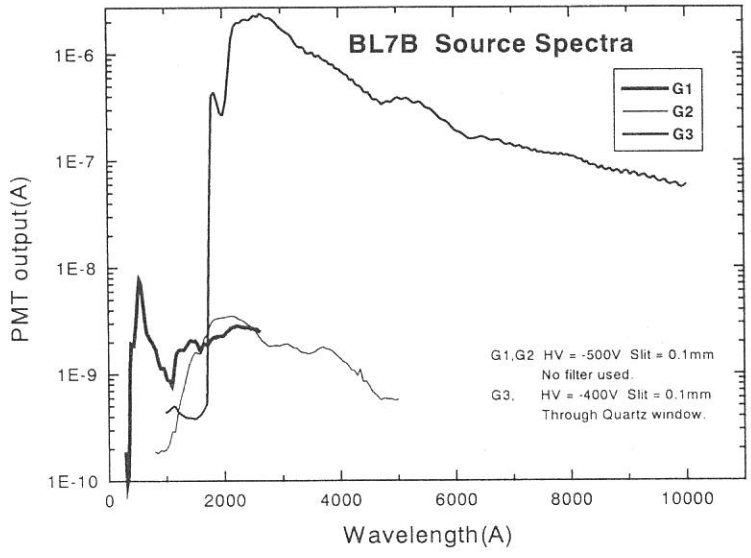

Fig. 2

The outline of the new beamline is illustrated at BL7B page of Status of UVSOR in this report. The optical design is also shown in Fig. 1. The design parameters of the optical elements are summarized in Table 1, 2 and 3. The 3 m NIM is a modified

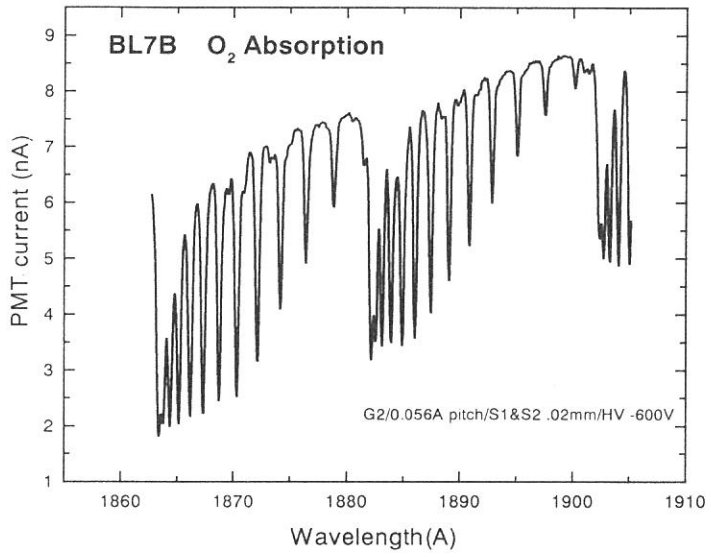

Fig. 3

version of the McPherson model 2253. The coverange of the three gratings in design is 50 – 150 nm for G1, 80 – 300 nm for G2 and 150 – 1000 nm for G3.

Figure 2 shows the source spectra of BL7B which are direct outputs from the photomultiplier with a sodium salicylate energy converter for G1 and G2, and through quartz window for G3. The lower limits of G1 and G3 are almost same as the desigin values, but that of G2 is not clear. Though the intensity of each spectrum can not compare with each other, whole range of BL7B is covered by G1 and G3. It is due to misfit of the actual blazing angle. The grating G2 will be replaced in near feature. The actual focus positions (Q1 and Q2 in Fig. 1) are almost same as design values. The spot size at Q2 is about 3 (H) x 0.8 (V) mm at present. Since spot size is strongly depend on the configuration of M0 and M1, the precise configuration adjustment of both M0 and M1 should be carried out.

Figure 3 shows the absorption spectrum of O_2 gas between 186.2 and 190.5 nm using G2 grating. The slit width of both entrance and exit slits are 0.02 mm. E/ΔE is more than 5000. It is not so difficult to measure such a spectrum, so that this beamline has enough resolution for solid state measurements.

Table 1

Pre-mirrors	Incidence angle (deg)	Radius (mm)	Dimensions (mm)	Coat	Material
M0	87.5	- (plane)	700 x 140	Au	SiC
M1		60568 x 115 (Toroidal)			SiO_2

Table 2

Grating	Deviation angle (deg)	Radius (mm)	Dimensions (mm)	Coat	Material	Grooves (mm^{-1})
G1	15	3000	40 x 120	Au	SiO_2	1200
G2				Al		600
G3				Al		300

Table 3

Post-mirrors	Incidence angle (deg)	Radius (mm)	Dimensions (mm)	Coat	Material
M21	7.5	3483 x 3348	120 x 120	Au	SiO_2
M22		3786 x 3633		Al + MgF_2	

(BL8B2)

A new angle-resolved UPS system for organic thin films at BL8B2

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Angle-resolved photoelectron spectroscopy (ARUPS) is a well-known technique to investigate the electronic structure of surfaces. One can in principle determine the orientation and electronic states of molecules adsorbed on crystal surfaces by the quantitative analysis of the photoelectron angular distribution. For thin films of functional organic molecules, which are promising candidates to realize new electronic devices, the determination of molecular orientation and the electronic structure in the ultrathin films is of fundamental importance, since the molecular orientation is different from that in a bulk crystal, and thus new electronic states appear owing to the molecule/substrate, molecule/overlayer and molecule/molecule interactions which depend on the molecular orientation. Although ARUPS experiments have been widely performed on such thin films, the quantitative analysis of the ARUPS intensity and the determination of molecular orientation have little been realized due to the difficulty of quantitative analysis of the photoelectron angular distribution. We have recently succeeded to analyze the photoelectron angular distributions from thin films of large functional organic molecules. The goal of our project is to obtain very precise information on both geometrical and electronic structure typical of ultrathin films of functional organic molecules by the quantitative analysis of photoelectron angular distribution, and open a door to realize quantitative chemical analysis of organic ultrathin films using ARUPS with synchrotron radiation.

For these studies, a new ARUPS spectrometer, which enable us to measure accurate photoelectron angular distributions from functional organic thin films with high energy-resolution and high sensitivity, were required. We constructed the new ARUPS system at the BL8B2 of the UVSOR facility. VG-ARUPS-10 spectrometer was introduced with a μ-metal measurement chamber. The angle-resolving spectrometer consists of a 75 mm hemispherical sector analyzer with two-axes rotations, electrostatic lens of various operation offering various angles of acceptance, and a high speed multi-channel detection system. A high-precision sample manipulator was also constructed to realize precise ARUPS measurements. Furthermore, a new simplified organic-sample preparation chamber with a liquid N_2 trap, which was designed to be cleaned up easily and to keep the UHV pump free from organic contamination, was constructed to realize ARUPS measurements of wide variety of organic thin films. The previous sample preparation chambers with LEED/Auger optics were also connected to the new measurement chamber. The new spectrometer station is shown in Fig. 1.

Although the new system is dedicated to organic materials, it will be also used in investigating inorganic materials.

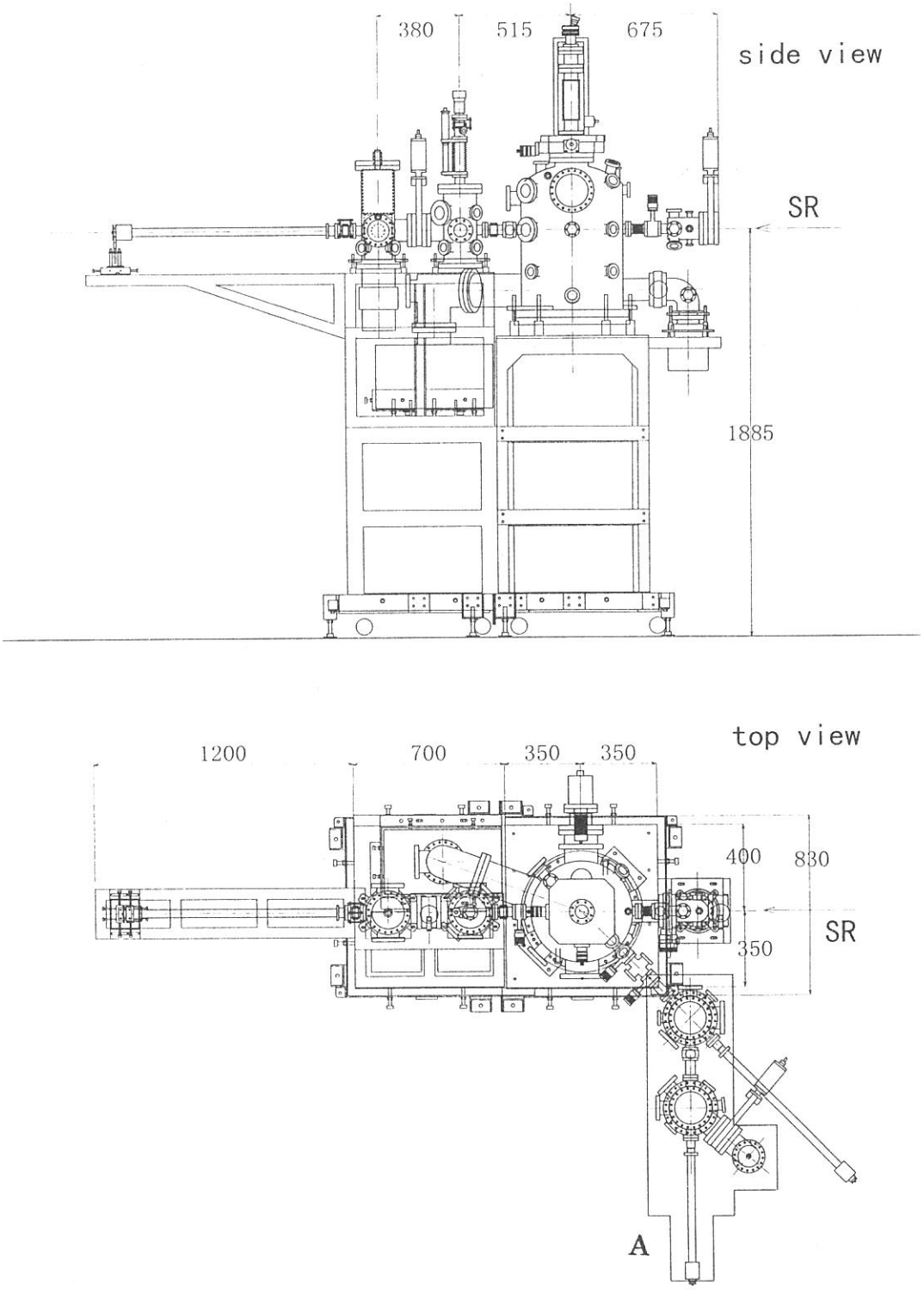

Fig. 1 The new ARUPS apparatus for organic thin films at the BL8B2. In the top-view drawing, the previously constructed sample preparation chambers (A) are also shown.

(BL8B1)

Cleaning mirrors and gratings at BL8B1 with UV/Ozone

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In the measurement with Soft X ray monochrometer, existence of carbon on mirror surfaces often give arise the problem: During the use of monochrometer, residual hydrocarbon reacts photochemicaly and gradually sticks on the surfaces. Since the residue contains carbon, it absorbs the photon, especially, one in the C K-edge energy region (290 ～ 310 eV). Consequently, it makes "a dark hole" in the output spectra of monochrometer. When the absorbance becomes more than 50 %, this may affect the absorption spectra obtained, because UV photon beam in stray light, which should be subtracted, become significant.

Since ozone is high reactive with hydrocarbon, UV/Ozone cleaning technique has been used to remove residual hydrocarbon and clean surfaces, mainly those of semiconductors: Ozone attack to the surface and make reactions with photochemicaly. We have applied this UV/ozone cleaning technique to mirrors and gratings in BL8B1. The UV apparatus (Nippon Laser Denshi, UV/Ozone cleaner) are used for generation of ozone. We flowed air to this apparatus and pumped by funs. At the exit, ozone were removed on the copper warmed up by heater. Typically, the mirrors were kept in this apparatus for 3 hours. Tow mirrors (M1 and M21) and two gratings (G2 and G3) were cleaned with the above procedure.

Fig 1 shows the output spectra of BL8B1 (200-600 eV) before and after ozone cleaning. The dip around 290 eV in fig. 1a) is due to the carbon on the surface of mirrors and gratings. After the cleaning,, we were successfully able to regain the throughput at 290 eV from 10% to 80 %. This provides the reasonable measurement in this energy region at Bl8B1.

We thank Mrs. Hayashi and Kondo at IMS for their technical support.

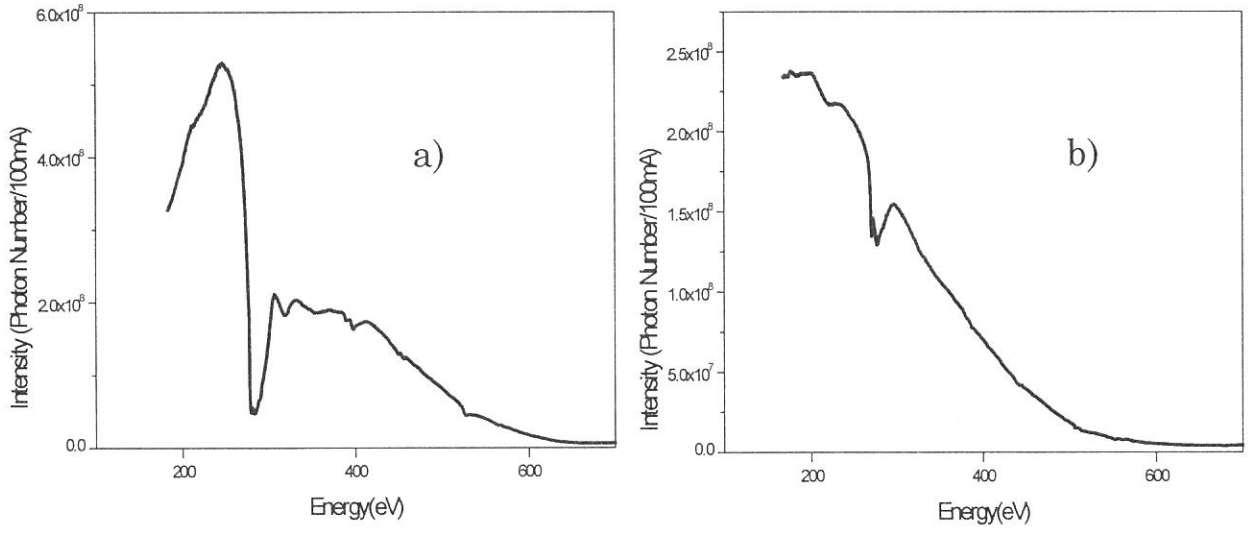

Fig. 1: Output spectra at BL8B1 when using the G2 grating (540 l/mm: R =15m).
a) and b) show the spectra before and after ozone cleaning, respectively.