BL3U

Construction of an Endstation of BL3U for X-Ray Emission Studies

T. Hatsui[1], T. Horigome[2], K. Matsushita[3], H. Yoshida[4], M. Suzui[4], N. Kosugi[1]

[1]*Dept. of Vacuum UV photoscience, Institute for Molecular Science, Okazaki 444-8585 Japan*

[2]*UVSOR Facility, Institute for Molecular Science, Okazaki 444-8585 Japan*

[3]*Technical Center, Nagoya University, Chikusa-ku, Nagoya, 464-8602, Japan*

[4]*Equipment Development Center, Institute for Molecular Science, Okazaki, 444-8585 Japan*

Optical Design

High-resolution soft-x-ray emission spectroscopy (XES) generally requires small beam size at the sample position, because a smaller opening of the spectrometer entrance slit is needed to achieve higher energy resolution. Such a beam is usually produced by refocusing optics downstream of the exit slit. In the case of BL3U, installation of such refocusing optics is impossible, due to a very limited space.

On the other hand, monochromators with short arm lengths, such as BL3U, are operated with small exit-slit opening for practical energy resolution. It is feasible to carry out XES studies at the exit-slit position. The constant exit-arm length of the BL3U monochrometer is essential for such design. Based on the above consideration, an XES endstation has been constructed at the exit-slit position of the in-vacuum undulator beamline BL3U.

Figure 1 represents the optical layout of the XES endstation. X-rays dispersed by the varied-line-spacing plane grating are horizontally focused by the plane-elliptical mirror, M2X, with the demagnification of 20 [1]. The exit slit, S1X, monochromatizes the x-rays. The ray-trace calculations based on the upgraded lattice parameters (the lowest emittance mode), which will be operated from May 2005, indicate that the beam on the sample position has a Gaussian profile with full width at half maximum (FWHM) in horizontal direction of 62 μm.

On the other hand, the vertical beam size is determined by the slit opening of S1X, and the diffraction effect. The distance between S1X and the sample position is set to 22.5 mm. The smallest vertical beam size limited by diffraction through S1X is shown in Fig. 2. Here the smallest beam size is defined as the beam size, where the slit opening of S1X matches FWHM of the beam at the sample position, which is estimated within Fraunhofer diffraction.

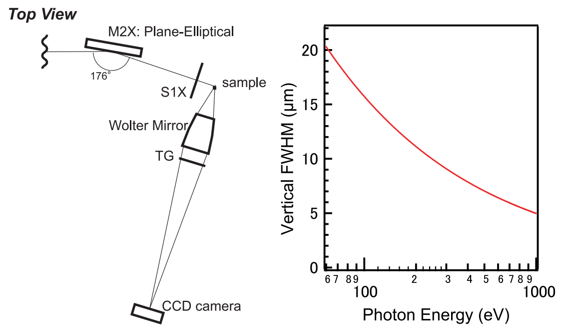

Fig. 1 Schematic layout of the XES endstation (left), and theoretical prediction of the vertical beam size (right).

Results and Discussion

Horizontal beam size is evaluated by using a knife-edge scanning method. Obtained profile was well fitted a Gaussian function with FWHM of 68 μm (Fig. 2, left), which is slightly larger than the theoretical prediction of 62 μm. This deviation arises from the operation with the moderate emittance mode (60 nm-rad). The horizontal beam size will be improved after the user operation with the upgraded lattice (27.4 nm-rad).

Vertical size was evaluated by measuring the 0^{th} order diffraction of the recently developed transmission-grating spectrometer for XES (Fig. 1) [1,2]. The Wolter type I mirror has a magnification of 10, which enables the measurement of the vertical beam size at the sample position. Fig. 2(right) shows the observed image of the beam at 110 eV with the S1X opening of 18.5 μm, corresponding to E/ΔE=7000. In the vertical direction, the beam shows only a simple Gaussian profile with FWHM of 24 μm, slightly larger than the theoretical prediction. No undulated tail originated from the diffraction through S1X is observed. This may indicate slight misalignment of the Wolter type I mirror, which causes blur in the image. The obtained flux was 10^{10}-10^{11} ph/sec.

In summary, a new XES endstation was successfully constructed at BL3U. The beam size of 68 (horiz.) x 24 (vert.) μm^2 is obtained.

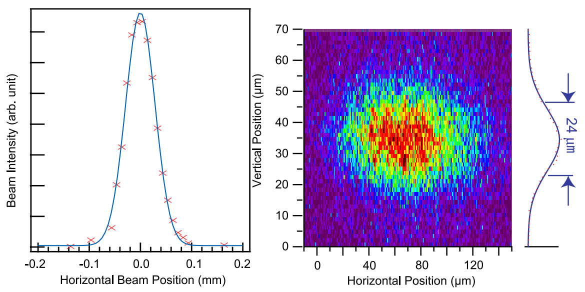

Fig. 2 Horizontal beam profile (left), and a image of the beam (right) at 110 eV.

[1] T. Hatsui, *et al.*, AIP Conf. Proc. **705**, 921 (2004).

[2] T. Hatsui, *et al.*, J. Electron Spectrosc. Relat. Phenom., in press.

Improvement of the SGM-TRAIN Monochromator at UVSOR-II BL5U for Low Excitation-Energy Photoemission

T. Ito[1,2], H.J. Im[2], S. Kimura[1,2], E. Nakamura[1], T. Horigome[1]
[1]*UVSOR Facility, Institute for Molecular Science, Okazaki 444-8585, Japan*
[2]*School of Physical Science, The Graduate University for Advanced Studies, Okazaki 444-8585, Japan*

BL5U at UVSOR-II storage ring has been reconstructed in 2004's for high-resolution photoemission (HRPES) study for solids and surfaces [1]. The energy and angular resolutions of the photoemission apparatus constructed at the end-station of BL5U have been improved to ΔE ~ 1.2 meV and Δθ ~ ±0.1°, which is sufficient to study the anomalous physical properties such as the metal-insulator transition, superconductivity, magnetic phase transition, *etc*. However, it has been hard to study the above properties at BL5U because of the old-type beamline designed in 1995's, in spite of the extensive improvement of the end-station and the storage ring [1,2]. Main problems interrupting a high-resolution study were as follows. (1) Mechanism for optimizing the front mirror was too rough to operate the focus position of the undulator light. (2) Entrance slit has no cooling system. (3) The grating G3 with normal incident mount for the low energy region (hν = 5 – 25 eV) has been optimized to the bending magnet radiation [3]. The above has caused the extremely low throughput at the low-energy region and restricted the HRPES experiment.

Taking account of the problems listed above, we have reconstructed the beamline in the following way to improve the efficiency in the PES experiment with using the low-energy photons at BL5U. (1) The mechanics at the front mirror was updated to the high-precision system controlled by the pulse-motors. (2) The water-cooling system was attached at the holder of the entrance slit. (3) The monochromator (SGM-TRAIN) was re-arranged to the optimum condition to the undulator light.

Figure 2 shows the improved throughput from the SGM-TRAIN monochromator after the present reconstruction. Comparing with the previous throughput spectra (Fig. 1), we can clearly find that the mesh current increases about 30 times higher, and the energy resolution becomes better because of the sharper interference from the optical klystron-type undulator as shown in Fig. 2. Due to the high-throughput of the photocurrent at the low-energy region, the HRPES measurement at BL5U becomes available. For example, HRPES spectrum at the Fermi-level of gold (Fig. 3) has been corrected within 1 hour with the resolution of hν/ΔE ~ 1000. We believe that the present reconstruction makes it possible to explore the origin of the anomalous physical properties by using the high-resolution bulk-sensitive angle-resolved photoemission apparatus at UVSOR-II BL5U.

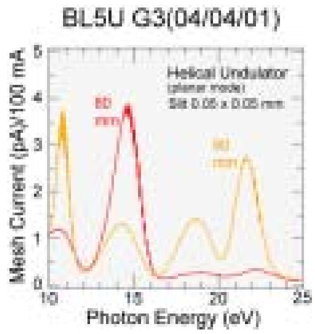

Fig. 1 Throughput spectra from the SGM-TRAIN monochromator with the normal incident grating G3 measured before the present reconstruction [1].

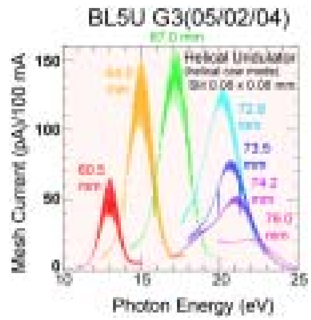

Fig. 2 Same as Fig. 1, but measured after the present reconstruction.

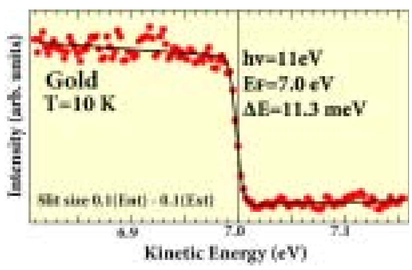

Fig. 3 HRPES spectrum at the Fermi level of gold measured after the present reconstruction.

[1] T. Ito *et al.*, UVSOR Activity Report 2003, 40.
[2] M. Katoh *et al.*, UVSOR Activiry Report 2003, 5.
[3] M. Kamada *et al.*, Rev. Sci. Instrum. **66** (1995) 1537.

BL5B

Aging Stability of Mg-Based Reflection Multilayers in the 25–35 nm Region

T. Ejima[1], A. Yamazaki[1], T. Banse[1], K. Saito[1,2], Y. Kondo[1,3], S. Ichimaru[4], H. Takenaka[4]

[1]*IMRAM, Tohoku University, Sendai, 980-8577 Japan*

[2] *Venture Business Laboratory, Saga University, Saga 840-8502, Japan*

[3] *Akita Research Institute of Advanced Technology, Akita 010-1623, Japan*

[4] *NTT-AT Co., Tokai 319-1193, Japan*

Reflection measurements in the 25–35 nm region are made for Mg/SiC- and Mg/Y_2O_3- multilayers kept under a low humid atmosphere for 4 or 5 years. Both aged Mg/SiC and Mg/Y_2O_3 multilayers keep their reflectances.

Introduction

In the 25–35 nm wavelength region, Mg/SiC- and Mg/Y_2O_3-multilayers have been proposed and fabricated as a reflection multilayer [1, 2]. However, magnesium is known to have a high reactivity and is usually found in nature in the form of oxide, carbonate or silicate, often in combination with calcium. This aspect of high reactivity presents a demerit for the practical application of Mg-based multilayers, despite their high reflectance.

Experiments

All samples used for the aging-stability measurements were kept in a desiccator at RT and a humidity estimated at lower than 50%, except for during the time of the measurements.

Reflectances of the aged and heated multilayers were measured with the reflectometer at the beamline BL5B. In the measurements, a combination of the G3 grating and the M24 mirror was used. The resolving power of the wavelength, $\lambda/\Delta\lambda$, was about 500 at 30 nm. Reflectances of the non-aged multilayers were measured with a home-made reflectometer [3], a 166° constant-deviation type using a grating that was 600 grooves/mm concave with a 3 m radius of curvature. The resolving power of the wavelength was estimated to be 240 at 25.6 nm.

Experimental Results

One of measured reflectances of the aged Mg/SiC-multilayers is represented with the simulation result in Fig. 1(a). The ordinate of the figure is s-polarized reflectance. The measured results are represented by solid curves and the simulation results, by broken ones. As can be seen in the figure, measured reflectances were well reproduced by the simulated ones. The reflectance of the non-aged multilayer measured before storage is represented in Fig. 1(b). The ordinate of the figure is non-polarized reflectance. A comparison of reflectances between before and after storage, and a comparison of the measured reflectances with the simulated ones show that the multilayer represents high reflectance after 4 years storage. Mg/Y_2O_3-multilayers retained also their reflectance even after 5 years storage in a low humidity atmosphere. The condition will be easily achieved in the EUV instruments.

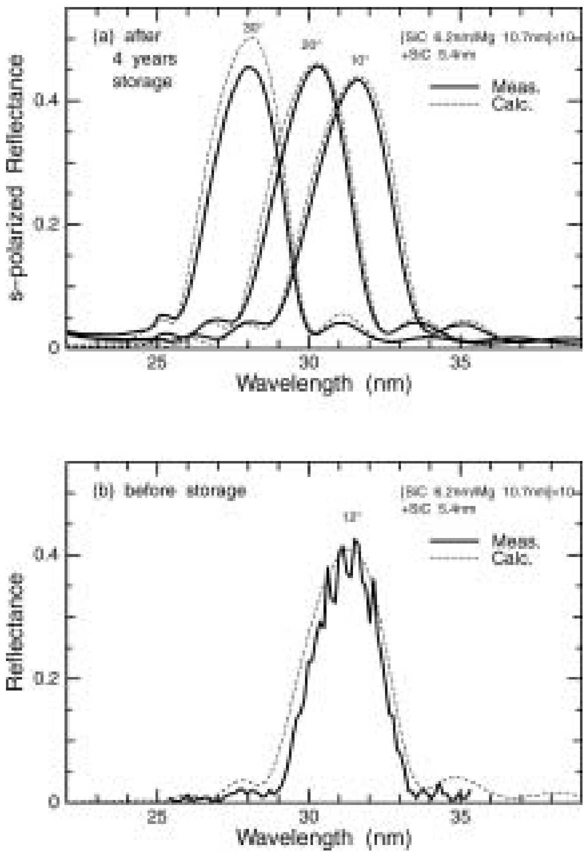

Fig. 1 Reflectance of Mg/SiC multilayer after 4 years storage (a), and before storage (b).

[1] Y. Kondo, T. Ejima, K. Saito, T. Hatano, and M. Watanabe, Nucl. Inst. Meth. Phys. Res. A **467-468** (2001) 333.

[2] T. Ejima, Y. Kondo, and M. Watanabe, Jpn. J. Appl. Phys., **40** (2001) 376.

[3] S. Nakayama, M. Yanagihara, M. Yamamoto, H. Kimura, and T. Namioka, Physica Scripta, **41** (1990) 754.

Thermal Stability of Mg-Based Reflection Multilayers

T. Ejima[1], A. Yamazaki[1], T. Banse[1], K. Saito[1,2], Y. Kondo[1,3], S. Ichimaru[4], H. Takenaka[4]
[1] *IMRAM, Tohoku University, Sendai, 980-8577 Japan*
[2] *Venture Business Laboratory, Saga University, Saga 840-8502, Japan*
[3] *Akita Research Institute of Advanced Technology, Akita 010-1623, Japan*
[4] *NTT-AT Co., Tokai 319-1193, Japan*

Reflection measurements in the 25–35 nm region are made for Mg/SiC- and Mg/Y_2O_3- multilayers annealed from room temperature to 400°C with 50°C intervals. Both Mg/SiC and Mg/Y_2O_3 multilayers keep their reflectances under 200°C annealing.

Introduction

In the 25–35 nm wavelength region, Mg-based multilayers have been proposed and fabricated as a reflection multilayer [1, 2]. Reflection multilayers used for practical optics are usually exposed to high heat-load circumstances through being baked in a vacuum chamber or enduring a high flux of incident light. Magnesium is known to have a low melting point (648.8°C), much lower than that of typical molybdenum (2622°C) and silicon (1414°C). This low melting-point presents a demerit for the practical application of Mg-based multilayers, despite their high reflectance.

Experiments

The multilayers used for the thermal-stability measurements were heated from RT to 400°C at 50°C intervals in an IR furnace with an Ar atmosphere for 1 hour. Temperature was monitored by three thermocouples in contact with the sample surface.

Reflectances of the heated multilayers were measured with the reflectometer at the beamline BL5B. In the measurements, a combination of the G3 grating and the M24 mirror was used. The resolving power of the wavelength, $\lambda/\Delta\lambda$, was about 500 at 30 nm. The resolution of the angle of incidence was about 0.1°. To suppress high ordered light from the monochromator, a reflection-type filter was placed in front of the sample.

Experimental Results

The measured reflectances of the annealed Mg/Y_2O_3 multilayers are represented in Fig. 1(a). Bragg reflection peaks are observed at around 25.5 nm, and no movement of the peak positions is observed with increases in the annealing temperature. Temperature dependence of the reflectance that are normalized by the reflectance at RT is represented in Fig. 1(b). The value obtained for the measured reflectance in the Mg/Y_2O_3 multilayer at RT was 0.43, and in Mg/SiC multilayer it was 0.42. The temperature dependence of both multilayers is that the reflectance remained constant from RT to 200°C, but decreases with increases of temperature above 200°C, becomes half at 300°C, and then vanishes over 400°C. This temperature-durability will be high enough in the EUV instruments.

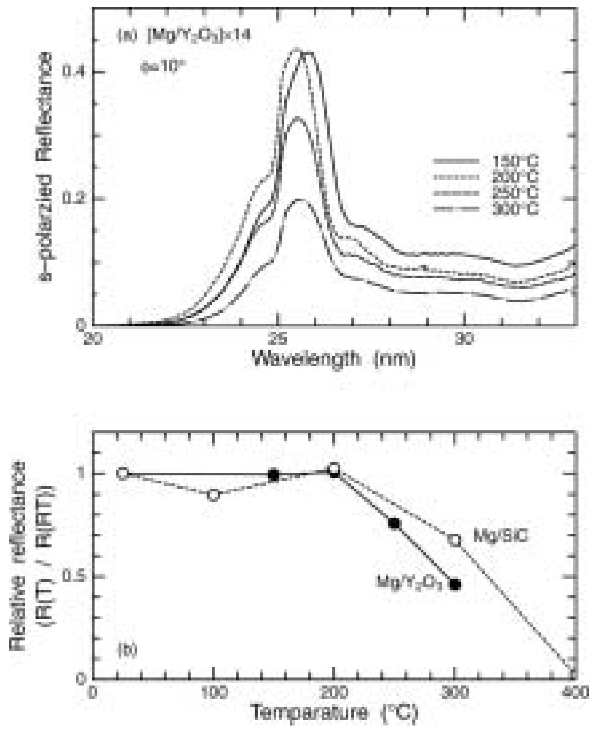

Fig. 1 Reflectances of Mg/Y_2O_3 multilayers annealed from 150°C to 300°C with 50°C intervals (a), and the relative reflectance of each annealing temperature normalized by that of RT (b).

[1] Y. Kondo, T. Ejima, K. Saito, T. Hatano, and M. Watanabe, Nucl. Inst. Meth. Phys. Res. A **467-468** (2001) 333.

[2] T. Ejima, Y. Kondo, and M. Watanabe, Jpn. J. Appl. Phys. **40** (2001) 376.

Development of Multi-Layer Mirror for Imager of O^+ Ions Flowing from Planets

T. Murachi[1], K. Okada[1], M. Kanao[1], A. Yamazaki[2], I. Yoshikawa[3], W. Miyake[4], M. Nakamura[1]

[1]*Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency, Sagamihara, Kanagawa 229-8510 Japan*

[2]*Planetary Plasma and Atmospheric Research Center, Graduate School of Science, Tohoku University, Aoba-ku, Sendai, Miyagi 980-8578 Japan*

[3]*Graduate School of Science, The University of Tokyo, Bunkyo-ku, Tokyo 113-0033 Japan*

[4]*National Institute of Information and Communications Technology, Koganei, Tokyo 184-8795 Japan*

It is known that the hydrogen atoms and ions and the oxygen ions are main components of outflow from the atmospheres of the Venus and the Earth to the interplanetary space. The oxygen ions make important roles in the interaction with the solar wind plasma. In order to investigate the 2 dimensional distribution and temporal variation of the oxygen ions, which is difficult for the in-situ observation using the satellites, we think of the remote sensing of the solar photons resonant-scattered by the oxygen ions (O II: 83.4 nm).

However, resonant-scattered light of the hydrogen atoms (the Lyman α line: 121.6 nm) has the wavelength near that of the O II (83.4 nm). The hydrogen atoms surrounding the planets resonant-scatter the solar light and shine to form a corona. The brightness of the hydrogen Lyman α line is 100 - 10000 times stronger than that of the O II. Therefore, it is necessary to produce the optics, which have little sensitivity at the hydrogen Lyman α line. Until now, we produce the optics using a molybdenum mono-coated mirror (Mo mirror) and an indium filter, and it rejects the Lyman α line. In this experiment in order to make the sensitivity of the hydrogen Lyman α line lower, we design and produce a multi-coated mirror of molybdenum and MgF_2 (1 pear of Mo: 8.0 nm over MgF_2: 8.5 nm, Mo/MgF_2 mirror) on an aluminum substrate.

Fig. 1 shows the measurements of the reflectivity of the Mo mirror and the Mo/MgF_2 mirror in the EUV facility (using the atomic spectral line, whose wavelength is discrete) of the Institute of Space and Astronautical Science (ISAS), Japan Aerospace Exploration Agency (JAXA). At the hydrogen Lyman α line the reflectivity of the Mo mirror and the Mo/MgF_2 mirror is 28 % and 5 % respectively. The reflectivity of the Mo/MgF_2 mirror is 6 times lower than that of the Mo mirror.

Like the calculated value of the reflectivity shown in Fig. 2, the reflectivity of the Mo/MgF_2 mirror should become very low in the vicinity of 121.6 nm. Then we measured the reflectivity of the Mo/MgF_2 mirror with continual radiation of the UVSOR BL-5B line. Fig. 2 represents the measurement result (because of P polarized light of UVSOR BL-5B, the reflectivity in Fig. 2. differs from that in Fig. 1.). The calculation of the reflectivity of the Mo/MgF_2 mirror becomes very low near 121.6 nm, but the experimental result does not become so. We elucidate this cause in future.

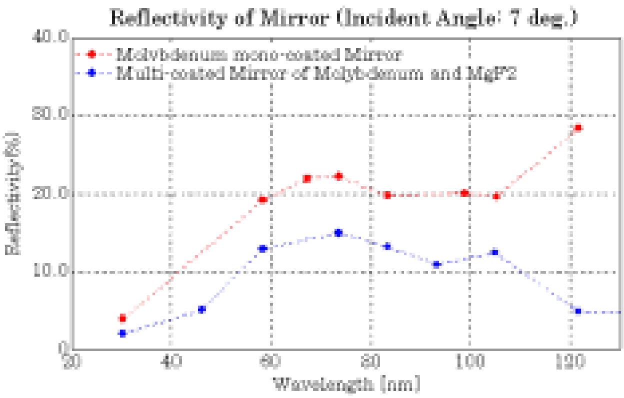

Fig. 1 The reflectivity of the Molybdenum mono-coated mirror (red) and the multi-coated mirror of Molybdenum and MgF_2 (blue) in the EUV facility of ISAS of JAXA.

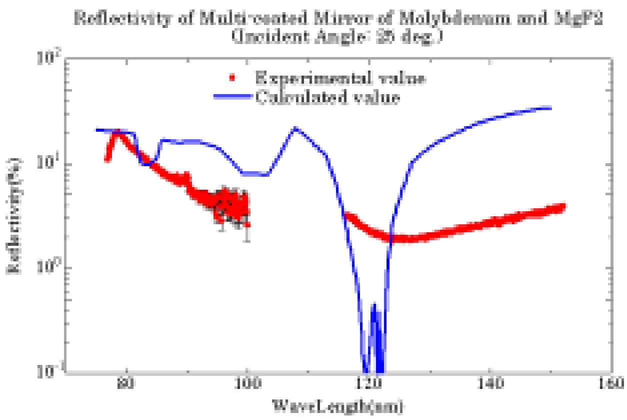

Fig. 2 The experimental value (red) and the calculated value (blue) of the reflectivity of the multi-coated mirror of Molybdenum and MgF_2 in the UVSOR BL5B.

Construction and Performance Test of BL6B(IR)

S. Kimura[1,2], E. Nakamura[1], T. Nishi[2], Y. Sakurai[1]
[1]*UVSOR Facility, Institute for Molecular Science, Okazaki 444-8585, Japan*
[2]*Deparment of Molecular Structural Science, The Graduate University for Advanced Studies, Okazaki 444-8585, Japan*

We have newly installed an IR-THz beam line at UVSOR-II. UVSOR had the oldest IR beamline (BL6A1) dedicated at 1986 [1]. Recently, UVSOR storage ring was upgraded to be a low emittance ring and to be able to equip six undulators at three long and three short straight sections. Since the old IR beam line locates on the extended line of one of short straight sections (S6), the emission point was moved to the downstream position in the bending magnet (B6) to make a new undulator beam line at S6. The name of the IR beam line was changed to BL6B(IR).

The beam line has a large acceptance angle of 215(H) x 80(V) mrad^2 to obtain the high flux in the IR and THz regions. So-called "magic mirror" with vertical angle focusing that has been installed at SPring-8 BL43IR at first [2] was employed as the first mirror. The mirror chamber was directly connected to the bending magnet chamber for collecting high photon flux [3]. To avoid heat load from SR, the orbital plane on the mirror was masked by a copper rod with water cooling. The SR is focused to the imaging source point that locates out of the ultra-high vacuum area of the bending and mirror chambers only by the magic mirror. The beam size at the first focus in the distance of 2640 mm from the magic mirror was 1.17(H) x 1.20(V) mm^2 that is similar to the corresponding ray-tracing result of 1.0(H) x 2.0(V) mm^2.

The beam line equips two rapid-scan-type interferometers, one is old Michelson-type (Bruker 66v) and the other newly installed Martin-Puplett-type (JASCO FARIS-1). The former covers in the photon energy range of 6 meV – 3 eV (50 – 25,000 cm^{-1}) and latter of 1.2 – 25 meV (10 – 200 cm^{-1}). One of the results produced by the latter interferometer is shown in this issue [4].

The obtained and expected brilliance and photon flux are plotted in Fig. 1. In the figure, the results of SPring-8 BL43IR and an expected intensity of a black body light source (The temperature of 1400 K is assumed.) are also plotted. BL6B is higher brilliance in the THz region and higher photon flux in the whole region than BL43IR. This result indicates that BL6B is suitable for the microspectroscopy in the whole region, on the other hand, BL43IR is good for the mid-IR microscopy with diffraction limit resolution.

The present end station is only for a reflection-absorption spectroscopy for mm-size samples. In spring of 2005, a new spectromicroscopy apparatus is installed. The apparatus employs large schwartzschild mirrors with 140 mm in diameter to cover the THz region.

[1] T. Nanba *et al.*, Int. J. Infrared and Millimeter Waves **7** (1986) 1769.
[2] S. Kimura *et al.*, Nucl. Instrum. Meth. A **467-468** (2001) 437.
[3] S. Kimura *et al.*, AIP Conf. Proc. **705** (2004) 416.
[4] S. Kimura, S. Kunii, in this issue.

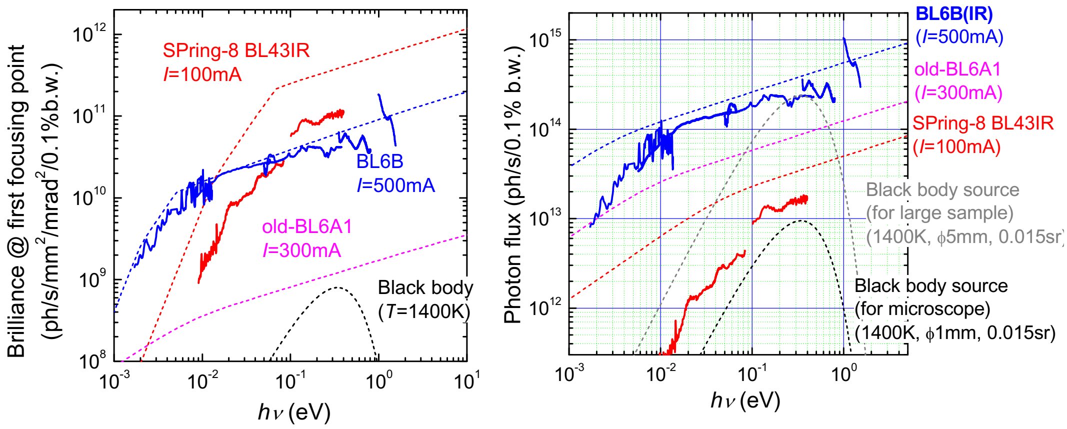

Fig. 1 Brilliance (left) and photon flux (right) spectra of UVSOR BL6B, SPring-8 BL43IR and black body light sources. The dashed and solid lines are calculated and measured spectra, respectively. UVSOR BL6B is brighter in the THz region and higher photon flux in the whole region than SPring-8 BL43IR.

BL7U

Design of a High-Resolution and High-Flux Monochromator for VUV Angle-Resolved Photoemission at BL7U

S. Kimura[1,2]

[1] *UVSOR Facility, Institute for Molecular Scinece, Okazaki 444-8585, Japan*

[2] *Deparment of Molecular Structural Science, The Graduate University for Advanced Studies, Okazaki 444-8585, Japan*

We plan to construct a new undulator beam line for studying electronic structures of condensed matters by a high-energy-resolution angle-resolved photoemission in the VUV region. The beam line equips an undulator light source, a VUV monochromator and a photoelectron spectrometer.

The APPLE-II type undulator [1] will be installed to produce not only horizontal but also vertical linear polarization in the photon energy range of 7 – 40 eV. The undulator period length (λ_u) and the number of period are 70 mm and 40, respectively. The photoemission end station equips a 200-mm-radius hemispherical photoelectron analyzer. The target of the total energy resolution in the angle-resolved photoemission spectroscopy is below 1 meV. To attain the purpose, the monochromator must be high energy resolution below 1 meV and high photon flux above 10^{11} ph/s on samples. Here we propose the design of the new type normal-incident monochromator for such purpose.

The schematic figure of the monochromator is shown in Fig. 1. The monochromator has no entrance slit because the very small vertical beam size at the center of the undulator after upgraded UVSOR-II. The beam size (2σ) is calculated to be 0.07(V) x 1.2(H) mm^2 in 3-%-coupling operation [2]. When the light is derived to a grating without extrance slit, not only high photon flux but also high energy resolution is expected because of the long distances between the emission point and the grating and between the grating and the exit slit. The similar monochromator has already installed at SRC, Wisconsin [3].

The distances from the emission point to the grating and from the grating to the exit slit are 22 m and 6.67 m, respectively. Then the radius of the spherical grating is 10 m. The source size is reduced by 1/3 on the exit slit. The focusing element is only the spherical grating to reduce the focusing errors. The dispersion direction of the grating is vertical and the incident angle is 0.5 deg.

Three gratings of 1,200, 2,400 and 3,600 *l*/mm optimized at 10, 20 and 30 eV, respectively, are installed for keeping the energy resolution below 1 meV. The highest energy resolution is expected to be $E/\Delta E \sim 6\times10^4$ with the grating of 3600 *l*/mm and 1-%-coupling operation. The photon flux keeps above 10^{11} ph/s in 0.01-% band width.

The beam line equips three branches. The first is for the angle-resolved photoemission, the second for the photochemistry and the third for micro-focus photoemission.

The beam line will be constructed at BL7U in the summer of 2006.

[1] S. Sasaki *et al.*, Jpn. J. Appl. Phys. **31** (1992) L1794.

[2] M. Hosaka, private communication.

[3] J. Bisognano et al., Nucl. Instr. Meth. A **467-468** (2001) 492.

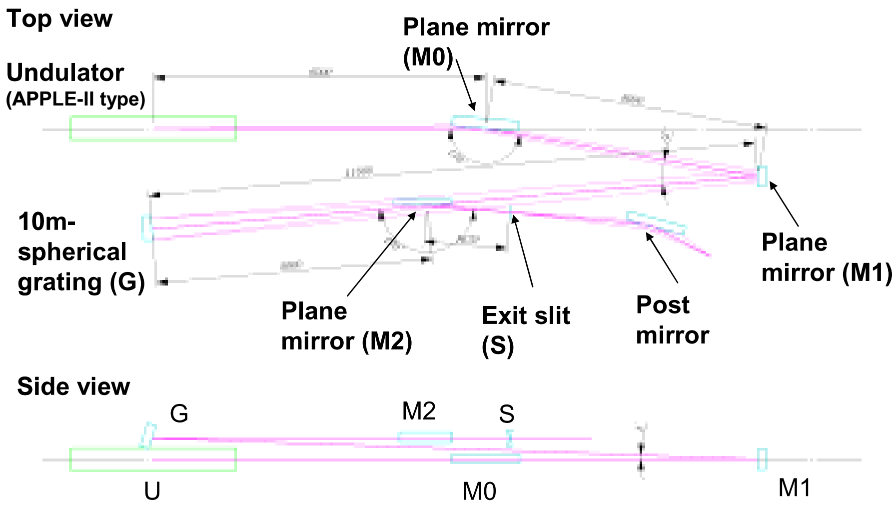

Fig. 1 Schematic figure of the new normal incident monochromator at BL7U.

Quality Evaluation of Mass-Produced Nuclear Emulsion Films for OPERA Neutrino Oscillation Experiment

S. Hiramatsu, N. Naganawa, A. Ariga, J. Kawada, S. Miyamoto, T. Ban, K. Hamada, N. Koike, K. Miyanishi, K. Narita, T. Nakamura, M. Nakamura
F-Laboratory, Faculty of Science, Nagoya University, 464-8602, Japan

Nuclear Emulsion Film can record trajectories of high-energy charged particles with sub-micron position accuracy. The trajectories are recorded as three-dimensional images in the emulsion layers of the film.

Nuclear emulsion has been used in the study of elementary particle physics from 1950s, but at the end of 60s it became a minor detector in that field, because other useful electric detectors were emerged. But, by the recent development of automated image read-out system by us, Nuclear emulsion came back to the frontier of elementary particle physics. The frontier, where the recent nuclear emulsion is working, is Neutrino physics.

In 2000, we have succeeded to detect Tau neutrinos at the first time in the world. Following this success, we are preparing a large scale neutrino oscillation experiment, named OPERA. In this experiment, we intend to confirm the existence of the neutrino masses. We intend to detect Tau-neutrinos oscillated from Mu-neutrinos during the 2.4 msec (732 km) flight from Geneve (Switzerland) to Gran Sasso (Italy). We need a large detector that the mass is around 1700 ton to detect the oscillated Tau neutrinos with high S/N ratio.

About 12 M films corresponding to the area of 150,000m^2 is required to realize the experiment. The emulsion film, so-called OPERA film, has been developed by us with the collaboration of Fuji Photo Film Co., Ltd. We have succeeded to implement a special function “Refreshing”. By this function, we can reset or erase the images recorded in the film before its use.

For OPERA, we are applying the refreshing process after the delivery from Fuji Photo Film Co., Ltd. Then transport the film to Gran Sasso.
We must evaluate the quality of the films in each step, *i.e.*, after the delivery from Fujifilm and after the refreshing, Also we must evaluate the quality of the refreshing process. In order to do those, high energy electrons available in the UVSOR facility has been used.

The exposed electrons were produced during the electron beam transfer from the Booster Synchrotron to the Electron Storage ring. Those are the converted electrons and positrons of gamma rays produced by electron interactions with residual gas or materials surrounding the beam transport. The average energy of the produced electron (positron) is around 50 MeV.

Figure 1 shows a photograph of an electron track recorded in an OPERA film to be evaluated the sensitivity of a film is defined as a density of the recorded grains along electron tracks. The size of the recorded grains is around 0.6 micron. The grain density was measured by eye and machines. We specified the grain density of 32 grains/100 microns as a threshed for good quality.

Fig. 1 A recorded trajectory of electron tracks. Horizontal scale is 120 microns.

By the exposure and measurement, all of the production batches and the refreshed films show enough sensitivity for our purpose. In Fig.2, the measured sensitivities of the first ten batches are shown. Though some fluctuation can be seen, the sensitivity is over 32 grains/100 microns in all samples.

The evaluation Job using the UVSOR electron will continue until the middle of 2006.

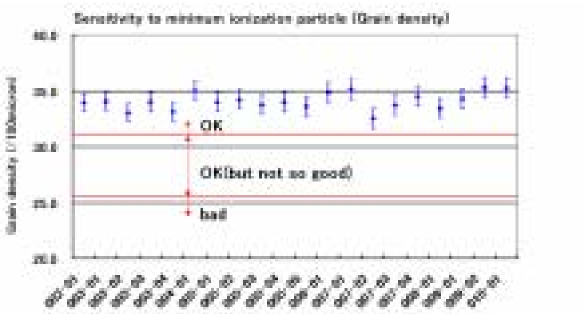

Fig. 2 Measured sensitivity of the films (grain density) of the first 10 production batches.