BL1B: A Dedicated THz Coherent Synchrotron Radiation Beamline

S. Kimura[1, 2], E. Nakamura[1], K. Imura[1], M. Hosaka[3], T. Takahashi[4] and M. Katoh[1, 2]
[1]UVSOR Facility, Institute for Molecular Science, Okazaki 444-8585, Japan
[2]School of Physical Sciences, The Graduate University for Advanced Studies (SOKENDAI), Okazaki 444-8585, Japan
[3]Synchrotron Radiation Research Center, Nagoya University, Nagoya 463-8603, Japan
[4]Research Reactor Institute, Kyoto University, Kumatori, Osaka 590-0494, Japan

Infrared (IR) and terahertz (THz) spectroscopies have now become conventional methods for the measurement of vibration modes and low-energy electronic structures. IR/THz synchrotron radiation (SR) is also used as a light source for spectroscopy and microscopy throughout the world. So far, many advanced types of spectroscopy have been developed such as IR imaging, pressure-dependent and magnetic-field-dependent THz spectroscopy, and so on. However, to realize further advances in spectroscopy, intense tunable light sources must be developed. One candidate for an intense broadband THz source is coherent synchrotron radiation (CSR). Then we planned to construct a dedicated beamline for THz coherent radiation at BL1B.

A top view of the THz beamline is shown in Fig. 1. The emitted THz light is collected by a three-dimensional magic-mirror (3D-MM, M0) of the same type as those already successfully installed at BL43IR in SPring-8 [1] and BL6B in UVSOR-II [2]. The 3D-MM was installed in the bending-magnet chamber and is controlled by a 5-axis pulse motor stage (x, z translation; θ_x, θ_y, θ_z rotation). To extract the emission at 34 degrees, the 3D-MM is located at the short distance of 55 mm from the electron orbit. The 3D-MM is made of aluminum and was fabricated by an NC length milling machine at the Equipment Development Center of Institute for Molecular Science. The surface roughness is less than ±1 μm, which is comparable to the visible wavelength but much smaller than the wavelength of THz light. Visible light is scattered by the surface of the 3D-MM, but THz light can be focused.

To eliminate the heat load from the SR, we employed a copper rod (6 mm in diameter) with water cooling on the emission plane because the power from the SR is concentrated in the emission plane.

The 3D-MM, which is located 880 mm from the center of the source, reflects the THz-CSR to the focal point (F0) on the outside of the bending-magnet chamber, as shown in Fig. 1 (1200 mm from M0). The THz-CSR collected by the 3D-MM is intercepted by a plane mirror (M1) located in the bending-magnet chamber and guided to the beamline. The focal point (F1) is located on the outside of the bending-magnet chamber through a tapered z-cut quartz window (24 mm in diameter and 5 mm thickness at the center). After F1, the light is formed into a parallel beam by a parabolic mirror (M1) and guided to the outside of the radiation shielding wall. The emitted THz-CSR and normal THz-SR light are measured by a Martin-Puplett type Fourier transform interferometer (FARIS-1, JASCO ltd.) installed. Reflection and transmission measurements can be performed in the beamline.

[1] S. Kimura *et al.*, Nucl. Instrum. & Meth. Phys. Res. A **467-468**, (2001) 437.
[2] S. Kimura *et al.*, Infrared Phys. Tech. **49** (2006) 147.

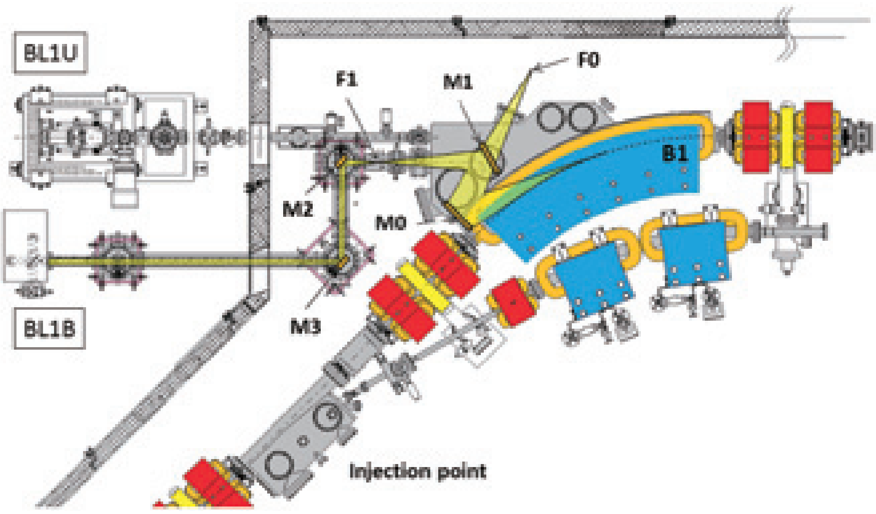

Fig. 1. Schematic top view of the beam extraction part of the THz-CSR beamline, BL1B. The three-dimensional magic mirror (3D-MM, M0) and a plane mirror (M1) are located in the bending-magnet chamber. A parabolic mirror (M2) is installed to form a parallel beam. The straight section (BL1U) is used for coherent harmonic generation (CHG) in the VUV region.

Present Status of a New VIS-VUV Photoluminescence Beamline BL3B

K. Fukui[1], Y. Imoto[1], M. Kitaura[2], K. Nakagawa[3], T. Ejima[4], E. Nakamura[5], N. Kondo[5], M. Sakai[5], M. Hasumoto[5] and S. Kimura[5]

[1]*Fac. Engi., Univ. Fukui, Fukui 910-8507, Japan*
[2]*Fac. Sci., Yamagata Univ., Yamagata 990-8560, Japan*
[3]*Grad. Sch. Human Dev. Enviro., Kobe Univ., Kobe 657-8501, Japan*
[4]*IMRAM, Tohoku Univ., Sendai 980-8577, Japan*
[5]*UVSOR facility, Institute for Molecular Science, Okazaki 444-8585, Japan*

The solid-state optical devices in ultraviolet (UV) region will bring dramatic improvements in not only the telecommunication applications but also the illuminating, environmental and medical applications. To achieve both technological and scientific investigations on such industrially important materials, the light sources which cover a wide photon energy region from visible (VIS) to vacuum ultraviolet (VUV) are required. In order to study photoluminescence (PL) of such materials in the VIS-VUV regions, a new bending-magnet beamline BL3B with a 2.5 m normal incidence monochromator (NIM) has been constructed. For the PL measurements in the wide energy region from VIS to VUV, two PL monochromators, one covers the VIS – UV regions and the other VUV region, are equipped.

The schematic layout of the BL3B which mainly consists of a 2.5 m off-plane Eagle-type monochromator is shown in Figs. 1(a) and 1(b). The actual parameters of the mirrors and gratings are listed in Table 1. The design concept has been reported in the previous report [1]. Fig. 2 shows the throughput using a Si photodiode (IRD AX-UV100), with S1 (entrance slit) = S2 (exit slit) = 100 μm. Fig. 3 shows the beam spot profile at the sample position (Q in Figs. 1(a) and 1(b)) using the G2 grating (at ~12 eV) with S1 = S2 = 100 μm. The FWHM of this spot is 0.25 mm (V) × 0.75 mm (H). The present status of the BL3B is as follows: photon energy coverage range: 1.7 ~ 31 eV, E/ΔE > 12000 (G1, ~ 7 eV), 0.8 ~ 2.8 × 10^{10} photons/s (E/ΔE ≈ 1000, G3), beam size (at Q) 0.25 mm (V) × 0.75 mm (H).

Table 1. Actual parameters of the mirrors and gratings.

Pre-mirrors	Incidence angle	Radius (mm)	Dimensions (mm)	Coat
M0	85°	∞ (plane)	110 × 300	Au
M1	81.1°	773.60 × 32,500 (toroidal)	210 × 200	Au
M2	87°	∞ (plane)	30 × 440	Au

Gratings	Deviation angle	Radius (mm)	Dimensions (mm)	Coat	Grooves (mm⁻¹)
G1	4°	2500	40 × 110	Au	1200
G2	4°	2500	40 × 110	Pt	600
G3	4°	2500	40 × 110	Al	300

Post-mirrors	Incidence angle	Radius (mm)	Dimensions (mm)	Coat
M3	82°	9390	40 × 400	Au
M4	86.49°	17090	50 × 270	Au

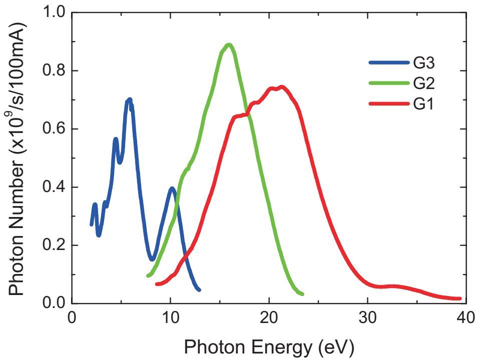

Fig. 2. Throughput from the off-plane Eagle type normal incidence monochromator beamline on BL3B.

[1] R. Ikematsu, K. Fukui, T. Ejima, E. Nakamura, M. Hasumoto and S. Kimura, UVSOR Activity Report **38** (2011) 44.

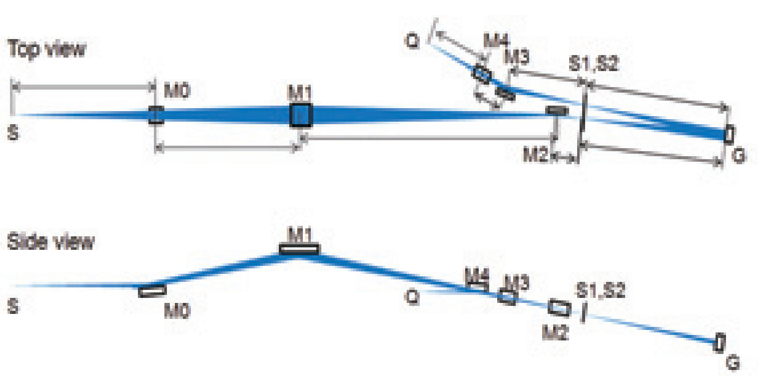

Fig. 1. Schematic layout of the BL3B: top view and side view.

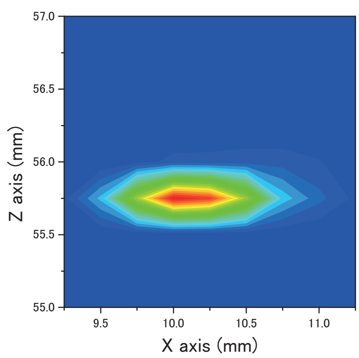

Fig. 3. Beam spot profile at the sample position [the point Q in Figs. 1(a) and 1(b)].

BL3B

Estimation of High Energy Limit of the 2.5 m Normal Incidence Monochromator Constructed at BL3B by Reflectivity Measurements

Y. Imoto[1], S. Watanabe[2], M. Kitaura[3], K. Fukui[1], K. Nakagawa[4], T. Ejima[5], E. Nakamura[6], M. Sakai[6], M. Hasumoto[6] and S. Kimura[6]

[1]*Department of Electric and Electronics Engineering, University of Fukui, Fukui 910-8507, Japan*
[2]*EcoTopia Science Institute, Nagoya University, Nagoya 464-8603, Japan*
[3]*Department of Physics, Faculty of Science, Yamagata University, Yamagata 990-8560, Japan*
[4]*Graduate School of Human Development and Environment, Kobe University, Kobe 657-8501, Japan*
[5]*IMRAM, Tohoku University, Sendai 980-8577, Japan*
[6]*UVSOR facility, Institute for Molecular Science, Okazaki 444-8585, Japan*

The 2.5-m normal incidence monochromator for the photoluminescence spectroscopy was newly constructed at the BL3B beamline. This monochromator was designed to cover the photon energy range from 2 eV to 30 eV. It is necessary to evaluate whether the monochromator works as expected or not. We have investigated the actual high-energy limit of this monochromator through the reflectivity measurements of alkaline and alkali-earth halides. It is well known that these materials exhibit the sharp peaks in the vacuum ultraviolet region spectra [1, 2]. These sharp peaks are due to the absorption of the cation's n*p* core excitons (n = 2-5). An observation of such core exciton peaks is expected to be an indication to grasp the high-energy limit that can be measured with a monochromator.

The single crystals of alkali and alkali-earth halides were cleaved in air, and quickly placed in a vacuum. The samples were attached at the cold finger of a liquid helium flow-type cryostat, and cooled down at 10 K. Both incident and reflected light were detected using a calibrated silicon photodiode sensor in the measurement chamber. The incident and reflected angles were fixed to be 15° for the direction perpendicular to the surface of samples.

Figure 1 shows the reflectivity spectrum of a $PbCl_2$ single crystal measured in the 5-30 eV range. There are three peaks between 21-25 eV, and the feature of these peaks is seen at two places in the low energy side. Since these values are about one half and one third, this result shows that the higher-order light has been observed, which was also observed with KCl single crystal. Therefore, we need to note the higher-order light, especially in the G1 and G2 grating regions.

Figure 2 shows the reflectivity spectrum of a MgF_2 single crystal measured in the 50-60 eV range. One can see two peaks split by 0.34 eV, which are of Mg 2*p* core excitons. From this result, the higher side limit of the photon energy coverage is set to be at least 55 eV at present.

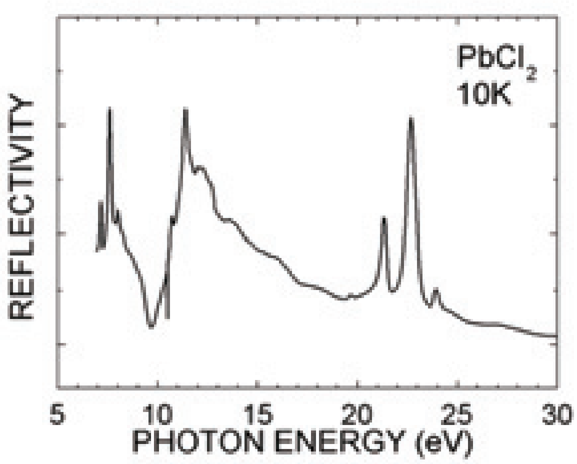

Fig. 1. Reflection spectrum of a $PbCl_2$ single crystal measured at 10 K.

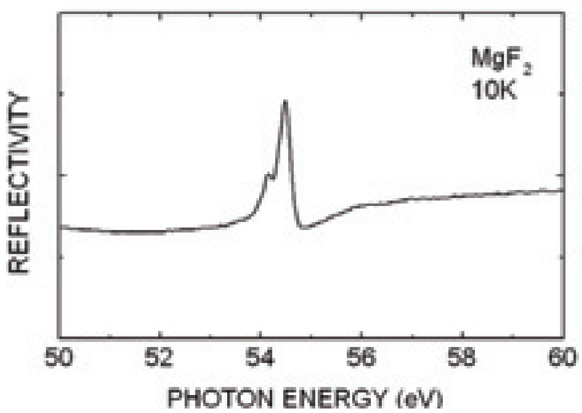

Fig. 2. Reflection spectrum of a MgF_2 single crystal measured at 10 K.

[1] G. W. Rubloff, Phys. Rev. B **5** (1972) 662.
[2] O. Aita *et al*., Phys. Rev. B **93** (1989) 10266.

Many thanks to Prof. M. Itoh (Shinshu Univ.) for providing alkali and alkali-earth halides single crystals.

Scanning Transmission X-ray Microscope Project at BL4U

T. Ohigashi[1], T. Araki[2], E. Nakamura[1], N. Kondo[1], E. Shigemasa[1], N. Kosugi[1] and M. Kato[1]
[1]*Institute for Molecular Science, Okazaki 444-8585, Japan*
[2]*TOYOTA Central R&D Labs., Inc. Nagakute Aichi 480-1192, Japan*

The soft x-ray spectroscopy gives plenty of information about the electronic structure of materials containing low Z elements and metals. By analyzing the photoabsorption and photoionization cross section near the soft X-ray absorption edges in detail, the chemical states of molecules and solids can be determined. Since a high brilliant soft X-ray source and advanced focusing optical elements have progressed in recent years, several microscopic methods have been combined with soft X-ray spectroscopy, such as XAFS (X-ray Absorption Fine Structure) and XPS (X-ray photoelectron spectroscopy), to obtain the 2-dimentional (2D) mapping of the chemical states with high spatial resolution. A scanning transmission X-ray microscopy (STXM) combined with XAFS is one of the promising tools in the soft X-ray spectroscopy.

In the STXM system, the incident X-rays are focused onto the sample by using a focusing optical element, such as a Fresnel zone plate (FZP), and the intensities of the transmitted X-rays through the sample are monitored by using a detector. By scanning the sample, the 2D mappings are obtained. The advantages of the STXM are the high penetrating power and the non-destructive property of the X-rays. That enables the STXM to apply to rather thick and/or rather radiation-sensitive samples in comparison with the electron-based microscopy. Therefore, even the 3-dimensional structural analysis of the sample can be performed by using the tomographic technique without any destructive process. The high penetrating power of the X-rays also allows us to observe the sample in air or wet condition (*i.e.* the vacuum is not necessary). Especially, the soft X-ray energy region from 282 to 540 eV, between the K edges of carbon and oxygen, is called the “water window” region. By using the X-rays in this energy region, carbon-based samples in water, such as living cells, can be observed without any staining. The STXM could be a unique technique to observe a living biological sample like cells in water with high resolution. Thanks to these features, the STXM has advantages over the electron microscopy and the optical one.

In 2011, the STXM beamline project has been launched with the upgrade project from the UVSOR-II ring to the UVSOR-III ring. A schematic image of the beamline is shown in Fig. 1. The soft X-ray source of the BL4U is equipped with an in-vacuum undulator. This undulator has 26 magnetic periods and the period length of 38 mm pitch and its gap width can be set from 13 to 40 mm. The monochromator is a Monk-Gillieson type with a varied line spacing plane grating. The energy range from 100 to 700 eV is available. The theoretical resolving power (E/ΔE) is 10000 at a maximum. In practical use for spectromicroscopy, the resolving power of 2000~4000 will be routinely utilized. The fixed exit slit is used as a virtual source of the focusing optics of the STXM (the third Bruker system following SLS and BESSY) and the FZP is placed at 1334 mm downstream from the slit. Two focusing FZPs of different pattern materials are in preparing. One is made of gold supported by Si_3N_4 membrane of 100 nm thick, and the other is made of hydrogen silsesquioxane (HSQ) supported by Si_3N_4 membrane of 50 nm thick. Their calculated efficiencies of +1 order diffraction including the absorption by the support membranes are plotted against the photon energy in Fig. 2. These plots show that better efficiencies are available by using the HSQ FZP for the carbon K-edge (around 285 eV) and the gold one for the oxygen K-edge (around 540 eV), respectively.

Operation of the BL4U is due to start in the end of 2012. Carbon nanotube will be used as a first reference sample to estimate the characteristics of the beamline; spectral resolution, spatial resolution, and polarization of the monochromatized radiation.

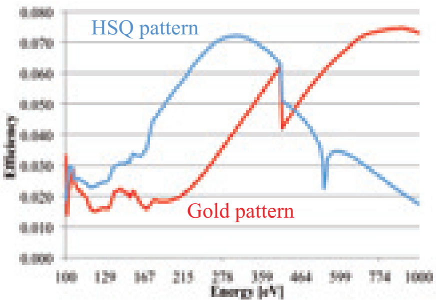

Fig. 2. Calculated efficiencies of the Fresnel zone plates of gold pattern and HSQ pattern.

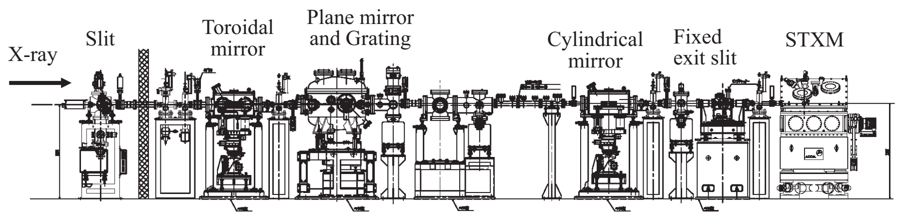

Fig. 1. Schematic image of the optical system of BL4U

Measurement of Transmissivity and Ghost Image Created by Ly-Alpha Filters for CLASP Slit-Jaw Unit

M. Kubo[1], Y. Katsukawa[1], N. Narukage[2], R. Kano[1], T. Bando[1], T. Kobiki[1], R. Ishikawa[1] and S. Tsuneta[1]

[1]*National Astronomical Observatory of Japan, Osawa, Mitaka, Tokyo 181-8588, Japan*

[2]*Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency, 3-1-1 Yoshinodai, Chuo-ku, Sagamihara, Kanagawa 252-5210, Japan*

A sounding rocket program called the Chromospheric Lyman-Alpha Spectro-Polarimeter (CLASP) will observe the upper solar chromosphere in Ly-alpha (121.567 nm), aiming to detect the linear polarization signal produced by scattering processes and the Hanle effect for the first time [1,2]. The solar image is focused at a slit by telescope mirrors, and the spectropolarimeter that measures the linear polarization with high accuracy of 0.1% order is located after the slit [3]. The solar image outside the slit is reflected to the slit-jaw unit and is monitored during flight. It is used to confirm the instrument pointing during flight and to obtain Ly-alpha context images for the interpretation of the data obtained by the spectropolarimeter. The images are also needed for co-alignment with other observations.

The slit-jaw unit consists of a fold mirror, a matched pair of off-axis parabolic mirrors, a pair of Ly-alpha narrow band filters, and a CCD detector. The Ly-alpha filter is the key to good quality Ly-alpha images. The prime candidate of the Ly-alpha filter is a 122-XN-1D developed by the Acton Optics & Coatings.

First of all, we have to know the transmissivity of the 122-XN-1D filter and its visible light rejection performance. Figure 1 shows the transmissivity of the 122-XN-1D filter as measured with the synchrotron radiation at the UVSOR BL7B. The transmission profile from 115nm to 200nm is consistent with that provided by the Acton Optics & Coatings, and the transmissivity is 7% in the wavelength of Ly-alpha (121.567nm). We find the transmissivity for the visible light is 0.01%. It is highest visible light rejection performance in the three types of 122nm narrowband filters developed by the Acton Optics & Coatings. From this measurements, we conclude that two 122-XN-1D filters are necessary for the slit-jaw unit to have the visible light contamination less than 1% in the Ly-alpha image.

Another issue on the Ly-alpha filter is a ghost image created by the filters. The ghost images are created by the reflection on the back and front surfaces of a filter and by the reflection between two filters. We take images of a main beam and ghost beams by using CCD camera. We plan to use the two Ly-alpha filters at the angle of incidence (AOI) of 0 degree in the slit-jaw unit. We have confirmed neither unexpected ghost image nor strange pattern created by the two filters at the AOI of 0 degree. Furthermore, we take images at some AOIs of the two filters in order to obtain the intensity ratios of the ghost beams to the main beam (Fig. 2), although it is a different configuration with the filters in the slit-jaw unit. The intensity ratio is less than 4% in every case, which is consistent with the expected value in our investigation of ghost images.

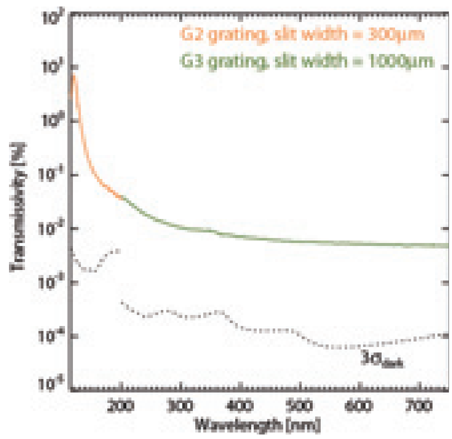

Fig. 1. Transmissivity of the 122-XN-1D filter.

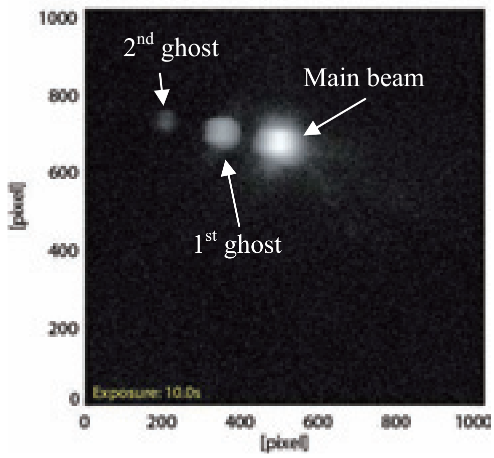

Fig. 2. Main beam and ghost beams created by two Ly-alpha filters at the AOI of 10 degree.

[1] R. Ishikawa *et al.*, ASP Conference Series, **287** (2011) 437.
[2] N. Narukage *et al.*, SPIE, **8148** (2011) 81480H.
[3] H. Watanabe *et al.*, SPIE, **8148** (2011) 81480T.

BL7B

Verifications of CLASP Polarimeter at an Oblique Incidence

R. Ishikawa[1], M. Kubo[1], D. Song[2], N. Narukage[3], T. Bando[1], R. Kano[1], T. Kobiki[1], S. Tsuneta[1] and H. Watanabe[4]

[1]*National Astronomical Observatory of Japan, Osawa, Mitaka, Tokyo 181-8588, Japan*

[2]*Department of Physics and Astronomy, Seoul National University, Gwanak-gu, Seoul 151-742, Korea*

[3] *Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency, 3-1-1 Yoshinodai, Chuo-ku, Sagamihara, Kanagawa 252-5210, Japan*

[4]*Kwasan and Hida observatories, Kyoto University, Yamashina-ku, Kyoto 607-8417, Japan*

A team consisting of Japan, USA, Spain, France, and Norway is developing a high-throughput Chromospheric Lyman-Alpha Spectro-Polarimeter (CLASP), which is proposed to fly with a NASA sounding rocket [1, 2]. CLASP will explore the magnetic fields of the upper chromosphere and transition region via the Hanle effect of the Ly-alpha line (121.567 nm) for the first time. This experiment requires specrtopolarimetric observations with high polarimetric sensitivity (<0.1%) and wavelength resolution of 0.01 nm.

CLASP polarimeter consists of a rotating MgF_2 half-waveplate and MgF_2 polarization analyzers at Brewster's angle [3]. The linear polarization in the Ly-alpha line is measured as the intensity modulation by the rotation of the waveplate. The CLASP polarimeter is located in the converging beam with a cone angle of 3-4 degree. Due to the oblique incidence, the retardation angle (δ) of the half-waveplate slightly deviates from 180 degree. As to polarization analyzer, the purity of s-polarization is reduced and the direction of s-polarization slightly rotates from that for a normal incidence. These effects will appear on the modulation patterns.

We developed a prototype of the CLASP polarimeter in 2010 [4] (Fig. 1). In this time we verified its response to an oblique incidence at the UVSOR BL7B. Using a MgF_2 plate mounted at Brewster's angle, we created a source beam which is highly linearly polarized in the horizontal direction, and the output signal was measured with a silicon photodiode or CCD camera. At a normal incidence, with the waveplate of δ=180 degree and the polarization analyzer at the Brewster's angle, the sinusoidal modulation must be observed as shown in Fig.2 (a). The minimum value in the modulation at a normal incidence is ~0 (comparable to the noise level) as expected [Fig. 2 (b)]. However, when we rotate the whole polarimeter by 3 degree horizontally, the minimum value becomes non-zero. This is due to the incident angle into the analyzer different from Brewster's angle and non-180 degree retardation angle of the waveplate. When we tilt the elevation angle of polarization analyzer by 6 degree (blue arrow in Fig. 1) without rotating the whole polarimeter, the phase is shifted by 3.7 degree from the normal incidence case [Fig. 2 (d)]. This is caused by the change of direction of s-polarization due to the oblique incidence to the polarizer.

Based on this experiment, we investigate the greater detail of the effect of an oblique incidence on the polarimetric observation with <0.1% accuracy, and refine the final design of the CLASP polarimeter.

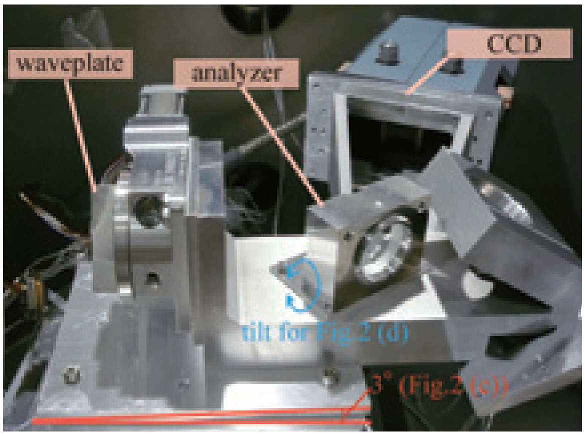

Fig. 1. Prototype of CLASP polarimeter.

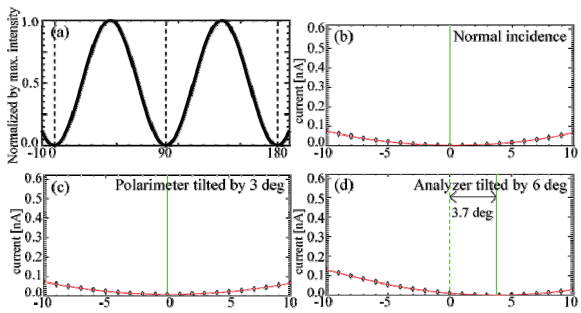

Fig. 2. (a) Ideal modulation in our experiment with normal incidence. Observed modulations around 0 degree at normal (b) and oblique (c, d) incidences. X-axis represents a rotation angle of the waveplate.

[1] R. Ishikawa *et al.*, ASP Conference Series, **287** (2011) 437.

[2] N. Narukage *et al.*, SPIE, **8148** (2011) 81480H.

[3] H. Watanabe *et al.*, SPIE, **8148** (2011) 81480T.

[4] H. Watanabe *et al.*, UVSOR Activity Report **38** (2010) 49.