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Abstract

The beamline BL7B at the UVSOR facility for solid-state spectroscopy has been opening for users after reconstruction. This beamline consists of a 3 m normal incidence monochromator and covers the spectral range from the vacuum ultraviolet to the infrared region. The optical configuration and the performance, such as photon number, purity and resolving power, are reported.

Keywords: Normal incidence monochromator; UVSOR; Beamline

1. Introduction

The beamline BL7B at the UVSOR facility is a dedicated beamline for solid-state spectroscopy, and has been reconstructed to provide sufficiently high resolution for solid-state spectroscopy, enough intensity for luminescence measurements, a wide wavelength coverage for Kramers–Kronig analysis, and the minimum deformation to the polarization characteristic of the incident synchrotron radiation for polarization measurements. It is also expected in the future that combined experimental systems are realized at the BL7B beamline, for example, with synchronization to the synchrotron radiation pulse or with the external magnetic field. The reconstructed BL7B mainly consists of a 3 m normal incidence monochromator which covers the vacuum ultraviolet (VUV), ultraviolet (UV), visible (VIS) and infrared (IR), i.e. the wavelength range 40–1000 nm, with three gratings and has been opening for users from April 1999.

The optical design and setup has been presented [1]. In this paper, the present performance of the BL7B beamline is reported.

2. Performance

2.1. Optical configuration

Fig. 1 shows the optical configuration of the reconstructed BL7B beamline which consists of four parts; pre-mirror system (M0, M1), 3 m normal incidence monochromator (modified version of McPherson model 2253) (S1, G, S2), post-mirror system (M2) and experimental area (Q1, Q2). All of the optical elements are on a vertical plane. The effective horizontal and vertical acceptance angles are 46.4 and 10.7 mrad, respectively. The beam spot size of the zeroth light at Q1 is about 3 mm (H) × 2 mm (V). The parameters of the optical elements are summarized in Table 1. There are three modifications from the original design study. One is the replacement of the elliptical mirror M1 by a toroidal mirror, because the figure error of the real toroidal mirror is better than that of an elliptical mirror. The countermeasure for the lack of overlap between the output spectra of the gratings G1 and G2 was carried out as the second modification, that is, the re-coating of the G2 surface from aluminum to gold. This re-coating makes the threshold of the G2 output spectrum shift to lower wavelength side by about 30 nm. The third one is a re-coating of the M_{22} surface from aluminum with MgF_2 to gold to permit experiments at lower wavelengths at Q2.

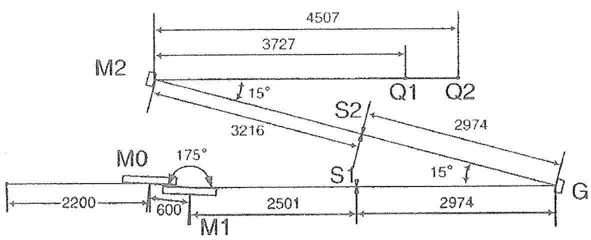

Fig. 1. Optical configuration of the reconstructed BL7B beamline.

2.2. Output spectra

Fig. 2 shows the output spectra of BL7B. A silicon photodiode (AXUV-100, IRD Inc.) was used for measurement, and the photon number was calculated from the quantum efficiency table for AXUV-100 photodiodes [2]. The slit widths of both entrance and exit slits are 0.5 mm (0.5–0.5 mm slit widths). The labels a to f represent output spectrum of G1 (a), G2 (b), G2 with a LiF filter (c), G3 with a quartz filter (d), G3 with a pyrex glass filter (e) and G3 with a colored glass cut filter (Toshiba Ltd. O-53) (f). All of these filter are located just before Q1 in Fig. 1. Under normal operation of UVSOR, the average beam current is more than 100 mA, so that the typical output photon number per second is in the range of

Table 1
Final parameters of optical elements

Pre-mirrors	Incident angle (deg)	Figure	Radius (mm)	Dimensions (mm × mm)	Coat material	Base material
M0	87.5	Plane	∞	700 × 140	Au	SiC
M1	87.5	Toroidal	60568 × 115.2	700 × 140	Au	SiO_2

Gratings	Incident angle (deg)	Figure	Radius (mm)	Grooves (mm^{-1})	Dimensions (mm × mm)	Coat material	Base material
G1				1200		Au	
G2	15	Spherical	3000	600	40 × 120	Au	SiO_2
G3				300		Al	

Post-mirrors	Incident angle (deg)	Figure	Radius (mm)	Dimensions (mm × mm)	Coat material	Base material
M21	7.5	Toroidal	3483 × 3348	120 × 120	Au	SiO_2
M22			3786 × 3633		Au	

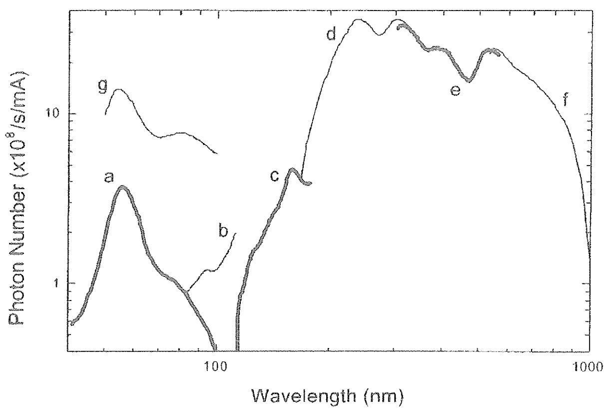

Fig. 2. Output spectra of the BL7B beamline. The slit widths of both entrance and exit slit are 500 μm. The labels (a)–(f) represent the output spectra of G1 (a), G2 (b), G2 with a LiF filter (c), G3 with a quartz filter (d), G3 with a pyrex glass filter (e) and G3 with a cut-on filter lower than 530 nm (f). The curve g shows the calculated output spectrum for G1.

10^8–10^9 and 10^{11}–10^{12} for 0.05–0.05 and 1–1 mm slit widths, respectively. The output spectra show their peaks at about 55, 160 and 230 nm for G1, G2 and G3, respectively. These spectral distributions are mainly determined by the reflectance of the optical elements and the efficiency of the gratings. The curve g in Fig. 2 shows the calculated output spectrum including the photon flux of the synchrotron radiation, the mirror reflectance [1], and the efficiency of the grating. The spectral shape of the real spectrum (a) is in agreement with that of the calculated one (g). The beam loss factor due to the two slits is estimated to be in the order of 10^{-1}. This suggests that the output intensity almost satisfies the design specification at least in the G1 region and the real efficiency of the grating G1 is close to the calculated efficiency ($\sim$40%) around the peak at 55 nm. Despite the mentioned re-coating of the G2 surface from aluminum to gold, the overlap between G1 spectrum and G2 spectrum seem to be still not enough.

In general, the reduction of the higher order light becomes important if a monochromator covers a wide wavelength region. As shown in Fig. 2, the required good spectral purity of the monochromated light is almost fulfilled over the whole spectral range by mean of the lower wavelength cut-off filters and the reflection thresholds of the gratings themselves. It is difficult to estimate the intensity of scattered light, but the transmission spectra at the absorption region of the filters indicate that the intensity of the visible scattered light can be expected to be less than 0.5% of the average output.

Fig. 3 shows a transmission measurement on molecular oxygen in a quartz windows gas cell at Q1. This spectrum was measured by means of grating G1 with 0.01–0.01 mm slit widths. The sharp lines in Fig. 3 are part of the Schumman–Runge bands. These bands have been well investigated [3], so that each line can be used for the wavelength calibration. The correlation between the experimental values and the reference data in the narrow range seen in Fig. 3 reveals that the wavelength accuracy at 95% confidence level is $\pm$ 0.02 nm. The similar test was carried out for a wider range. The absorption lines of xenon gas at 116.963, 119.204 and 129.559 nm [4] and those of benzene vapour at 252.9276 and 258.9667 nm [5] have been measured and the wide range wavelength accuracy is $\pm$ 0.06 nm. For the measurement shown in Fig. 3, the resolving power ($\lambda/\Delta\lambda$) was more than 8000. The measurements on xenon gas have been carried out using grating G2 and 0.04–0.04 mm slit widths, and $\lambda/\Delta\lambda$ was estimated to be about 3500 around 129.559 nm.

Fig. 4 shows a Fe_2VAl reflectance spectrum as an example of wide range measurements. The spectrum was obtained as the result of the

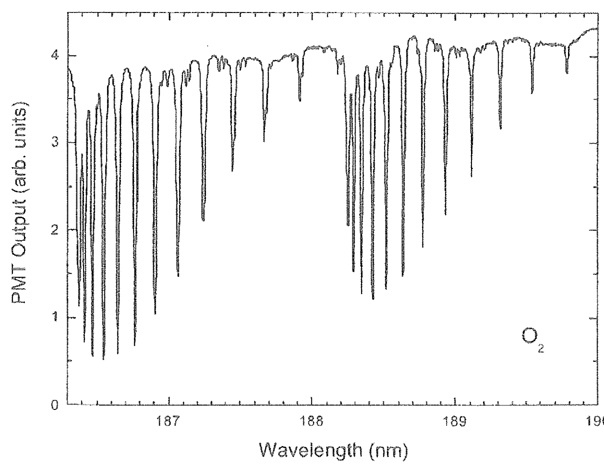

Fig. 3. Measured molecular oxygen transmission spectrum.

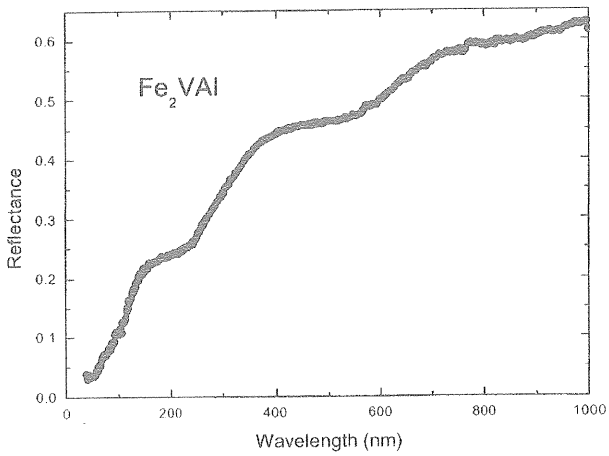

Fig. 4. Reflectance spectrum of a Fe_2Val sample.

combination of several measurements, in which the appropriate gratings and filters were used in the different wavelength regions shown in Fig. 2 to suppress higher harmonics. Details of the spectrum can be seen in Ref. [6].

The experimental setup at beamline BL7B allows for reflectance and absorption measurements, in which the sample temperature can be varied between 20 and 300 K. In addition, a second CCD monochromator with the full optical fiber optics is available for luminescence measurements with UV/VUV excitation and VIS/UV detection. Furthermore, the combination of BL7B with in situ type UV/VIS ellipsometer to measure highly reliable wide wavelength range optical constants is under construction.

3. Conclusions

The beamline BL7B at the UVSOR facility for solid-state spectroscopy has been reconstructed. This reconstructed beamline covers the 40–1000 nm range with three gratings and the average photon number per second of the monochromated light is in the order of 10^8 for ordinary reflectance measurements, and 10^{12} for excitation measurements. According to the combination with lower wavelength cut-off filters, the good purity of the monochromated light is almost fulfilled over the whole range, and the visible scattered light is suppressed to less than 0.5% of the average output. The resolving power is over 1000 for ordinary use and wavelength accuracy is better than 0.1 nm.

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