BL-12A/2024G112

Evaluation of second and third order diffraction of S-path, BL-12A, the Photon Factory above 600 eV

Tadashi HATANO*
International Center for Synchrotron Radiation Innovation Smart, Tohoku University,
2-1-1 Katahira, Aoba-ku, Sendai 980-8577, Japan

1 Introduction

In November 2024 the Photon Factory opened a new beamline BL-12A, which consists of the S-path with a diffraction grating monochromator and the T-path with a double crystal monochromator in parallel to cover soft X-rays over a wide wavelength region. The S-path is composed of mirrors at grazing angles of 1.5° or less covering up to 2 keV, which corresponds to the low energy limit of the T-path with Si(111) crystals. Since the beamline was designed to supply high throughput in the high energy region, spectral impurity due to second and higher order diffraction of the monochromator has been expected.

Quantitative analysis of higher order diffraction of beamline monochromators can be easily carried out by means of multilayer reflectometry [2-5]. To evaluate second and third order light contained in the S-path soft X-ray beam above 600 eV, a Mo/C multilayer with a period thickness of 1.88 nm and a period number of 100 was fabricated. Reflectance measurements were performed around angles of incidence between 74-81°.

Purity-impurity ratio depends on the detector, as well as the source and the beamline optics. Measurements reported here were carried out using a photodiode AXUV100 coated with 250 nm thick Aluminum, which our research group usually use for efficiency measurements of diffraction gratings around 1 keV [6].

2 Experiment and Results

Multilayer reflectance was measured in θ-2θ scan mode. When the monochromator setting was at 2000 eV, multilayer reflection peak was found at an angle of incidence of 80.48° as shown in the upper line in Fig. 1. The label "m=1" means that the diffraction order of the monochromator was the fundamental. The obtained peak hight was 0.068. It must be an accurate peak reflectance measured in a higher order free condition. Then the monochromator setting was changed at 1000 eV. The θ-2θ scan measurement was done again in the same angle region. The result is shown in the lower line in Fig.1. A small peak due to the second order 2000 eV component was found. The label "1000 eV, m=2" means that the monochromator setting and the diffraction order are 1000

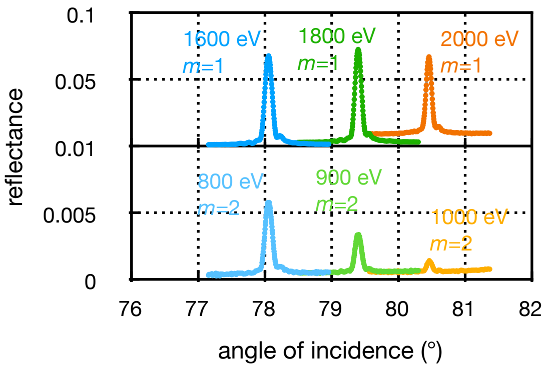

Fig. 1: Multilayer reflectances measured in the first and second order diffraction conditions of the monochromator.

eV and 2, respectively. The detected photon energy was the product, 2000 eV. The ratio of the peak reflectance to the true reflectance at 2000 eV gives the content ratio of the second order diffraction.

Similar measurements were done at 1200, 1400, 1600, 1800, 2200 eV and the half energies. No signal due to the

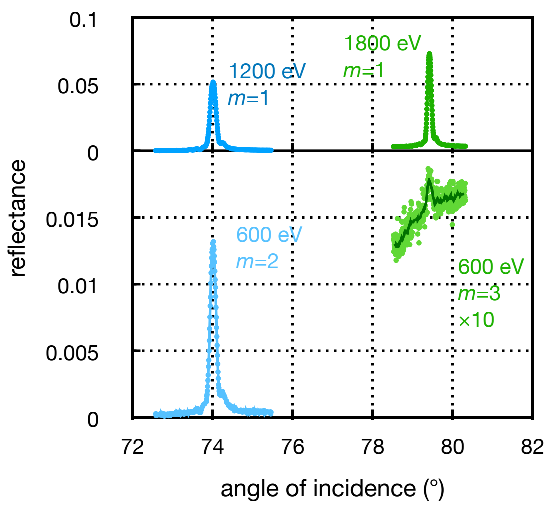

Fig. 2: Multilayer reflectances measured in the first, second and third order diffraction conditions of the monochromator.

second order diffraction was found when the monochromator setting was at 1100 eV and the energy of the second order light reached the M_5 absorption of Au, the mirror coating material.

At the monochromator setting of 600 eV, the reflection signal due to 1800 eV third order diffraction component was detected as shown in Fig. 2 with 10 times magnification. At 700 eV signal due to 2100 eV third order diffraction component was not detected.

Considering the detector is coated with Al, the content ratio of the second order diffraction could be expected to change across the half energy of the *K* absorption of Al. Therefore the similar measurements were done around that energy region. All measurements can be summarized as Fig. 3. Open circles mean the measured content ratio of the second and third order diffractions or spectral impurity factor.

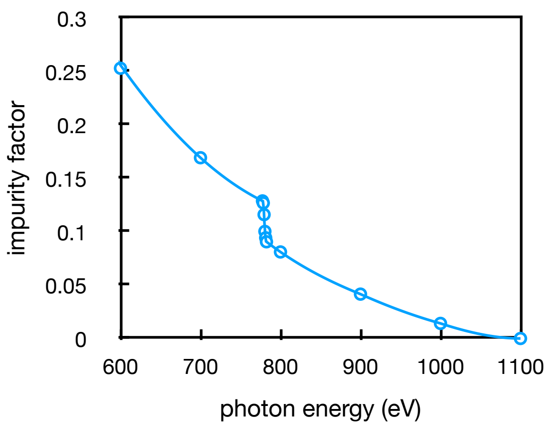

Fig. 3: Spectral impurity factor analyzed by means of multilayer reflectometry.

3 Discussion

The impurity curve shown in Fig. 3 makes it possible to divide monochromator output into the fundamental and higher order diffraction components. The thick curve in Fig. 4 shows the monochromator output spectrum from 650 to 850 eV. The total power *P* multiplied by the impurity factor F_i , $F_i \cdot P$ equals the power of second and third order diffraction. The thin curve in Fig. 4 shows the pure fundamental component power (1− F_i,)·P. A jump around 780 eV is not seen. This plot would make it clear that a jump of the total power around 780 eV should be caused by the Al *K* absorption of the second order light.

Obtained purity/impurity data can be used in mirror and diffraction grating evaluation experiments to estimate input power excluding impurity components. It should be noticed that the experiments with the different detector used needs the purity/impurity data with that detector.

.

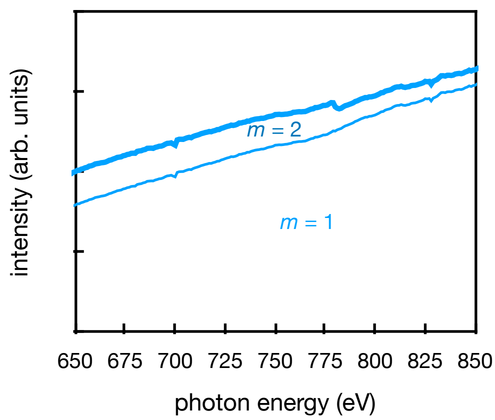

Fig. 4: Monochromator output spectrum divided into first and second order diffractions measured with a detector coated with Al.

References

[1] T. Ohigashi *et al.*, *13th Asia Pacific Microscopy Congress 2025*, Brisbane, February 2-7, 2025 (10.14293/APMC13-2025-0138).

[2] T. Hatano and T. Harada, *J. Electron Spectrosco. Relat. Phenom.* **196**, 156 (2014).

[3] T. Hatanoand T. Harada, *PF Act. Rep. 2016* #**34**, 276 (2017).

[4] T. Hatano, *PF Act. Rep. 2017* #**35**, 286 (2018).

[5] T. Hatano and T. Ejima, *PF Act. Rep. 2020* #**38**, 213 (2021).

[6] T. Hatano *et al.*, *PF Act. Rep. 2021* #**39**, 90 (2022).

* hatanotadashi@tohoku.ac.jp