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Micro-spot high resolution beamline of PLS: outside order SGM with moving entrance slit

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Abstract

A new design of spherical grating monochromator is proposed which uses the outside diffraction order and the entrance slit translation during the photon energy scan. This design has been studied by means of analytical calculation and ray-tracing. The resolving power of this monochromator is somewhat higher than that of DRAGON and the fixed exit slit allows the downstream refocusing mirrors to make a micro spot at the sample position.

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Keywords: Beamline; Spherical grating monochromator; NOGARD; Micro spot

1. Introduction

U10 undulator beamline, which will be constructed in Pohang Light Source (PLS) in Korea, is for micro-spot high resolution angle-resolved photoelectron spectroscopy. This beamline is specialized to measure the angle-resolved valence band spectrum at a small spot ($\leqslant 5\ \mu m$) with high energy-resolution. The core level measurement with soft X-ray beam will be performed for the same position of a sample. It is expected that additional core level measurements will clarify the chemical composition and bonding state of measured spot and eliminate the ambiguity of data analysis caused by the non-uniformity or inhomogeneity of sample surfaces.

As a monochromator of this beamline we selected a Spherical Grating Monochromator (SGM) because of its simplicity and reliability [1–4]. But to fix the object distance of downstream refocusing system, which is necessary in order to maintain the spot size below a few micro meters during photon energy scan, the exit slit should be fixed and the entrance slit translates. Similar type of SGM was proposed previously by F. Zanini et al. [4] and named as "NOGARD" to emphasize the fact their design is the reverse of DRAGON monochromator [1]. But our monochromator design is different from NOGARD in that we use the negative(outside) diffraction order to minimize the translation range of the entrance slit for a given energy tuning range, which makes the monochromator the real reverse of DRAGON.

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This solves the problem of the NOGARD design, which uses the positive diffraction order DRAGON [1,2], that high spectral resolution is difficult to achieve because of the restriction of the entrance slit moving range. In addition, the type of monochromator proposed here has better spectral resolution than the original DRAGON because of the intrinsic capability of reducing the primary coma of the grating.

2. Beamline layout

The optical layout of this beamline is shown in Fig. 1. This beamline is designed to have two beam paths in order to feed both highly energy-resolved EUV (Extreme Ultra Violet, from several eV to several tens eV) photon beam for the valence band photoemission experiment and soft X-ray beam with moderate resolution for the core level study. As shown in Fig. 1, the switch between two different beam paths is done by inserting or retracting a plane mirror PM1. The deflection angle of the gratings of low energy beam (10–100 eV) path is selected as 160° to make the maximum resolving power reach 30,000, which is sufficient for most valence band photoemission studies of condensed matter. The deflection angle of high energy beam (100–1000 eV) path is selected as 174° which is sufficient to maintain high transmission for this energy range with moderate energy resolution.

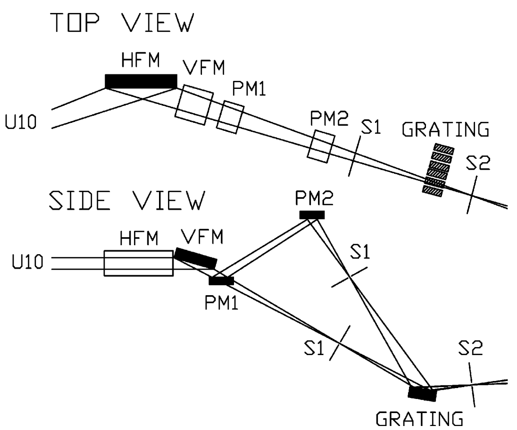

Fig. 1. The optical layout of U10 undulator beamline. This beamline has two beam paths.

The refocusing system of this beamline, which is not drawn in this figure, is a Kirkpatrik–Baez (KB) optic [5,6] which consists of two perpendicular elliptical mirrors. KB optic is advantageous in that it allows long image distance for electron spectroscopy, and the spot size and the transmission are well maintained for wide photon energy range.

As mentioned previously, the monochromator of this beamline is a particular one which uses the negative diffraction order of gratings and its entrance slit translates as the photon energy is scanned. Due to this mechanism, the ratio between two arm lengths is opposite to the conventional SGM and the exit slit arm length is by far shorter than the entrance slit arm length. Also, the bendable vertical focusing mirror is used to focus the beam into the entrance slit as the photon energy is scanned, while the horizontal focusing mirror focuses the beam onto the exit slit.

3. Optical design of the monochromator

For DRAGON type SGM [1,2], the entrance slit is fixed and the exit slit is translated to the focused image of the spherical grating. But due to the translation of exit slit DRAGON monochromator is not appropriate for micro-scale focusing with downstream focusing mirrors. In contrast to DRAGON, NOGARD monochromator [4] has a configuration that the entrance slit is translated instead of the exit slit. At first we considered this type of monochromator but its translation range is too large to be realized for the desired photon energy range with sufficient resolving power. But the choice of outside negative diffraction order makes it possible. In Fig. 2, the entrance slit movements between the positive order and the negative order are compared. The points represented with hollow circles are the points at which the Rowland circle condition is realized and the primary coma also vanishes. The energy scan range of a SGM should be around this condition and this figure shows clearly that the choice of the

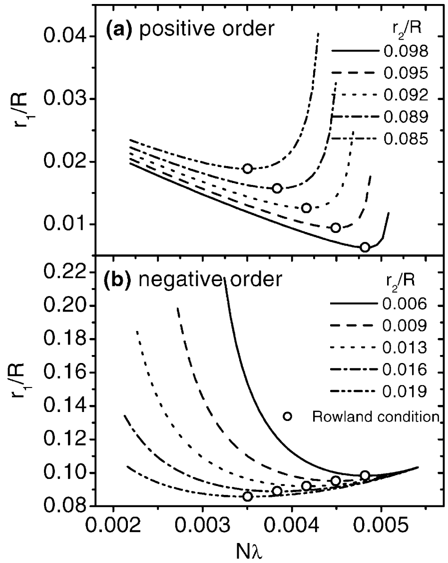

Fig. 2. The entrance slit movement of 174° grating as the monochromator's arm length ratio is varied. N is the groove density of grating, and r_1 and r_2 are the entrance and exit slit arm length, respectively.

negative order makes it possible to cover the wider energy range with the finite entrance slit moving length.

The entrance slit moving range is minimized by choosing a proper exit arm length, which is about 1 m for the grating with a radius of 55 m and a deflection angle of 174°. One may wonder whether such a short exit arm length makes the linear dispersion too small. But this value is in fact about the same as that of DRAGON. The linear dispersion is given by

$$\frac{\partial y}{\partial \lambda} = \frac{Nmr_2}{\cos\beta} = M\frac{Nmr_1}{\cos\alpha} \qquad (1)$$

where M is the magnification ratio of the grating. The value of the last expression is the same as that of the linear dispersion of positive order without M. The magnification ratio increases or decreases nearly linearly during the photon energy scan crossing 1 at the Rowland circle condition. So the linear dispersion is similar to that of a monochromator with long exit arm length. Rather, the longer entrance arm length makes the linear dispersion larger than that of DRAGON

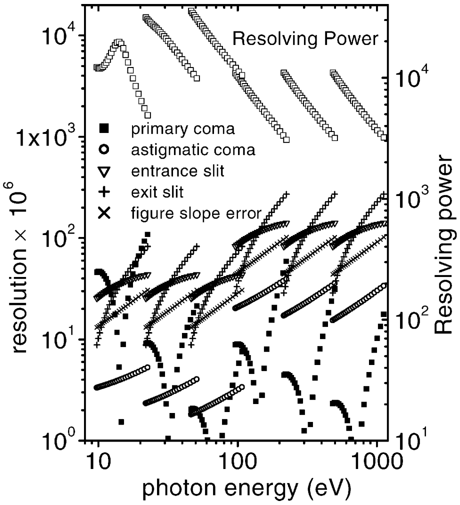

Fig. 3. The total resolving power and components of the energy resolution when the openings of both slits are 20 μm and the figure slope error is 1 μrad.

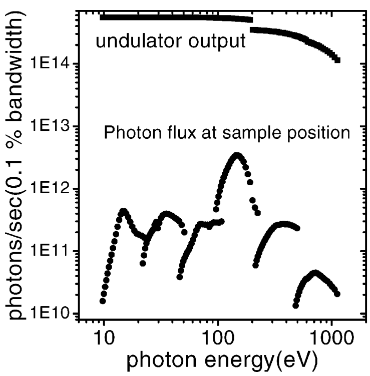

Fig. 4. Photon flux with the 20 μm entrance slit and the 20 μm ×100 μm ($V \times H$) exit aperture. The storage ring operation of the undulator parameters are as follows. Electron energy: 2.5 GeV, Ring current: 250 mA, U10 undulator length: 150 cm (15 periods).

and the more upright configuration of grating to the incident photon beam decreases the beam aberration by reducing the longitudinal beam size on it. So the transmission and resolving power of this monochromator is better than those of conventional SGM. The calculated 2σ resolving power and its resolution components are drawn together in Fig. 3, which shows the slit-width-limited resolution even with such a small value 20 μm. The calculated

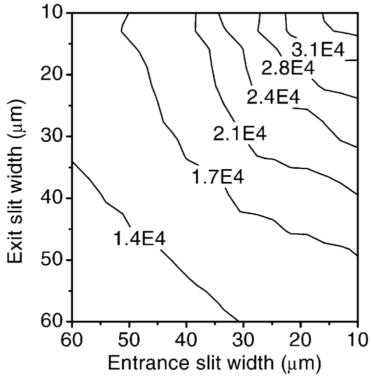

Fig. 5. Resolving power simulated by SHADOW for 15 eV photon beam as a function of entrance and exit slit widths.

photon flux at the sample position is also shown in Fig. 4 with typical storage ring operation parameters.

4. Ray-tracing result

The design of this beamline and the calculated performance are checked carefully and verified by ray-tracing with SHADOW [7]. As an example the dependence of the resolving power on both slit widths is checked by SHADOW as shown in Fig. 5. This figure shows the slit-width-limited resolution and the value at 20 and 20 μm slit-widths is well matched with the result from the previous analytical calculation.

5. Conclusion

The monochromator design of U10 undulator beamline, which may be characterized as the outside order NOGARD with fixed exit slit, is very unique and its theoretical performance has been shown to be better than that of previous SGM by both analytical calculation and ray-tracing program. So this monochromator is expected to be an excellent choice for the beamlines which are designed for high resolution microspectroscopy. U10 undulator beamline is now under construction in PLS and is scheduled to be commissioned in the middle of year 2002.

Acknowledgements

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