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Construction and performance test of SGM-TRAIN at UVSOR

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A new spherical-grating monochromator with translational and rotational assembly including a normal-incidence mount (SGM-TRAIN) has been constructed at BL5A of the UVSOR facility. The SGM-TRAIN is an advanced version of a constant-length SGM with the following improvements: (i) a wide energy range of 5–250 eV; (ii) a high resolving power; (iii) use of linear and circular polarization; (iv) reduction of second-order light; (v) two computer-controlled driving modes. Part of the performance tests are reported along with a detailed description of the design.

Keywords: monochromators; VUV; circular polarization; spherical gratings.

1. Introduction

The UVSOR facility is now on the way to renewal, and about one-third of the beamlines have been upgraded in recent years. At BL5A, a new monochromator called the SGM-TRAIN (spherical grating monochromator with translational and rotational assembly including a normal-incidence mount) has been constructed. The SGM-TRAIN is designed for experiments in which the circularly polarized synchrotron radiation from a helical undulator is used, as well as bending-magnet radiation. The SGM-TRAIN has the advantage that the small emittance of a storage ring and the large space requirements for a long beamline are not necessary. In this report, details of the design and part of the performance tests are described.

2. Design and ray-tracing calculations

The design of the SGM-TRAIN is based on the following requirements (Kamada *et al.*, 1995): (i) fundamentals from the helical undulator appear in the photon energy range 5–43 eV, with harmonic radiation being emitted up to 250 eV (Kimura *et al.*, 1996); (ii) the distance between the first pre-mirror and the sample position is limited to 8 m, due to the available floor space; (iii) the degree of circular polarization should be kept as high as possible; (iv) higher-order light must be suppressed; (v) bending-magnet radiation is used as well as undulator radiation; (vi) beam size and emittance in the vertical direction are 0.52 mm and 11.5π nm rad, respectively.

There are many types of monochromator mounts available, the choice of which depends on the photon energy, optical elements, mechanics, physical conditions, *etc.* A normal-incidence monochromator is the best choice for obtaining good circular polarization below 30 eV, whereas a glancing-incidence mount must be used for good polarization above 30 eV photon energy. Among many monochromator designs, a plane-grating monochromator, SX-700, designed by Petersen (1982), and a spherical-grating monochromator, DRAGON, designed by Chen & Sette (1989), are well known to have a resolving power higher than 1×10^4. However, these mounts are not suitable for our case because of the above requirements (i), (ii), (iv) and (vi). Moreover, optical elements such as ellipsoidal mirrors and variable-line-spacing gratings are so expensive that we have chosen the mount based on a spherical grating.

The SGM-TRAIN is an improved version of a constant-length monochromator proposed by Ishiguro *et al.* (1989) and Senf *et al.* (1992). The SGM-TRAIN consists of two glancing-incidence mounts and a normal-incidence mount. The parameters of the main optical elements are given in Table 1, and the layout of beamline 5A with the SGM-TRAIN is shown in Fig. 1. Pre-mirrors, *B*M0 and *U*M0, are used for bending-magnet radiation and undulator radiation, respectively. Two post-mirrors, M31 and M32, are exchanged for normal- and glancing-incidence mounts, and the focus point is about 1.5 m from the post-mirror.

Ray-tracing calculations were conducted using beam parameters of the UVSOR storage ring and the program *SHADOW*

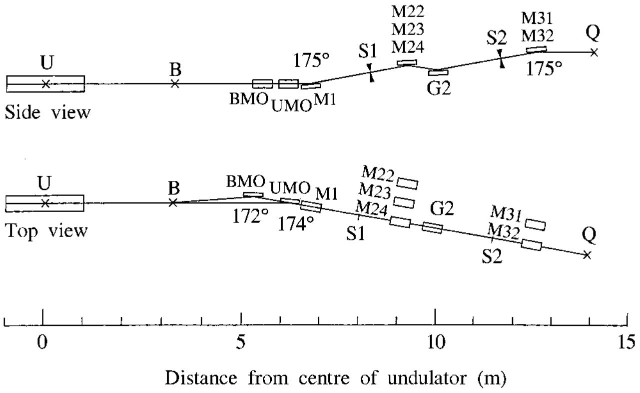

Figure 1
Layout of the SGM-TRAIN beamline. The undulator and bending magnets are shown by U and B, respectively. Note that the combinations with G1 and G3 gratings are omitted for simplicity.

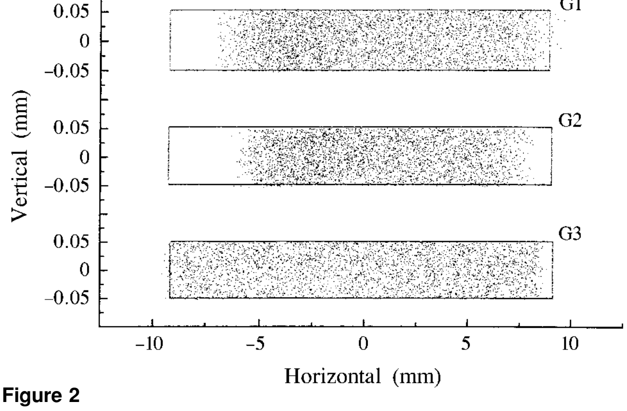

Figure 2
Ray-tracing calculations for bending-magnet radiation. Rays on an exit slit through an entrance slit of 0.1 mm are given for three gratings G1, G2, and G3.

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Table 1
Parameters of the main optical elements of the SGM-TRAIN.

Name	Shape	Coating	Angle (°)	Radius (m)	Dimension (mm)
BM0	Toroidal	Au	172	58.540 (ρ = 0.527)	310 × 25 × 25
UM0	Spherical	Au	174	181.607	340 × 25 × 25
M1	Spherical	Au	175	61.240	420 × 35 × 30
M21	Plane	Au	172		110 × 30 × 20
M22	Plane	Au	152		60 × 30 × 10
M23	Plane	SiC	152		60 × 30 × 10
M24	Plane	Al	152		60 × 30 × 10
M25	Plane	Pt	7		40 × 30 × 10
G1	Spherical	Au	172	25.406	110 × 30 × 20
G2	Spherical	Au	152	7.245	60 × 30 × 20
G3	Spherical	Au	7	2.549	40 × 30 × 20
M31	Toroidal	Au	175	26.090 (ρ = 0.164)	280 × 30 × 25
M32	Toroidal	Au	175	28.090 (ρ = 0.079)	280 × 30 × 25

supplied by CXrL, University of Wisconsin, USA. Fig. 2 shows the results for bending-magnet radiation at wavelengths of 50, 100 and 500 Å for G1, G2 and G3, respectively. The rays through an entrance slit of 0.1 mm are well focused on an exit slit for all cases, indicating good selection of the optical elements and their parameters (shown in Table 1).

Fig. 3 shows a drawing of the SGM-TRAIN. The distance between the entrance (S1) and exit (S2) slits is 3.5 m. Gratings and mirrors are installed in a grating chamber. The grating chamber with ion and getter pumps is driven along a guide lane to within an accuracy of 1 µm. The rotational motion of the gratings is realized by using a sine bar to within an accuracy of 1 × 10^{-5}°. Two types of scanning modes, the combination mode of rotation and translation and the rotational mode at fixed translational position, are available for the SGM-TRAIN, since all driving systems are directly controlled by computer.

3. Results of performance tests

Fig. 4 shows the photoelectric yield spectra of a gold mesh for bending-magnet radiation. The spectra 1–4 correspond to the combinations of G1M21, G2M22, G2M23 and G2M24, respectively. The gratings G1 and G2 cover the spectral range 30–120 and 80–500 Å, respectively. A dip at around 43 Å is due to the carbon *K*-absorption of the contamination on the mirrors and grating. The observed spectral distributions are mainly determined by the reflectivity of the optical elements and the efficiency due to the laminar profile of the gratings. In the case of the grating G1, the observed spectrum has a peak at around 80 Å. The efficiency due to the laminar profile is 40% at a peak of 50 Å, and the reflectivity including all mirrors is about 60% at a peak of 110 Å. Thus, a peak with an efficiency of 12% is expected at around 80 Å. The observed spectrum is in good agreement with the expected one. The photon flux at 100 Å with 0.1 mm slits is expected to be 1 × 10^{11} and 3 × 10^{11} photons s^{-1} for G1 and G2, respectively, but the observed values were three to four times less than the expected ones. This decrease in photon flux might be due to contamination on the mirrors and gratings, lower efficiency of the real optical elements, incomplete alignment of the optical elements, *etc.*

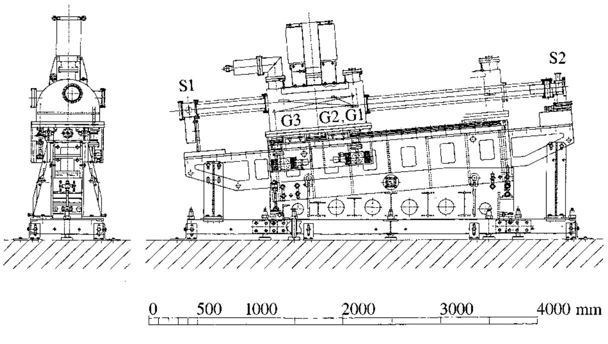

Figure 3
Drawing of the SGM-TRAIN.

Higher-order light presents one of the important problems common to monochromators covering wide energy ranges. We chose laminar profiles of the gratings and coating materials (Au, SiC, Al and Pt) on the plane mirrors in order to suppress the second-order light with a smaller decrease in the degree of circular polarization. As shown in Fig. 4, G1M21, G2M22, G2M23 and G2M24 are useful for spectral ranges 30–120, 80–200, 140–320 and 230–500 Å, respectively, where second-order light may be well suppressed.

Fig. 5 shows the doubly ionized spectrum of He at a pressure of 50 mtorr. The spectrum was obtained in the combination scanning mode with 10 µm slits and G2M22. Rydberg lines up to n = 11 are clearly observed, indicating a resolving power of about 4000 at 200 Å. A resolving power of about 3500 was also obtained

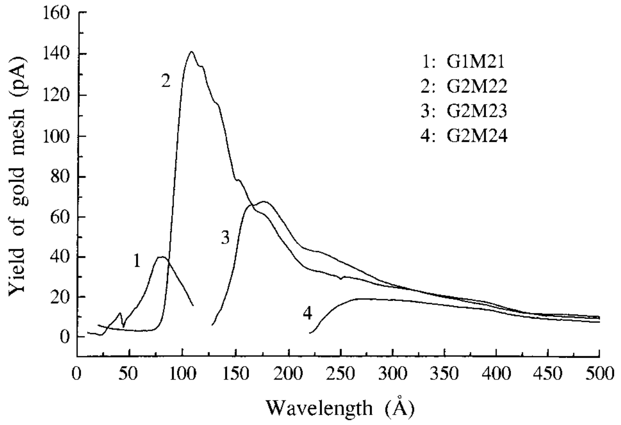

Figure 4
Photoelectric yield spectra of a gold mesh for bending-magnet radiation.

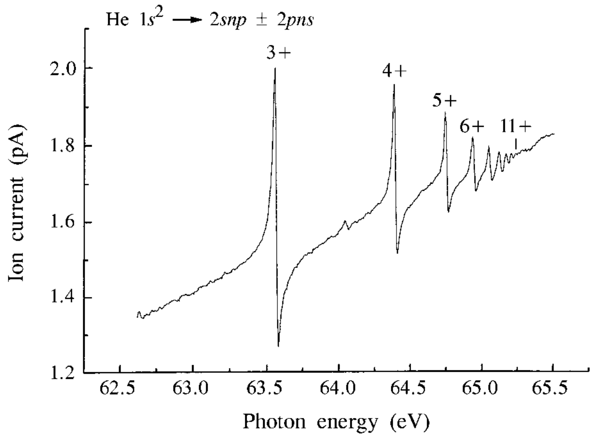

Figure 5
Ionization spectrum of He observed in the combination scanning mode of rotation and translation.

from the Ar $L_{\mathrm{II,III}}$ spectrum at 50 Å with the combination G1M21. These values are 20–30% less than the expected values (Kamada *et al.*, 1995).

4. Conclusions

In conclusion, a new monochromator, the SGM-TRAIN, has been constructed at BL5A of the UVSOR facility. A performance test was carried out for bending-magnet radiation indicating that the SGM-TRAIN is ready to use. Further testing and tuning of the SGM-TRAIN are requested in order to obtain better performance with circularly polarized light from a helical undulator, which was installed into one of the straight sections of the UVSOR storage ring (Kimura *et al.*, 1997).

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