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Title: Upgraded varied-line-space PGM beamline at CAMD

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Upgraded varied-line-space PGM beamline at CAMD

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Abstract

The Center for Advanced Microstructures and Devices'(CAMD) aging plane-grating soft x-ray monochromator beamline was upgraded to a varied-line-space plane-grating monochromator (VLSPGM) beamline. Preliminary measurements indicate significant performance improvements in both the resolving power and the throughput over its predecessor. However, it was found that the VLSPGM has less than the calculated resolving power. A possible reason is discussed.

07.85.Qe Synchrotron radiation instrumentation

Key words: synchrotron, beamline, plane grating monochromator

Introduction

The plane grating monochromator (PGM) beamline at CAMD [1] was commissioned in 1992. After serving over a decade, the PGM's performance no longer meets demands for critical modern research. This led to a strong demand for an upgrade to a higher performance beamline working over the 200 -1200 eV energy range. The PGM was a SX700-type monochromator [2]; the energy-scan mechanism included a translational/rotational plane premirror and a rotational plane grating, well suited for transformation into a Hetrick-type plane-grating monochromator design [3] in which a spherical premirror and a rotational varied-line-space (VLS) plane grating are utilized. Since the mirror and the grating chambers of the PGM were used with minor modifications, this transformation to a VLSPGM was inexpensive.

VLSPGM Beamline

A detailed description of the VLSPGM beamline design can be found elsewhere [4]. The beamline accepts radiation from a bending magnet (8 mrad horizontal). A pair of (sagittal and meridial-focusing) cylindrical mirrors is used to focus the beam vertically onto the entrance slit and to collimate it in the horizontal direction. This horizontal beam collimation (~30 mm in size) continues through the beamline until the beam reaches the focusing mirror which is located after the exit slit. The monochromator section is equipped with a spherical mirror and two plane-VLS (500 and 1000 gr/mm @ center) gratings manufactured by Jobin Yvon. The photon energy between 200 and 1200 eV is covered by the two gratings. After the exit slit, a toroidal mirror focuses the monochromatic beam at the sample position. The total length of the beamline is approximately 16 meters.

Displacement of optical components severely affects beamline performance, especially in the grazing-incidence condition utilized in the present design. Some displacement scenarios were analyzed by a ray-tracing program [5]. It was found that spectral resolution is very sensitive to the spherical mirror position. The simulation result is given in Fig 1a which shows a very rapid degradation of the resolving power once the spherical mirror is off-position from its ideal. Since the old PGM mechanism (where translational and rotational motions of the premirror are coupled) was utilized in the VLSPGM, we could optimize the spherical mirror position by adjusting only its translational position. This optimization was done by measuring total electron yield spectra of the oxygen 1s x-ray absorption edge of CuO. The relatively sharp peak at 530 eV was used for FWHM and intensity analysis (Fig. 1b). It can be seen from Fig. 1c that the optimal position of the spherical mirror provides not only the maximum resolution but also the maximum intensity, which is a clear indication of successful positioning. After the spherical mirror position was finalized, the same procedure was used for optimizing the beamline exit slit position.

Throughput

Measured beamline throughput from the VLSPGM is given in Fig. 2 together with that from the old PGM. In both beamline the flux was measured by using a GaAsP diode [6]. The preliminary ray-tracing calculation predicted two to five times better throughput from the VLSPGM over the old PGM, mainly due to the fact that the VLSPGM consists one less mirror than the PGM. In contrast to the calculated prediction, a much higher gain, nearly two orders of magnitude, was observed in the measured throughput from the VLSPGM. This indicates the existence of substantial carbon contamination on the old PGM optical surfaces, accumulating over a decade of operation.

Theoretical flux values at the selected photon energies for the VLSPGM are also given in Fig. 2. The calculation includes CAMD synchrotron source, beamline transmission, reflectivity of the gold-coated mirrors, and efficiency of the VLS grating calculated by the manufacturer. The measured throughputs are in reasonable agreement with the calculated values.

Resolution

Although theoretical resolving power of the old PGM was 3000, actual performance was substantially lower, ~1000 judging from the measured spectra. In the past this resolving power was adequate for experiments such as ultraviolet photoemission spectroscopy which the PGM was mostly used. New demand for NEXAFS spectroscopy at the facility requires a higher resolution beamline in the soft x-ray energy range. The VLSPGM was designed for the resolving power of 20000 – 8000 at photon energies from 200 eV to 1200 eV.

The resolving power of the VLSPGM was evaluated by measuring total electron yield spectra of N_2 ($1s \rightarrow \pi^*$) gas. From peak-width analysis (Gaussian and Lorentzian) of the N_2 vibration peaks, it was found that the resolving power is ~5000 for the high-energy (1000 gr/mm @ center) VLS grating. This is a great improvement over the old PGM, but lower than the theoretical value by a factor of four. Measurements were made to understand the cause of lower resolving power. In Fig. 3, the influence of the exit-slit tilt angle θ (rotation around the beam) on the resolution is shown. At the VLS monochromator, the beam is wide (30 mm) and collimated in the horizontal direction, a slight tilt of the exit slit (40 mm wide opening) to the beam plane can considerably reduce resolution. This effect is shown in Fig. 3 where a small angular deviation of 0.4° strongly deteriorates the spectral resolution. This suggests that it is critical to align all four monochromator optical elements, namely the entrance slit, spherical mirror, plane grating, and exit slit perfectly in order to achieve the maximum resolving power. Since the current monochromator chamber design does not allow adjustment of the spherical mirror tilt angle independently, it is quite difficult to obtain a perfect alignment. In conclusion, it is suspected that the wide horizontal beam and misalignment of the spherical mirror are possible causes for the degraded resolving power.

A polarization aperture providing right and left circular polarized beams from the bending magnet is scheduled to be installed in the front-end section of this beamline that will provide the opportunity to perform X-ray Magnetic Circular Dichroism (XMCD) spectroscopy experiments in the near future.

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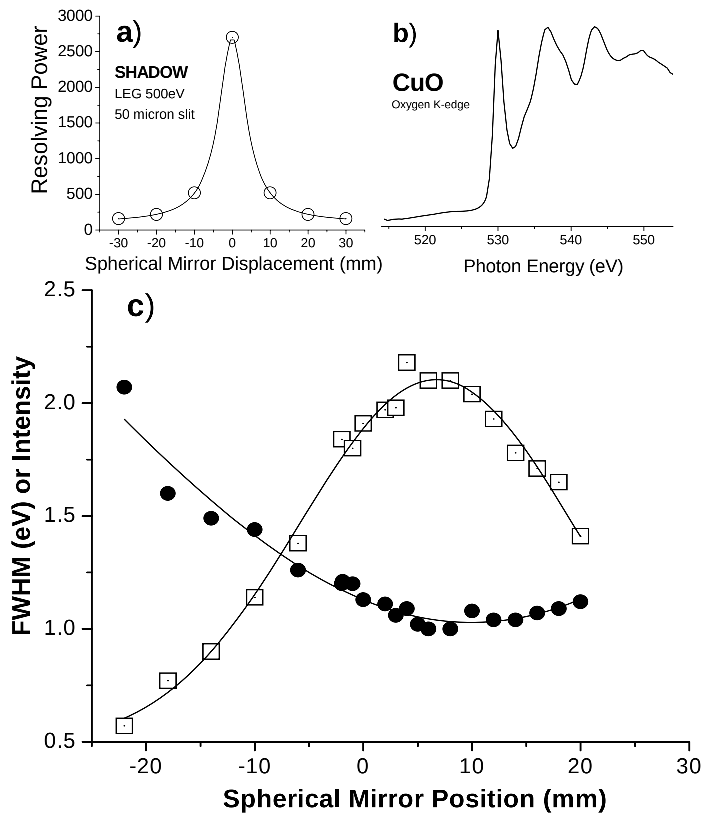

Figure 1

Optimization of the spherical mirror position, a) Spherical mirror displacement *versus* resolving power calculated by the ray-tracing program Shadow, b) CuO oxygen K-edge spectrum, and c) FWHM (solid circles) and intensity (open squares) of the 530 eV peak *versus* spherical mirror position.

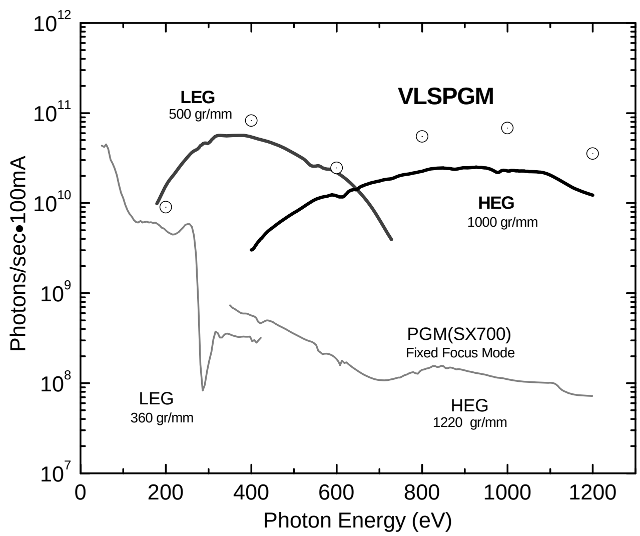

Figure 2

Measured (thick solid lines) and calculated (open circles) throughput from the VLSPGM beamline together with that from the old PGM (thin solid line). Both entrance and exit slits were set at 100µm.

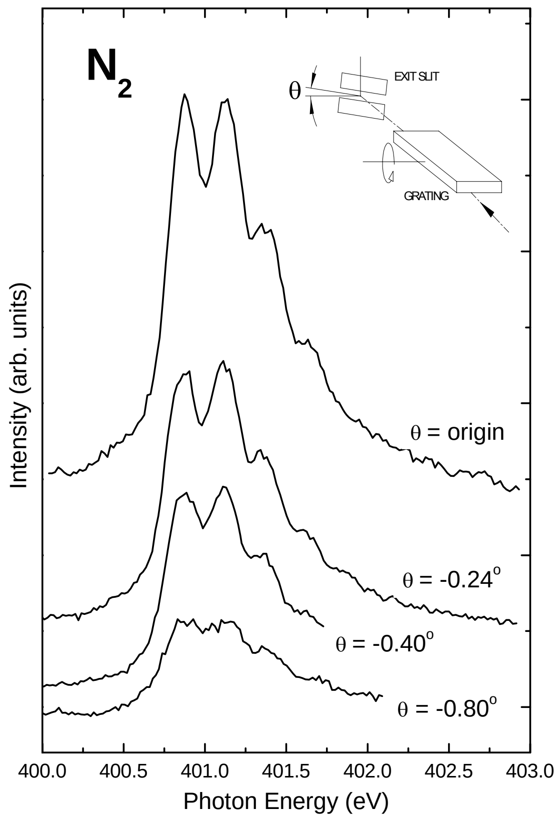

Figure 3

N_2 ($1s \rightarrow \pi^*$) gas total electron yield spectra measured at the different tilt angles of the exit slit.