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Diffraction efficiency of a 2400-lines/mm flat-field grating for spectroscopy of highly charged ion plasma emission in soft x-ray spectral region from 1 to 10 nm

Thanh-Hung Dinh[1], Yoshiki Kondo[1], Toshiki Tamura[1], Yuichi Ono[1], Goki Arai[1], Hiroki Oikawa[1], Shigeru Ohta[2], Ken Kitano[2], Takeo Ejima[3], Tadashi Hatano[3], and Takeshi Higashiguchi[1,*]
[1]Utsunomiya University, Yoto 7-1-2, Utsunomiya, Tochigi 321-8585, Japan
[2]Vacuum and Optical Instruments, 2-18-18 Shimomaruko, Ohta-ku, Tokyo 146-0092, Japan
[3]IMRAM, Tohoku University, 2-1-1, Katahira, Aoba-ku, Sendai 980-8577, Japan

1 Introduction

Interest in highly charged ion (HCI) spectroscopy has increased in the last decade due in part to the development of efficient and powerful extreme ultraviolet (EUV) and soft x-ray sources for applications in x-ray microscopy [1], diffractive imaging [2], absorption spectroscopy [3], and EUV lithography [4]. Laser-produced HCI plasmas are potentially suitable as laboratory scale high power sources, in which the use of intense unresolved transition arrays (UTAs), instead of discrete line emission, with reflective rather than transmissive optics has been proposed [5].

A flat-field grazing incidence spectrograph is a very convenient tool to study the soft x-ray emission from Laser Produced Plasmas (LPPs) or other sources. The dispersing optic is a concave reflection grating with varied line spacing between the grooves that was designed to image the spectrum on a flat plane instead of on the Rowland circle. However, the diffraction efficiency was only reported for the spectral range below 5 nm [6]. For HCI plasma research, LPPs of high-Z elements with Z = 60–83 produce intense UTA emission between 1 and 10 nm, whose peak wavelengths follow a quasi-Moseley's law [5]. The diagnostics of these plasmas requires spectral data, with reliable intensity information, of the emission involved over a wide range wavelengths, from which the plasma parameters such as ion charge state and temperature can be determined. However, the fact remains that the lack of a database for of the grating performance prevents the practical use of the 2400 lines/mm grating in the wavelength range from 5–10 nm.

2 Experiment

The diffraction efficiency of the 2400 lines/mm grating was measured by using the soft x-ray reflectometer installed at the BL-11D beamline of the Photon Factory (PF) at the KEK in Japan. The incident beam with a divergent angle less than 0.1° and a full width at half maximum (FWHM) diameter of approximately 200 μm was incident on the gating located at the center of the reflectometer chamber, as shown in Fig. 1. The angular profiles of the incident and diffracted beams were scanned by a detector, which consisted of an x-ray diode and a slit with a width of 100 μm. The distance from the grating to the detector was about 255 mm and was fixed due to the configuration of the reflectometer.

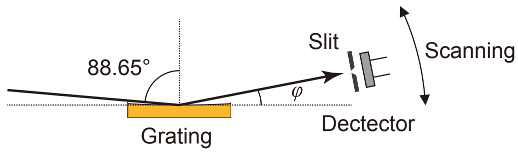

Fig. 1: Schematic diagram of the measurement of grating efficiency.

3 Results and Discussion

We measured angular profiles of the first, second and third orders at a wavelength of 3 nm, as shown in Fig. 2. On both sides of these profiles, the detected signal is close to zero, which implies that no scattered light from the grating could be observed. The grating efficiency is given by the ratio between the areas of under the incident profile and the diffracted profile.

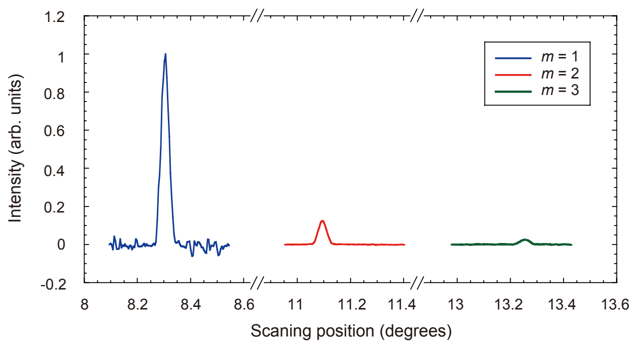

Fig. 2: The angular profile of the first, second, and third orders of the diffracted beam at a wavelength of 3 nm.

Figure 3 depicts the grating efficiency as a function of the incident wavelength. A first order diffraction efficiency exceeding 3% was observed for the wavelength region around λ = 2.75 nm and λ > 8.0 nm. The presence of a dip in the short wavelength region could be observed in both first- and second order spectra. These dips are caused by K-edge absorption of oxygen and carbon originating from hydrocarbon contamination on the surface of the grating. The evaluation of this effect is very important in estimating absolute photon flux in the water- and carbon-window spectral regions.

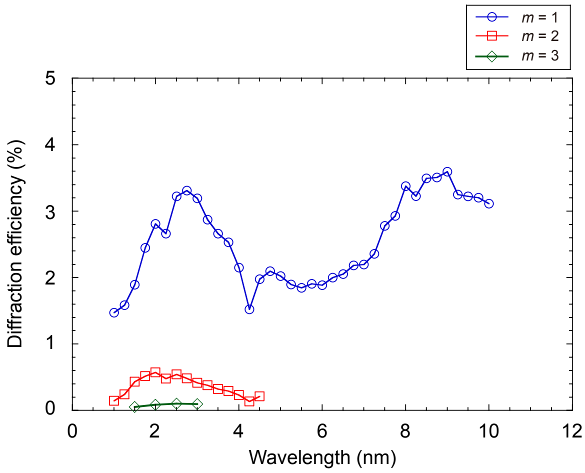

Fig. 3: The diffraction efficiency of the 2400-lines/mm grating.

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References

[1] A. Sakdinawat and A. David, *Nature Photonics* **4**, 796 (2010).

[2] P. A. C. Takman, H. Stollberg, G. A. Johansson, A. Holmberg, M. Lindblom, and M. Hertz, *J. Microscopy* **226**, 175 (2007).

[3] R. L. Sandberg, A. Paul, D. A. Raymondson, S. Hädrich, D. M. Gaudiosi, J. Holtsnider, R. I. Tobey, O. Cohen, M. M. Murnane, H. C. Kapteyn, C. Song, J. Miao, Y. Liu, and F. Salmassi, *Phys. Rev. Lett.* **99**, 098103 (2007).

[4] C. Peth, F. Barkusky, and K. Mann, *J. Phys. D: Appl. Phys.* **41**, 105202 (2008).

[5] H. Ohashi, T. Higashiguchi, Y. Suzuki, G. Arai, Y. Otani, T. Yatagai, B. Li, P. Dunne, G. O’Sullivan, W. Jiang, A. Endo, H. A. Sakaue, D. Kato, I. Murakami, N. Tamura, S. Sudo, F. Koike, and C. Suzuki, *Appl. Phys. Lett.* **104**, 234107 (2014).

[6] M. Koike, K. Sano, E. Gullikson, Y. Yoshihisa, and H. Kumata, *Rev. Sci. Instrum.* **74**, 1156 (2003).

* higashi@cc.utsunomiya-u.ac.jp