Evaluation of a flat-field grazing incidence spectrometer for highly charged ion plasma emission in 1−10 nm

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Abstracts: *A flat-field grazing incident spectrometer was built to investigate soft x-ray spectral structure and photon flux emitted from highly charged ion (HCI) plasmas in the spectral region from 1 to 10 nm. It consists of a flat-filed grating with 2400 lines/mm as a dispersing element and an x-ray charged coupled device (CCD) camera as the detector. In order to produce accurate intensity calibrated spectra of the HCI plasmas, the diffraction efficiency of the grating and the sensitivity of the CCD camera were directly measured by use of the reflectometer installed at the BL-11D of the Photon Factory (PF).*

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 (SXR) sources for applications. 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 transmission optics has been proposed. Ideally the UTA emission should lie within the reflectance bandwidth of a multilayer mirror. The in-band high-energy emission is attributable, in some cases, to hundreds of thousands of near-degenerate resonance lines lying within a narrow wavelength range. Despite the fact that ideally UTA emission cannot be resolved by a spectrometer, their spectroscopy plays an important role for further understanding of the processes occurring and the physics of high temperature and high energy density plasmas.

In the following article we measure the diffraction efficiency of the holographic fabricated grating with 2400 lines/mm for use in wavelength range from 1 to 10 nm. A flat-field grazing incidence spectrometer (GIS) is built for investigating the SXR emission from laser-produced HCI plasmas. The diffraction efficiency of the 2400 lines/mm grating and a thermoelectrically cooled back-illuminated x-ray charge coupled device (CCD) camera were 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. 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 225 mm and was fixed due to the configuration of the reflectometer. This allows for highly accurate spectroscopy of HCI plasmas. We also studied the calibrated spectra of Gd HCI plasmas which were produced by a 10-ns Nd:YAG laser. A maximum energy conversion efficiency of 0.6% was observed at a laser intensity of 3×10^{12} W/cm^2 by use of a calibrated GIS.