## L.7: Characterization of higher diffraction order contribution in a flat field grating spectrograph using high order harmonic radiation

Flat field grating spectrograph (FFGS) is most widely used diagnostics in extreme ultraviolet and soft x-ray region of electromagnetic spectrum. Variable line spaced (VLS) grating is a key element of FFGS, which disperses and focuses the x-ray radiation in a flat plane. The VLS grating diffracts the incident photons in various higher diffraction orders (m=1, 2, 3, 4...). For a polychromatic source viz. synchrotron radiation source and high order harmonic source, the spectral bandwidth of the source exceeds one octave, i.e., the wavelength λ, 2λ, 3λ are simultaneously present in the spectrum of the radiation source. This leads to an overlap of the first diffraction order of desired wavelength (λ) and higher diffraction (m =1, 2, 3...) order of its sub-multiple wavelengths (λ/2, λ/3 ...). This leads to an erroneous estimation of photon flux at desired wavelength (λ). It is therefore essential to determine the contribution of higher diffraction order in the radiation spectrum recorded by FFGS. We have carried out experimental measurement of higher diffraction order contribution (HDOC) in FFGS spectrum using high order harmonic source at wavelengths from 80 Å to 170 Å. The use of high order harmonic source has an advantage over other sources as it has a wide spectrum consisting of discrete wavelengths at odd harmonics of the fundamental radiation emitting simultaneously.

Figure L.7.1 shows the experimental setup used for measurement of HDOC using HHG source. High order harmonics were produced by focusing a 45 fs Ti:sapphire laser pulse in helium filled gas cell of 15 mm length. The generated harmonics were dispersed using VLS grating and detected on a MCP detector. The VLS grating has mean groove density of 1200 lines/mm, blazed at 3.2 degree grazing incidence, blaze wavelength 10 nm. The distance between slit to source was 235 mm and the focal plane distance from grating center was ~237 mm. The photon flux was measured in the first diffraction order using an AXUV photodiode (Make-IRD, Model:-AXUV-HS20).

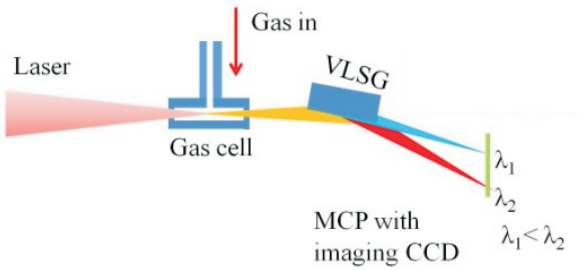


*Fig. L.7.1: Experimental setup for generation and detection of high order harmonic radiation from gas cell.*

The spectrograph wavelength calibration was done using an Al filter of ~ 750 nm filter inserted in the path of harmonic beam and the position of Al L-Edge (17.1 nm) was identified. The position of Al L-Edge closely coincides with 47$^{th}$ harmonic order of the Ti:sapphire laser having central wavelength of 800 nm. Once the 47$^{th}$ harmonic was tagged all other harmonic orders were identified, as only odd harmonic orders were present in the spectrum. The gas pressure and focal position of laser with respect to gas cell were optimized to obtain intense harmonic orders along with higher cutoff energy. At ~ 350 mbar gas pressures, the harmonics from 43$^{rd}$ to 99$^{th}$ orders were visible. The lower orders are absorbed in the cell at higher He gas pressure. At this optimum condition, the second and third diffraction orders of the harmonics were also visible.

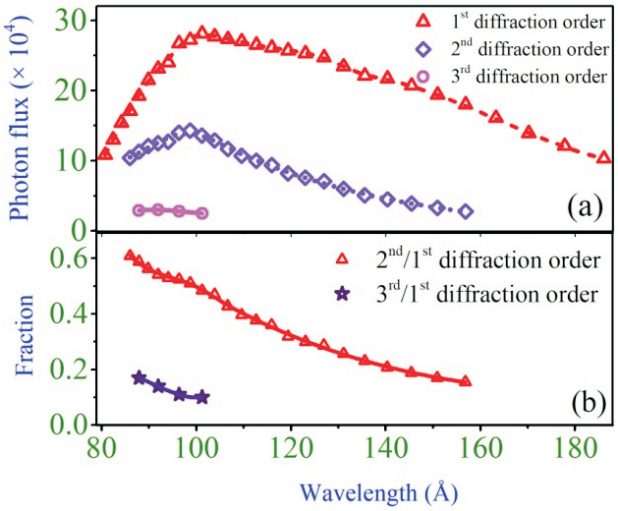


*Fig. L.7.2: (a) Photon flux in 1$^{st}$, 2$^{nd}$ and 3$^{rd}$ diffraction order and (b) fraction of photons in 2$^{nd}$ and 3$^{rd}$ relative to 1$^{st}$ order.*

Figure L.7.2(a) shows the measured photon flux of high order harmonics diffracted in first, second and third diffraction orders. From a) the fraction of photons diffracted in 2$^{nd}$ and 3$^{rd}$ diffraction orders relative to first order is calculated. It may be seen from Figure L.7.2(b) that the variation of fraction of 2$^{nd}$ to 1$^{st}$ diffraction order in the wavelength range of 85 nm to 170 nm is as high as ~60% at ~ 100 Å, and it reduces to ~ 15% at ~ 170 Å. Similarly, for the 3$^{rd}$ to 1$^{st}$ diffraction order, the fraction is relatively smaller and is ~ 20% at ~80 Å. It may also be seen from the Figure L.7.2 that the fraction varies non-linearly with wavelength. It is therefore highly desirable to know the contribution of the higher diffraction order to recorded spectra for correct measurement of the photon flux at a desired wavelength in case of a polychromatic source.

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