Monochromatizing a femtosecond high-order harmonic VUV photon source with reflective off-axis zone plates

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Application Note

Introduction

The development of ultra short coherent soft x-ray pulses paved the way for applications like diffraction microscopy of nanometer structures, ultrafast pump probe spectroscopy or the investigation of ultrafast atomic, molecular or magnetic phenomena. Of particular interest is high-harmonic generation (HHG). It is a small scale table top source providing ultra-short femtosecond light pulses in the VUV to XUV range. In this process a whole spectrum of distinct wavelengths is released concurrently in one beam. Many applications require this beam to be monochromatized and focused on a target. Here we investigate the optical properties (focal spot, diffraction spectrum, time dispersion and energy resolution) of a so called off-axis reflection zone plate (RZP) which meets these demands with only one optical element. To achieve this, the diffracted light was recorded with an Andor CCD camera.

Experimental Setup

The setup consists of a Ti:Sapphire laser driving the HHG process in a Xenon gas cell. The relevant harmonic spectrum generated in our experiment lies in the range between 15eV and 45eV with three prominent peaks at 20.4eV, 23.6eV and 26.7eV. Thus three RZPs were calculated for these energies and fabricated on a total reflection gold mirror on a silicium substrate. Each RZP focuses its designated energy at the same distance and spot. The RZPs were mounted on a manipulator for alignment and to switch between RZPs.

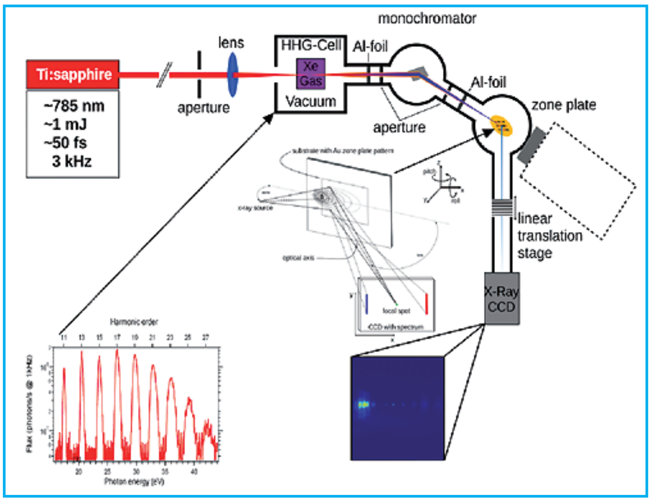

Figure 1: Experimental Setup

To image the resulting spectra and to investigate the optical properties we used the highly sensitive Andor x-ray CCD camera (Andor iKon-L DO936N-MW-BN). A high sensitivity was necessary due to the low flux of a single harmonic. A shutter connected to the internal trigger of the camera controls the beam and synchronizes it with data acquisition.

Results and Discussion

Basically an RZP uses the same principle like the classic Fresnel zone plate with two distinctions: it works in reflection mode (contrary to transmission of classic Fresnel zone plates) and its zone structure is not concentric but as if seen from an angle (here 30°) combining the dispersive properties of a grating and the focusing ability of the Fresnel principle. Figure 2 shows a typical diffraction spectrum of one of the RZPs and the magnified focal spot. The desired harmonic is focused on the CCD chip whereas the other harmonics are focused before the chip (higher harmonics) or behind the chip (lower harmonics) and thus appear blurry. The chip consists of 2048 x 2048 pixels each measuring 13.5 μm². Its big dimensions enabled us to see almost all spectral lines/spots without changing the orientation of the RZP. On the other hand the pixel size is small enough to measure reliably the spot size (100μm - 200μm) and the distance between harmonics to calculate the energy resolution and dispersion. By comparing intensities of the focal spot and the remainder of the spectrum a determination of the transmission efficiency can be done. Knowing the quantum efficiency and the exposure time we obtained an approximation of the photon flux of our RZP focused VUV light.

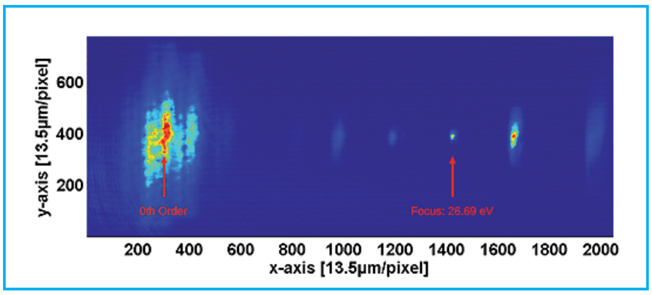

Figure 2: Full HHG spectrum diffracted by RZP (26.69 eV)

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