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Intense harmonic generation from various ablation media

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Abstract: Systematic investigation of ablation harmonics are performed for various targets, using the 40 mJ, 25 fs output from the Advanced Laser Light Source. Optimum pre-pulse and main pulse conditions for ablation harmonics are studied.

High-order harmonic generation (HHG) is a unique source of coherent extreme ultraviolet (XUV) radiation, which can produce soft x-rays within the spectral "water-window" (between 2.3 and 4.4 nm) [1], and ultimately short pulses with attosecond duration [2]. However, the intensity of present-day harmonics is still low, and serious applications will need an increase of the conversion efficiency. Instead of using gas media, one can also use ablation material, produced on solid targets using a low-intensity prepulse [3], as the nonlinear medium to generate high-order harmonics. Recently, we have successfully demonstrated the generation of up to the 63rd harmonic (λ=12.6 nm) of a Ti:sapphire laser radiation using boron ablation [4], and a strong enhancement in the intensity of the 13th harmonic from indium ablation [5]. These harmonics were generated with a modest laser (10 mJ, 150 fs) and with the pre-pulse to main pulse energy ratio constant. In this paper, we perform systematic investigations of ablation harmonics, using the 200 mJ, 30 fs Ti:sapphire beam line of the Canadian Advanced Laser Light Source (ALLS) facility. ALLS allows studying ablation harmonics over wider experimental parameters, and with independent control over the pre-pulse and main pulse energies.

The 10 Hz, 200 mJ Ti:sapphire beam line of ALLS is divided into two beams. Each beam has its own energy control system, which allows independent control over the energy of each beam. One of the beams is used as a pre-pulse for creating ablation, which is focused onto the solid target without pulse compression, with pulse duration of 200 ps. The second beam is used as the main pulse for harmonic generation. The main pulse is delayed in time relative to the pre-pulse by propagating through an optical delay line, and then sent through a pulse compressor. The compressed pulse duration have typical pulse duration of 30 fs FWHM, which is then focused onto the ablation medium using MgF_2 lens (f = 680 mm). The high-order harmonics were spectrally resolved using a flat-field grazing-incidence XUV spectrometer with a Hitachi 1200-grooves/mm grating. The XUV spectrum was detected by a microchannel plate with phosphor screen and recorded by a CCD camera.

Ablation harmonic experiments were performed with silver and indium targets. We selected silver because of its high conversion efficiency, and indium for its peculiar intensity enhancement effects of the 13th harmonics [6]. Due to the high intensities of the ablation harmonics, all harmonic spectra were obtained in a single shot. Experiments reveal that the pre-pulse condition for maximum harmonic generation is distinctly different for the two targets. Hydrodynamic simulations using the HYADES code [6] show that the high density of the ablation medium results in strong absorption of the generated harmonics. Therefore, the trade-off between high harmonic efficiency and high absorption is especially important in the present scheme, which can change significantly with the pre-plasma condition. Results with indium targets also reveal a distinct change in the ratio between the 13th and 15th harmonic intensity when varying the main pump intensity. This phenomenon is attributed to the change in the resonance conditions of the 13th harmonic with a strong radiative transition of the In^+ ion, due to the AC-Stark effect. We will also present new results on ablation harmonics using tin targets.

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