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# Numerical Simulation of High Harmonic Generation Using Liquid Flat-Jet Targets

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An intense laser pulse can create a thin plasma surface capable of reflecting the laser field, a phenomenon commonly referred to as a 'plasma mirror.' Within this plasma, electrons are influenced by the laser field, displaying oscillatory motion. At high laser intensities, the oscillatory electron motion becomes highly nonlinear due to the relativistic effects, resulting in the generation of high harmonics (HHG). Given the difficulty of directly measuring the ultrafast dynamics of electrons driven by such intense laser fields, a detailed analysis of HHG generation mechanisms has heavily relied on theoretical approaches. Two prominent generation mechanisms, Coherent Wake Emission (CWE) and the Relativistic Oscillating Mirror (ROM) model, explain these nonlinear phenomena. In this study, we present results from numerical simulations conducted using the particle-in-cell simulation code, Smilei. Our investigation focuses on assessing the influence of laser properties (intensity, beam shape, wavefront, and chirp) as well as plasma properties (scale length and thickness) on HHG from a liquid plasma mirror [1]. Our findings indicate that the amplitude of plasma oscillations increases linearly with laser intensity. Additionally, we observed that positively chirped pulses tend to generate HHG more efficiently in the CWE regime. Furthermore, adjusting the laser beam focus slightly away from the target surface leads to a reduction in the divergence of the harmonic beam. These results provide insights into identifying optimal conditions for maximizing HHG yield, thereby guiding the development of an intense attosecond light source in the EUV and X-ray wavelength range.

[1] Yang Hwan Kim et al., "High-harmonic generation from a flat liquid-sheet plasma mirror,"Nature Communications 14, 2328 (2023).

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