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高次高調波によるアト秒 X 線パルスの増幅
Amplification of X-ray attosecond pulses

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研究成果概要

Our research, spanning from 2018 to 2024, has focused on understanding ultrafast laser-matter interactions, particularly in the context of high harmonic generation (HHG) yield amplification. We have combined theoretical analyses, advanced numerical simulations, and experimental observations to explore fundamental nonlinear optical phenomena.

In 2024, we focused our theoretical and computational efforts to address key approaches for future experimental applications. We investigated the influence of waveplates on HHG spectra in helium by conducting initial simulations with 3D-TDSE to analyze polarization effects, though further refinements are needed. Significant efforts have been dedicated to exploring methods for producing shorter wavelength HHG, specifically targeting 6 nm for next-generation EUV lithography. Several approaches have been tested, including a pre-pulse ionization scheme to generate He+ ion channels by removing free electrons. These simulations calculated channel sizes and charge clearing dynamics, revealing challenges in achieving sufficient electron displacement within required timescales. While the potential for enhanced harmonic generation is evident, challenges related to high-intensity limitations require further investigation. Another promising approach involves trajectory simulations for proton-driven HHG using (HeH)+ molecules. This challenging approach, along with its theoretical feasibility, is under investigation.

To support these simulations, we are utilizing advanced numerical tools, including NWChem, Gaussian, and 3D-TDSE, to model ionization dynamics, harmonic generation processes, and beam profile effects. Benchmarks of pre-pulse and gas medium propagation scenarios were conducted to assess their feasibility for experimental realization. This work will culminate in detailed computational predictions for optimal experimental parameters, including laser intensities, gas pressures, and alignment conditions, providing crucial insights for experiments planned for 2025. The simulation efforts aim to refine the 3D propagation models to include complex ionization dynamics and circularly polarized driving fields.

Our progress in 2024 highlights the importance of combining computational insights with theoretical exploration to tackle the challenges of HHG at shorter wavelengths. These advances set the stage for significant experimental developments in 2025, reinforcing the critical role of continued supercomputer access.

Thank you for considering our application for supercomputer allocation in 2025.