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Strong-Field Control of Laser Filamentation Mechanisms

ROBERT LEVIS, DMITRI ROMANOV, ALESKEY FILIN, RYAN COMPTON,
Temple University — The propagation of short strong-field laser pulses in gas and solution phases often result in formation of filaments. This phenomenon involves many nonlinear processes including Kerr lensing, group velocity dispersion, multi-photon ionization, plasma defocusing, intensity clamping, and self-steepening. Of these, formation and dynamics of pencil-shape plasma areas plays a crucial role. The fundamental understanding of these laser-induced plasmas requires additional effort, because the process is highly nonlinear and complex. We studied the ultrafast laser-generated plasma dynamics both experimentally and theoretically. Ultrafast plasma dynamics was probed using Coherent Anti-Stokes Raman Scattering. The measurements were made in a room temperature gas maintained at 1 atm in a flowing cell. The time dependent scattering was measured by delaying the CARS probe with respect to the intense laser excitation pulse. A general trend is observed between the spacing of the ground state and the first allowed excited state with the rise time for the noble gas series and the molecular gases. This trend is consistent with our theoretical model, which considers the ultrafast dynamics of the strong field generated plasma as a three-step process; (i) strong-field ionization followed by the electron gaining considerable kinetic energy during the pulse; (ii) immediate post-pulse dynamics: fast thermalization, impact-ionization-driven electron multiplication and cooling; (iii) ensuing relaxation: evolution to electron-ion equilibrium and eventual recombination.

Robert Levis
Temple University

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