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Numerical Modeling of Intense and High Frequency Laser-Gas Interactions

In this communication we are interested in mathematical, numerical and modeling tools for ultrashort, high intensity and high frequency laser-matter interactions in dense gaseous media. These last 15 years, in this extreme regime, several new phenomena have been experimentally discovered (High Harmonic Generation, Filamentation, ATI), and will likely be very useful for practical applications in laser technology (virtual antennas, atmospheric applications, communications, dynamic imaging, etc). We have recently presented one of the first multiscale models and a corresponding numerical 3-D scheme for laser-gas interaction in this regime. The model involves the coupling of macroscopic non-homogeneous Maxwell's equations with Time-Dependent Schroedinger Equations (TDSE's). Indeed, in order to consider high order nonlinearities, the polarization, response of the gas to the electromagnetic field, is computed using quantum-level laser-molecule TDSE's; in contrast, perturbative nonlinear expansions are used in classical nonlinear Schroedinger models that do not model precisely important small scale phenomena and ionization. The complexity of the model requires the accurate computation in parallel of Maxwell's equations and thousands of 3D TDSE's.

In this contribution after a discussion on the mathematical modeling, we will present some recent numerical and mathematical results that involve in particular artificial boundary conditions for laser-molecule TDSE's and domain decomposition techniques for these multiscale Maxwell–Schroedinger equations. Coupling macroscopic Maxwell's equations with thousands of TDSE's necessitates the use of High-Performance Computers such as mammouth (`http://ccs.usherbrooke.ca`). Typical realistic simulations that will be presented with the actual code require several days on hundreds (up to 512) of processors and hundreds of GBytes of RAM.