**Efficient algorithms for multi-level ionization of**

**high-atomic-number gases and applications**

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An efficient numerical algorithm for multi-level ionization of high-atomic-number gases has been developed. It is based on analytical solutions to the system of differential equations describing evolution of ionization states [1]. The algorithm fully resolves multiple time scales associated with ionization processes coupled to electromagnetic processes of laser-plasma interaction. The effects of the orbital quantum numbers and their projections are also examined. The algorithm efficiency is improved by using a locally reduced system of differential equations. The multi-level ionization algorithm has been implemented in SPACE, a parallel, fully relativistic, three-dimensional particle-in-cell code [2]. In addition to Vlasov-Maxwell equation solvers, SPACE implements a novel, highly adaptive particle method for Vlasov-Poisson equations called Adaptive Particle-in-Cloud (AP-Cloud) that replaces the traditional PIC mesh with octree data structures. Verification and validation problems for the multi-level ionization algorithm in SPACE will be presented. The code has been applied to the study of ionization injection of electrons into laser-driven plasma wakefields. Comparison of simulations with BNL-ATF experiment on ionization-injection will also be discussed.

**References**

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