Towards Multi-Scale Models of Intense Laser-Plasma Interactions

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Intense, short-pulse laser-plasma interactions in the under-dense regime are of interest for number of technological applications, most notably, the acceleration of electrons and the production of high-quality electron bunches. Much of our knowledge of these systems come from numerical studies which can be quite computationally demanding. These systems possess three, widely separated time-scales: the laser period, the plasma period and the time scale of laser-pulse evolution. Applications such as particle acceleration require following the system over distances equivalent to some 10^5-10^6 laser periods. Removing this shortest time-scale has much attraction for the computational perspective. We will discuss the physics content and corresponding computational advantages (and disadvantages) of a class of reduced models where this time-scale has been removed. We will examine the range of validity of these reduced models by comparing to models that keep the full-time dependence. For example, in the laser-plasma accelerator case, the propagation distances of interest are so large, that small phase errors introduced in these reduced models build up and can become significant depending on the quantity of interest. We will end with some speculation on possible true multi-scale approaches.