Nonlinear physics of laser-irradiated micro-clusters

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Abstract

A nonlinear model has been developed to describe self-consistently electron response and ion acceleration in dense clusters that are smaller in size than the laser wavelength. This work is motivated by high-intensity laser-cluster interaction experiments [1]. The theory reveals that the breakdown of quasi-neutrality affects the cluster dynamics in a dramatic way. It produces an ion shell that expands quickly due to its own space charge whereas the central part of the cluster expands at a much slower rate under the thermal electron pressure. Another manifestation of non-neutrality is an anisotropy of the ion expansion. The developed model shows a natural trend for the electron population to have a two-components distribution function [2]: a cold core that responds to the laser field adiabatically and a halo that undergoes stochastic heating [3]. As the ion shell expands, the potential well for the electron core becomes more shallow, producing a leak of the core electrons from the cluster. The coherent response of the cold electron core to the laser field is very similar to that of a nonlinear pendulum driven by an external force. This analogy explains the enhancement of the third harmonic generation observed when the frequency of the applied field is close to 1/3 of the core eigenfrequency. It is essential that the ion background has to be non-uniform or non-spherical to produce a nonlinear electron response [4]. The key predictions of the model have been verified in 3D numerical simulations.

Research is supported in part by the NSF FOCUS center.

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