Radiation reaction in interactions between ultrahigh intensity laser fields and cluster media

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Abstract

With the development of ultrashort high power lasers, the laser intensity reaches to the regime of $10^{19\text{-}21}$ W/cm^2 where electrons irradiated by such lasers are accelerated to relativistic energies within a few laser period. The high intensity laser-matter interaction has opened up various innovative applications such as compact particle accelerators [1], fast ignition-based laser fusion, strong magnetic field generation in the level of kilo-tesla [2], and intense radiation and neutron sources. Higher intensities of $10^{22\text{-}25}$ W/cm^2, which are expected in near future [3], lead to new fields of high energy density science including laboratory astrophysics and nonlinear quantum vacuum physics [4]. In this regime, plasmas consisting of relativistic electrons and ions, intense radiations, strong magnetic fields and electron-positron pairs can be expected to be generated depending on state, structure and species of target materials irradiated by lasers.

As the material state, besides gas and solid, clusters have been interested owing to its unique interaction features with laser fields such as high energy absorption due to the large ratio of surface to volume, efficient ion acceleration by Coulomb explosion and laser field propagation by the cluster mode [5], which have so far been studied for the regime below 10^{20} W/cm^2. Today, higher intensities of 10^{22} W/cm^2 are becoming feasible. In this intensity level, the energy of radiations from electrons accelerated by the laser fields reaches to the range of γ-ray, and accordingly, damping of electron motion by the radiation reaction, i.e., radiation damping, becomes not negligible [6]. Since clusters exhibit strong interactions with laser fields, the radiation damping can be specifically important, and the interaction properties will be different qualitatively from those in the lower intensity regime.

Here, we study the effects of radiation reaction in the interaction between laser fields and cluster mediums i.e., mediums compose of multi-clusters, in the intensity regime of $10^{22\text{-}23}$ W/cm^2 using the particle-in-cell (PIC) simulation that includes the radiation reaction [7]. Intense radiation emission is found in the cluster media where electrons suffer from strong accelerations by both the laser field and charge separation field of clusters. As a result, the clustered structure increases the energy conversion into high energy radiations significantly compared with a uniform plasma at the expense of the conversion into particles. The maximum ion energy achieved in the interaction with cluster media is found to decrease through the radiation reaction into the same level with that achieved in the interaction with the uniform plasma. The clustered structure thus enhances high energy radiation emission rather than the ion acceleration in the considered intensity regime.

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