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# Radiation damping effects in the interaction of cluster mediums with ultraintense laser fields

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With the recent development of ultrashort high power lasers, the intensity of laser light is reaching to the regime of $10^{22-24}$ W/cm$^2$. Such intense laser fields can accelerate electrons to relativistic velocities within a few laser cycle period which results high energy radiation emission from the accelerated electrons in the energy level of gamma-ray. Accordingly, damping of electron motion by the radiation reaction becomes not negligible in the interaction dynamics [1].
Here, the state and/or structure of target material is a key ingredient in determining the interaction. Besides gas and solid, cluster and cluster medium, i.e., a medium composed of multi-clusters, are interested owing to its high energy absorption resulted from large ratio of surface to volume, unique optical properties, e.g., high harmonic generation and laser propagation via cluster polarization, and energetic ion generation via the Coulomb explosion of clusters [2]. These studies for laser-cluster interaction have been so far conducted mainly in the intensity regime under $10^{21}$ W/cm$^2$.
In our previous study, we investigated the fundamental interaction with lasers and ion acceleration process in cluster mediums in the laser intensity regime of $10^{22-24}$ W/cm$^2$ based on the fully-relativistic particle-in-cell code EPIC3D [3]. The effects of internal clustered structure were observed in the significant enhancements of energy absorption and maximum ion energy associated with the radiation pressure acceleration in the cluster mediums compared with a uniform solid foil.
Due to such a stronger interaction of ultraintense laser field with clusters than uniform plasmas, the effect of radiation reaction will be of specific importance in cluster mediums. Based on this idea, we here study the effects of radiation reaction to the interaction dynamics assuming cluster mediums with various cluster sizes irradiated by the laser of intensity regime $10^{22-23}$ W/cm$^2$ in the PIC simulation including the radiation reaction force [4]. By considering various cluster sizes with a fixed total mass, we found that the incident laser can penetrate into the cluster medium and accelerate a number of electrons inside of the medium that results higher energy conversion rate from laser to radiations. In the case of laser normalized amplitude $a_0 = 200$, around 35% of the input energy is converted to radiation loss in the cluster medium, which is significantly increased compared to the radiation loss rate of a spatially-uniform plasma. As a result, the energy absorption rate by electrons and then ions, which shows higher values in cluster mediums than the uniform plasma in the case where radiation reaction is not taken into account, is found to be reduced by the radiation reaction to the same level as that in the uniform plasma. Effects of the radiation damping of electrons to the ion maximum energy will be also discussed.

[1] A. Zhidkov et al., Phys. Rev. Lett. 88, 185002 (2002); J. Koga, Phys. Rev. E 70, 046502 (2004).
[2] Y. Fukuda et al., Phys. Rev. Lett. 103, 165002 (2009); T. Tajima et al., Phys. Plasmas 6, 3759 (1999); T. Ditmire et al., Nature 398, 489 (1999).
[3] N. Iwata, Y. Kishimoto, R. Matsui and Y. Fukuda, to be published in Proc. IFSA 2013.
[4] N. Iwata et al., to be published in Proc. 14th Symp. Advanced Photon Research.

## Summary

We study the effects of the radiation reaction to the interaction between cluster medium and laser field in the intensity regime of $10^{22-23}$ W/cm$^2$ based on the PIC simulation that includes the radiation reaction to electrons. By considering various cluster sizes with a fixed total mass, we found that the incident laser can penetrate into the cluster medium and accelerate a number of electrons inside of the medium that results higher energy conversion rate from laser to radiations. In the case of laser normalized amplitude $a_0 = 200$, around 35% of the input energy is converted to radiation loss in the cluster medium, which is significantly increased compared to the radiation loss rate of a spatially-uniform plasma. Effects of the radiation damping of electrons to the ion maximum energy will be also discussed.

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