Characteristics of radiation in non-equilibrium plasma produced by high intensity laser

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Abstract

The interaction between high power laser in the range of $10^{20\text{-}23}$W/cm^2 and high-Z structured material can lead to a high energy density plasma consisting of high energy relativistic electrons, multiply charged high-Z ions, strong fields with wide range of frequency from those of quasi-static and/or low-frequency electromagnetic fields, high intensity laser field including higher harmonics, strong X-rays and γ-rays resulting from various types of electronic transition from exotic atomic states, Bremsstrahlung, radiation reaction. Such a plasma, which we refer it as "*non-equilibrium extreme radiation plasma (NERP)*", is highly non-stationary and non-thermodynamic equilibrium and present a new class of material state where nonlinear process regulated by complex ionization and radiation process plays a key role. The exploration of such plasma, theoretically and experimentally, provide a new platform in studying extreme state in universe, e.g. magnetic turbulence, self-organization of magnetic field, particle acceleration, and also in exploring new application such as exotic nuclei acceleration and strong γ-ray source, etc.

In order to study such plasmas, it is of specifically importance to reproduce the interaction as precisely as possible by including both micros-scale physics, e.g. various kinds of ionization process and radiation process incorporated with quantum electrodynamics, and that of macro-scale, .e.g. long range kinetic dynamics of plasma over Debye length, but keeping self-consistency between them. For this purpose, we have developed a particle based integrated code, which includes key ingredients to reproduce the interaction between high power lasers and high-Z structured material specifically emphasizing on radiation model.

Here, we have introduced three kinds of radiation process to EPIC3D which are self-consistently incorporated with those of ionization and collisional relaxation. They are 1) K-α X-ray emission from radiative auger process associated with inner cell ionization of K-shell electrons and the generation of hole ion, 2) Bremsstrahlung resulting from collisional process between multiply charged ion and relativistic high energy electrons [1], 3) radiation reaction using classical and quantum models[2]. Incorporating with quasi-static and/or low-frequency component of electro-magnetic fields including those of laser and their higher harmonics, we can determine the spectrum of radiation in wide frequency range which is a key ingredient in studying the NERP. By using the code, we investigated the characteristics of NERP such as the emission energy and angle for each radiation process and the dependence of radiation efficiency coupled with the ionization process of high-Z target.

[1] W. Heitler, et al,. The Quantum Theory of Radiation Clarendon, Oxford, 1954
[2] Igor V. Sokolov, et al,. Phys.Plasmas, 18,093109 (2010)