Formation of power law electron energy distribution in picosecond interaction of relativistic laser and dense plasma

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High power lasers with relativistic intensities above 10^{18} W/cm^2 and pulse lengths exceeding picosecond (ps) have been developed in recent years. In over-ps laser-plasma interactions, energy slope of high-energy electrons tends to be higher than the scaling laws used in the sub-ps regime. One of the key mechanisms of such a superthermal electron generation is stochastic heating in a laser-irradiated thin foil, where fast electrons recirculate around and suffer multiple kicks from the laser field during the pulse duration [1]. The blowout of hot plasma towards the laser, which takes place under the ps laser heating [2], also enhances the multiple interactions of fast electrons with laser light. Understanding characteristics of the energy distribution resulted from the new accelerations arise in ps relativistic regime is essential for various applications for intense lasers. Furthermore, the stochastic acceleration by superthermal fields is related to the acceleration of cosmic rays which exhibit power law spectrum in high energy tail. For a non-relativistic laser interaction with underdense plasma, the electron energy spectrum is found to be a kappa distribution which becomes power law in high energy limit [3].

Here, we model the electron acceleration in the laser-thin foil interaction and study the resulting electron energy distribution based on the relativistic Fokker-Plank equation in momentum space. We introduce new diffusion and friction coefficients that represent the stochastic heating at the front side and the energy dissipation by the sheath potential trap at the rear side, respectively. We find that the steady solution of the Fokker-Plank equation becomes a power law when the diffusion by the laser kick is in proportion to the momentum p. This analysis can specify the origin of the power law formation, and provide an insight for further development of theoretical models for complex laser interactions in multi-ps time scale.

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