Semi-analytical model of electron heating during high-intensity laser/solid interaction

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Thirty years after the first articles, a quantitative understanding of the electron heating and acceleration induced by laser/solid interaction remains a daunting challenge, of interest not *only per se*, but also for the many related applications (ion acceleration, XUV-X-ray emission, isochoric heating, collisionless shock generation…). The plethora of absorption mechanisms identified over the past decades testifies to the complexity at stake.

To gain new insight into this issue, we have developed a sophisticated 1D laser-plasma model [1-2] which provides a unified, self-consistent description of the so-called anomalous skin effect, Brunel effect and J×B heating. Within some assumptions, semi-analytical solutions of the laser and the longitudinal electrostatic field are derived, and found to match the results of 1D PIC simulations [3]. The evolution of test electrons in these field solutions reveals different heating patterns depending on the laser incidence angle, polarization, intensity and plasma density. For strong enough intensities, the electrons are trapped between the laser fields and the longitudinal electrostatic field. Due to the laser ponderomotive force, the position of the potential well oscillates along with the electron plasma surface, while its amplitude oscillates at the plasma frequency. Consequently, bunches of energetic electrons are produced, with a frequency determined by the electron plasma surface oscillations. At normal incidence, the main bunches are produced at twice the laser frequency and accompanied by weaker, plasma frequency-modulated bunches. For a p-polarized, obliquely incident laser beam, the bunch formation becomes far more complex owing to a competition between the aforementioned 2ω mechanism and the relativistic Brunel effect. A criterion for determining the prevailing mechanism is obtained. High incidence angles favor the relativistic Brunel mechanism: the main bunches are generated at 1ω, with weaker bunches modulated at the cyclotron frequency. The mean electron energy and laser absorption are computed against the plasma density and the laser parameters, and qualitatively agree with PIC simulations.

References

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