Laser driven electron acceleration in nanoscale grated targets

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Relativistic lasers interacting with solid target are able to produce photon, electron, and ion beams over a wide range of energies, opening the way for innovative experiments in different areas like nuclear fusion science, laser-based acceleration, and medical research. It was shown that the structured targets can enhance the laser absorption and thus the acceleration of electrons. Different target designs have been studied experimentally and numerically (e.g., see [1, 2, 3] and references therein). However, the details of the electron acceleration mechanism during the laser-target interaction is not yet understood. In this work, we study a relativistic laser interaction with a grated target both numerically and analytically, and clearly reveal the physics processes governing the electron acceleration.

The laser-target interaction is simulated with the relativistic particle-in-cell code EPOCH [6]. Simulation results show that, during the laser-target interaction, quasi-static electric and magnetic fields are developed in the gratings due to the laser induced electron extraction from the solid. These quasi-static fields promote electron acceleration in the laser field beyond the ponderomotive energy scaling [4]. We employ a 3/2-dimensional Hamiltonian approach [5] to investigate the electron dynamics in both laser and quasi-static electromagnetic fields and show that the electrons can be stochastically accelerated in these fields to high energies. It is shown that a residual between the quasi-static electric and magnetic field amplitudes is important for the electron acceleration as it can reduce the dephasing rate between the electron and laser. A good agreement between our semi-analytic model and numerical simulation results is found. The dependence of the maximum electron energy scaling on both laser and target parameters is given. Our findings can stimulate the development of new design of the structured targets.

References

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