Transition from the kinetic stage to the hydrodynamic stage during relativistic laser-solid interaction

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The work presents results of Particle-In-Cell modeling of relativistically intense ($\simeq 10^{18}$ W/cm^2) femtosecond laser interaction with a solid-state density aluminum target, performed with the open code Smilei [1] taking into account target ionization and particle collisions. Generation and propagation of an ensemble of fast electrons created as a result of relativistic $\mathbf{J} \times \mathbf{B}$ heating [2, 3] were analyzed along with the energy transfer from these electrons to the cold target material. Spatial profiles of mass density, particle temperatures and mean velocities were obtained. Their analysis shows that on the time scale of $\simeq 10$ ps the fast laser-induced matter flow transforms into a hydrodynamic shock wave with the characteristics closely matching the Hugoniot curve for aluminum. The plasma state at $t \simeq 10$ ps can therefore be used as the initial conditions for much less computationally expensive hydrodynamic modeling to describe the long-term ($\gtrsim 1$ ns) shock wave evolution and crater formation.
The work was founded by the Russian Science Foundation, Project # 26-19-00292, https://rscf.ru/project/26-19-00292/.

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[3] Gibbon P 2005 *Short pulse laser interactions with matter: an introduction* (London: Imperial College Press)