Efficient relativistic laser pulse absorption in a near-critical plasma

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Near-critical plasmas are promising media for the laser ion acceleration in high repetition rate systems because of their robustness and possibility of a volumetric heating. However, the physical mechanisms of an efficient collisionless laser energy absorption are not sufficiently understood. An efficient relativistic laser pulse absorption in a near-critical plasma due to the stimulated Raman scattering (SRS) was demonstrated in Ref. [1] by using high resolution numerical simulations with a Particle-In-Cell code. Because of the relativistic plasma transparency, the SRS is excited in the density above quarter critical density and it leads to the transfer of 70% of the laser pulse energy to electrons. This instability leads to an homogeneous electron heating all along the distance of propagation of the laser pulse through the plasma. The ions are efficiently accelerated at the plasma edges and can get near 30% of the initial laser energy. A simple model is proposed, which predicts the velocity of laser pulse propagation and the energy deposition.

The laser pulse propagation is accompanied by the formation of electromagnetic cavities. The process of cavity formation is studied in detail, and it consists in the following three steps. It is initiated by the modulational (Benjamin-Feir [2]) instability in the front of the laser pulse, which is split in a train of electromagnetic solitons. These solitons propagate inward, excite plasma waves in their wake, lose energy and are finally trapped in the plasma. These trapped solitons present seeds for the formation of density depressions. The depressions may develop into cavities, if they trap electromagnetic fields produced in the plasma. The cavities survive for a long time thanks to an equilibrium of the trapped field radiation pressure and the electron kinetic pressure at their borders. The cavities control the laser energy absorption, generation of acoustic solitons and acceleration of charged particles.

References

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