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Research Article

Macroscopic laser–plasma interaction under strong non-local transport conditions for coupled matter and radiation

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Abstract

Reliable simulations of laser–target interaction on the macroscopic scale are burdened by the fact that the energy transport is very often non-local. This means that the mean-free-path of the transported species is larger than the local gradient scale lengths and transport can be no longer considered diffusive. Kinetic simulations are not a feasible option due to tremendous computational demands, limited validity of the collisional operators and inaccurate treatment of thermal radiation. This is the point where hydrodynamic codes with non-local radiation and electron heat transport based on first principles emerge. The simulation code PETE (Plasma Euler and Transport Equations) combines both of them with a laser absorption method based on the Helmholtz equation and a radiation diffusion scheme presented in this article. In the case of modelling ablation processes it can be observed that both, thermal and radiative, transport processes are strongly non-local for laser intensities of 10^{13} W/cm^2 and above. In this paper simulations for various laser intensities and different ablator materials are presented, where the non-local and diffusive treatments of radiation transport are compared. Significant discrepancies are observed, supporting importance of non-local transport for inertial confinement fusion related studies as well as for pre-pulse generated plasma in ultra-high intensity laser–target interaction.

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1. Introduction

High-intensity laser ($\gtrsim 10^{18}$ W/cm^2) interaction with a solid target has been studied extensively in the last decades, experimentally and numerically. Even though the parameters of the main pulse can be finely adjusted, less attention is paid to accurate predictive analysis of the pre-pulses appearing in these experiments. In general, pre-pulses are inevitable precursors of high-intensity main laser pulses, where especially amplified spontaneous emission (ASE) contributes significantly. As a consequence, a pre-plasma is created in front of the target, which may affect the interaction of the main laser pulse by itself or by means of the caused disruption or deformation of the target. These effects have been observed and proved their significance in proton acceleration by irradiation of thin foils [1–3], fast-ignition schemes [4,5] and also interaction of fs-pulses with high-Z targets [6,7]. Moreover, a recent paper investigates the pre-pulse effect on a 10^{23} W/cm^2 peak intensity main pulse interaction [8].

This article focuses solely on the pre-pulse interaction with a solid target. A comparison is made as far as the material is concerned, where moderate-Z materials are represented by Aluminium and high-Z ones by Copper. Simulations for laser

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