A hybrid (ablation-expansion) model for low-density foams

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Low-density foams have a wide variety of applications in the fields of inertial confinement fusion and high energy density physics. However, direct simulations of laser propagation through a foam are difficult due to the large separation of scales, given by the necessity to spatially resolve the density differences in the foam microstructure. Unfortunately, low-density foams also cannot be modeled as a uniform material of an equivalent mean density as such results overestimate the propagation speed of the laser-driven ionization wave.

Recent interests in foam simulations led to the development of two-scale models [1,2], where a simplified interaction model is computed on the scale of an individual foam pore in addition to the conventional macroscale hydrodynamics. These models describe the laser-foam interaction in terms of volumetric heating and expansion of planar or cylindrical, wire-like foam microstructure. However, further analysis of laser absorption in sub-wavelength objects and detailed particle-in-cell simulations show that laser is being absorbed mostly at the surface of the overcritical elements and that ablation plays an important role in the overall dynamics. The mass ablated from the surface layer rapidly fills the empty space in the pores and creates a high-temperature, low-density plasma background. Moreover, it also carries away a significant portion of the absorbed laser energy in the form of ion kinetic energy.

We present a novel approach to the foam modeling that combines a self-similar expansion of cylindrical elements with a surface ablation by laser. In our microscale model, each foam pore is divided into two regions (central cylinder and outer plasma) with separate masses, densities and temperatures. The movement of the boundary between these two environments is controlled by the self-similar expansion while the mass transfer between regions is given by a stationary ablation model. Laser deposition is calculated according to the Mie theory for electromagnetic scattering on cylindrical particles. The proposed model is implemented in the PALE and FLASH hydrodynamic codes for laser-plasma interaction. The simulation results are compared to experimental data available in literature.

References

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