Hydrodynamic simulations of plasma devices for compact particle-accelerator applications

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Compact plasma-based particle accelerators are an exciting emerging technology that promise acceleration gradients well above the GeV/m level, orders of magnitude higher than conventional technologies [1]. The ability to characterize and manipulate the plasma conditions within plasma devices such as laser waveguides [2,3,4], plasma lenses [5], and plasma accelerator modules [6] is paramount to their development and optimzation.

We have recently implemented a two-temperature, quasi-neutral, single-fluid, non-LTE plasma model as a set of custom modules in the COMSOL Multiphysics software. In this study, we investigate the formation and evolution of key plasma structures on ns+ timescales in response to a) laser energy deposition, and b) an electrical discharge, using our COMSOL simulations. The former has applications to hydrodynamic optical-field-ionized (HOFI) channel formation, which has emerged as a promising method to create metre-long laser waveguides suitable for guiding tightly-focused laser pulses in a plasma [3]. The latter has applications to discharge laser-waveguiding, active plasma lensing of charged-particle beams, as well as to the tailoring and future high-repetition-rate operation of plasma accelerator modules [4,5,6].

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