Coherent scattering from ponderomotive-driven density perturbations for plasma diagnostics

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Single-shot coherent Rayleigh Brillouin scattering (CRBS) [1] is a four-wave mixing diagnostic technique already established in atomic and molecular gases. It involves two laser beams with the same polarization interfering in a medium. This interference produces an optical dipole potential trapping and pushing atoms and molecules to high-electric field locations due to the dipole force, generating an optical lattice. A third laser beam, with polarization orthogonal to that of the pumps, called the probe, is Bragg diffracted off from the optical lattice, producing a fourth wave, called the signal. The resulting CRBS signal is the summation of a Rayleigh peak due to the individual motion of the atoms and molecules, and two Brillouin peaks due to the bulk movement of the particles centered at the speed of sound. The CRBS signal is proportional to the pump and probe intensities, the square of the induced density perturbation and the polarizability of the particles. By scanning the relative frequency difference between the two pumps, the velocity distribution function of the sampled species can be recovered and thus thermodynamic properties such as translational temperature, density, polarizability [2] can be determined [3].

The application of coherent scattering from optical lattices in plasmas is an unexplored area of research with potential applications in plasma diagnostics. Here, we report on the progress of this matter.

LTPs consist of electrons, ions, and neutrals, thus electromagnetic forces and collision phenomena play an important role. Charged species experience the ponderomotive force, driving them towards regions of low-intensity electric fields. Additionally, ions and neutrals are affected by the dipole force, directing them towards areas of high-intensity electric fields. Currently, our focus lies in developing a model to analyze the dynamics of optical lattices with charged particles and neutrals. Figure 1 illustrates preliminary findings regarding the density perturbation of electrons and ions. The density perturbation has been obtained by solving the two-fluid plasma equations numerically, where ponderomotive forces, collision with neutrals, and a self-consistent electric field have been considered.

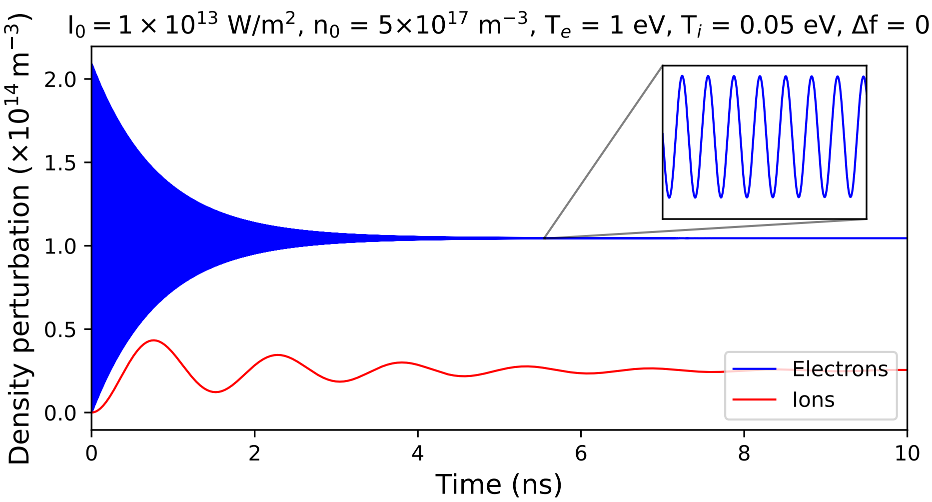

Fig. 1: Electron and ion density perturbation due to ponderomotive forces.

According to our initial findings, the enhanced density perturbations resulting from ponderomotive forces acting on electrons and ions suggest that scattering from these perturbations could provide a notable advantage for plasma diagnostics.

It is important to note that the hydrodynamic regime is used to study high-pressure gases in which Brillouin peaks are observable. At low pressures, in the kinetic regime, the neutral gas contributes mainly to Rayleigh scattering, but the Brillouin peaks do not always appear. In plasmas, scattering on charged particles is associated with Thomson scattering, and on collective periodic perturbations induced by ponderomotive forces - with coherent Thomson scattering.[4].

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