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Measurements of ion species separation in strong plasma shocks

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Shocks are important dynamic phenomena in inertial confinement fusion (ICF) and astrophysical plasmas. While the relationship between upstream and downstream plasmas far from the shock front is fully determined by conservation equations, the structure of shock fronts is determined by dynamic kinetic processes. Kinetic theory and simulations predict that the width of a strong (M >2) collisional plasma shock front is on the order of tens of ion mean-free-paths. The shock front structure plays an important role for overall dynamics when the shock front width approaches plasma scale lengths, as in the spherically converging shock in the DT-vapor in an ICF implosion. However, there has been no experimental data benchmarking shock front structure in the plasma phase. The structure of a shock front in a plasma with multiple ion species has been directly measured for the first time using a combination of Thomson scattering and proton radiography in experiments on the OMEGA laser. Thomson scattering of a 263.25 nm probe beam is used to diagnose electron density, electron and ion temperature, ion species concentration, and flow velocity in strong shocks (M ~5) propagating through low-density (ρ ~0.1 mg/cc) plasmas composed of H(98%)+Ne(2%). Within the shock front, velocity separation of the ion species is observed for the first time: the light species (H) accelerates to of order the shocked fluid velocity (450 microns/ns) before the heavy species (Ne) begins to move. This velocity-space separation implies that the separation of ion species occurs at the shock front, a predicted feature of shocks in multi-species plasmas but never observed experimentally until now. Comparison of experimental data with PIC, Vlasov-Fokker-Planck, and multi-component hydrodynamic simulations will be presented.