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Studying astrophysical collisionless shocks with high-power laser experiments

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Shocks in astrophysics are ubiquitous, occurring in supernovae, gamma ray bursts, and protostellar jets. In a broad range of low density astrophysical plasmas, the ion-ion collision mean free path is typically very large compared to the relevant spatial scales. Hence, when shocks form they are typically collisionless, resulting from plasma instabilities and self-generated magnetic fields. High power laser experiments can achieve the conditions necessary for the formation of collisionless shocks, allowing laboratory studies of this unique nonlinear physics. The experiments are aimed at probing the importance of the current filamentation (Weibel) instability and external magnetic field in collisionless shock formation. A series of Omega experiments have begun using high velocity interpenetrating plasma flows to create collisionless shocks. Single and double CH_2 foils have been irradiated with a laser intensity of $\sim 10^{16}$ W/cm^2. The laser ablated plasma was characterized 4 mm from the foil surface using Thomson scattering. A peak plasma flow velocity of 2,000 km/s, an electron temperature of $\sim$110 eV, an ion temperature of $\sim$30 eV, and a density of $\sim 10^{18}$ cm^{-3} were measured in the single foil configuration. Significant increases in electron and ion temperatures were seen in the double foil geometry. The measured double foil plasma conditions were used to calculate the Coulomb mean free path, $\lambda_{mfp} \sim 30$ mm, and the ion skin depth, $c/\omega_{pi} \sim 0.12$ mm, with an interaction length, L, of $\sim$8 mm. With $c/\omega_{pi} < L < \lambda_{mfp}$ we are in a regime where collisionless shock formation is possible. Experimental results will be shown and compared with simulations and theory. Planned follow-on NIF experiments will be described. Prepared by LLNL under Contract DE-AC52-07NA27344.