January 2011 Progress Report on the Laboratory for Laser Energetics

Inertial Confinement Fusion Program Activities

Thomson-Scattering from Direct-Drive Targets: The laser beams used to drive the capsule in a direct-drive experiment propagate through an underdense coronal plasma where they are susceptible to laser–plasma instabilities. To understand and mitigate the effect of these instabilities it is necessary to characterize the plasma conditions. The laser-intensity threshold for the onset of these instabilities must be taken into account in the design of fusion capsules and small variations in the plasma conditions can lead to large differences in the impact of these instabilities. In recent experiments at the Omega Laser Facility, a frequency-quadrupled (0.263-μm) laser beam was used to perform Thomson-scattering measurements of the plasma conditions of a target's coronal plasma. Figure 1(a) shows the scattering spectra obtained from two shots where a directly driven CH target was irradiated by a laser pulse consisting of three picket pulses followed by a main drive pulse.

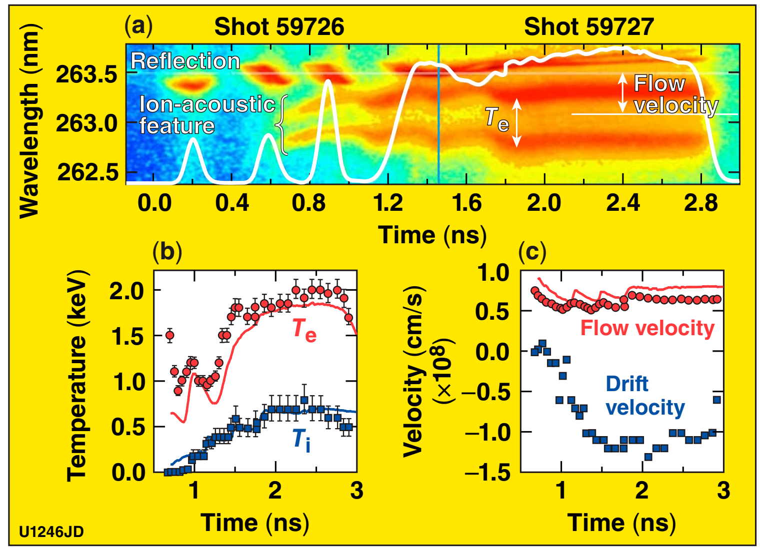

Figure 1. (a) Composite Thomson-scattering spectra collected from a volume 400 μm from the initial surface of a direct-drive fusion capsule at the Omega Laser Facility. The pulse shape of the drive beams is shown (white line). (b) The electron (ion) temperatures, (c) plasma-flow velocity, and the ion-to-electron flow velocity are determined from the ion-acoustic features observed in the Thomson-scattering spectra. The data are compared with hydrodynamic simulations that use a "nonlocal" heat-transfer model [red and blue solid curves in (b); red solid curve in (c)].

Nearly 0.7 ns after the initial picket illuminated the target, the plasma expanded to a distance 400 μm from the initial target surface and two characteristic ion-acoustic wave features were observed. The wavelength separation between these features is a function of the phase velocity of the ion-acoustic waves, which leads to a direct measure of the electron temperature shown in Fig. 1(b). Furthermore, the multiple ion-acoustic modes present in the CH plasma provide an accurate measure of the ion temperature. The light scattered from the ion-acoustic waves is heavily blue shifted as a result of the outward plasma-flow velocity [Fig. 1(c)], which, through conservation of momentum, drives shocks into the capsule. The ion-acoustic features also provide a measure of the relative drift between the ions and electrons near the phase velocity of the ion-acoustic waves [Fig. 1(c)]. This drift velocity is a reaction of the plasma to maintain quasi-neutrality as "fast" heat carrying electrons move outward and is related to the heat flux calculated in fluid simulations. The solid lines in Figs. 1(b) and 1(c) are from 1-D hydrodynamic simulations including a nonlocal heat-transfer model.

The spectral feature nearest the wavelength of the probe [top feature in Fig. 1(a)] is a result of light from the wings of the probe beam that is reflected from near the 3ω critical surface. The wavelength shift provides a measure of the changing path length along the probe beam, which incorporates the movement at the critical surface (i.e., Doppler shift). The intensity modulation is a result of absorption; between the pickets, the plasma rapidly cools and the probe light is absorbed.

The combination of these measurements provides a powerful set of criteria to assess the hydrodynamic models used to design direct-drive fusion experiments.

Omega Operations Summary: The Omega Facility conducted 178 target shots in January—132 shots on the OMEGA laser and 41 on OMEGA EP. The experimental effectiveness averaged 96.3% for the facility as a whole—96.4% for OMEGA and 96.3% for OMEGA EP. The NIC program accounted for a total of 80 target shots taken by experimental teams led by LLNL and LLE scientists. Forty target shots were taken for the HED program by scientists from LLNL and LANL. The LBS program accounted for 18 target shots for two experiments led by LLE and LLNL scientists, one NLUF team led by Rice University carried out 12 target shots, and the AWE conducted 28 target shots.

Contact: John M. Soures (585) 275-3866; fax: (585) 256-2586; e-mail: jsou@lle.rochester.edu