December 2014 Progress Report on the Laboratory for Laser Energetics

Inertial Confinement Fusion Program Activities

ShockSoundSpeed EP Experiment*: A material's equation of state (EOS) describes its response to high-pressure compression. Most EOS data are derived from shock-wave experiments that typically provide the "kinematic" portion of the Hugoniot. Recent experiments have shown that EOS models based mostly on Hugoniot data can incorrectly predict a shocked material's release behavior.[1] This is critical to shock timing and implosion dynamics for inertial confinement fusion (ICF) experiments. Measuring the sound speed provides knowledge of thermodynamic properties that affect the shape of the release curve and helps constrain the EOS for off-Hugoniot states.

The ShockSoundSpeed EP experiment measured the sound speed of shocked fused silica at pressures of 6 to 13 Mbar. The targets comprised a CH ablator on a solid quartz base plate with 250-μm-thick samples of fused silica and quartz (the reference material) attached as shown in Fig. 1. These targets were designed to produce modulations in pressure over the duration of the laser pulse. The shock velocity in the fused silica and quartz were measured using velocity interferometer system for any reflector (VISAR). By comparing the arrival time of the pressure modulations (seen as velocity modulations) in the two materials, the sound speed in fused silica was measured relative to that of the quartz standard. This was done using the unsteady-wave correction model described by Fratanduono *et al.*[2] The method tracks these "acoustic disturbances" as they interact with features in the target, such as material interfaces, rarefaction fans, or shocks. The coefficients derived therein depend on the Mach numbers in the two materials, thereby providing a sound speed in the sample relative to the reference material. Separate absolute measurements of the sound speed in shocked quartz are used to calibrate the results in fused silica.[3] The measured sound speed in fused silica was found to be accurately described by the *SESAME* 7386 table (Fig. 2).

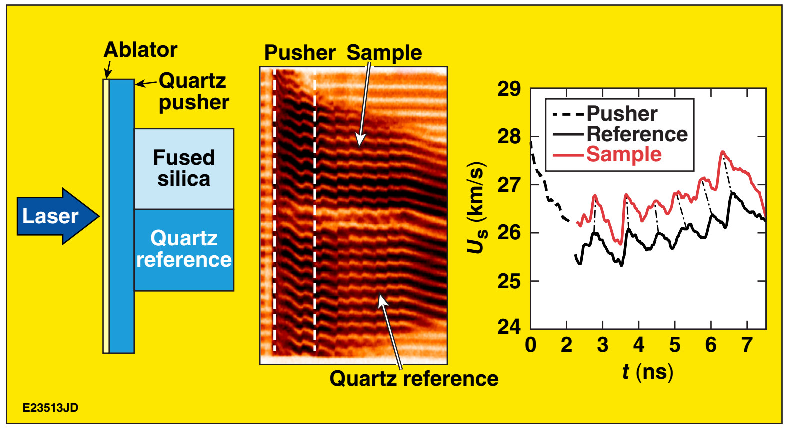

Figure 1. Schematic of target design and VISAR data showing arrival time of shock perturbations in a quartz reference and a fused-silica sample.

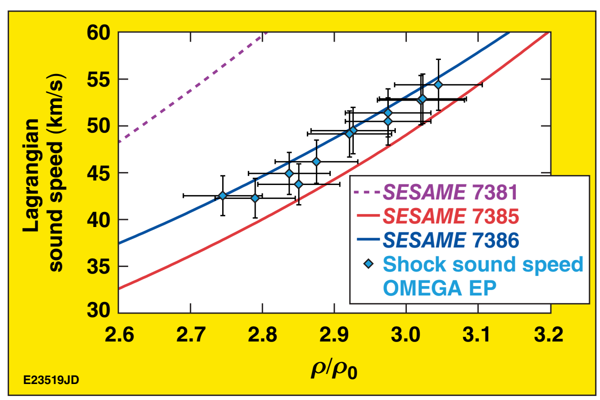

Figure 2. Experimental data from the ShockSoundSpeed EP experiment plotted against *SESAME* tables for single-crystal quartz (7381), polycrystalline quartz (7385), and fused quartz (7386) calculated from the initial density of fused silica.

These results show that the unsteady-wave correction produces accurate and precise measurements of the sound speed at high pressures relative to existing models. Future experiments will measure the sound speed in the plastic ablator material used in ignition targets.

***Omega Facility Operations Summary*:** The Omega Facility conducted 169 target shots in December 2014, with an average experimental effectiveness of 97%. Of these shots, 110 were conducted by the OMEGA laser (experimental effectiveness of 94.5%) and 59 shots were carried out by OMEGA EP (experimental effectiveness of 100%). The ICF program accounted for 47 target shots taken by LLNL and LLE-led teams; the HED program had 107 shots for experiments led by LANL, LLNL, and LLE; two LBS experiments led by LLNL had 15 target shots.

*The ShockSoundSpeed EP experiment is being carried out by Frank J. Horton Fellow Chad McCoy as part of his doctoral thesis research.

1. H. F. Robey *et al.*, Phys. Plasmas **19**, 042706 (2012).
2. D. E. Fratanduono *et al.*, J. Appl. Phys. **116**, 033517 (2014).
3. C. A. McCoy *et al.*, "Sound Velocity and Grüneisen Parameter Measurements in High-Pressure Quartz from Release into Near-Impedance-Matched Materials," to be submitted to Physical Review B.

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