Shocked-Silica Aerogel Radiance Transition

B. J. Henderson,[1,2] J. R. Rygg,[1,2,3] M. C. Marshall,[1] M. K. Ginnane,[1] L. E. Hansen,[4] E. Davies,[5] P. M. Celliers,[5]
and G. W. Collins[1,2,3]

[1]Laboratory for Laser Energetics, University of Rochester
[2]Department of Physics and Astronomy, University of Rochester
[3]Department of Mechanical Engineering, University of Rochester
[4]Sandia National Laboratories
[5]Lawrence Livermore National Laboratory

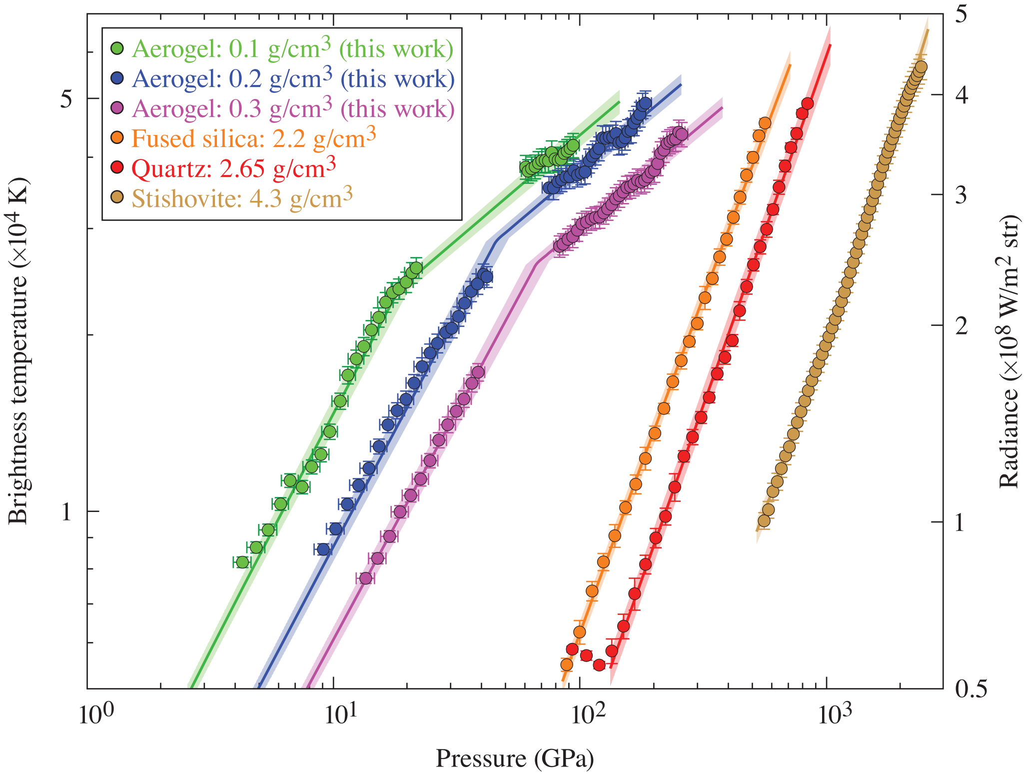
The objective of this work was to measure the radiance of shock fronts in SiO_2 aerogel at various initial densities. The optical properties of shock-compressed fused silica, quartz,[1] and stishovite[2] have been characterized and used as standards for temperature and reflectance measurements.[3] This work measures the optical radiant behavior of shock-compressed SiO_2 aerogel, which is expected to be significantly hotter, and thus brighter, at comparable shock pressures, than shock-compressed SiO_2 starting at solid density.[4,5] These measurements can be used to constrain radiative-hydrodynamics in inertial confinement fusion simulations of implosions using aerogel liners and to generate an optimally bright broadband source for high-energy-density–physics experiments.

Experiments were performed on the OMEGA EP Laser System. Targets were irradiated by one to four laser beams (λ = 351 nm) on a polystyrene (CH) ablator, producing strong shock waves that compress the planar samples. These experiments used laser irradiance between 10 and 200 TW/cm^2 produced by 2-, 2.5-, and 4-ns temporally square and ramp-top laser pulses with spatially uniform spot diameters of approximately 1100 or 1800 μm through the use of distributed phase plates. The targets were composed of a 40-μm CH ablator (refractive index n = 1.59 at λ = 532 nm, ρ_0 = 1.05 g/cm^3), a 50-μm quartz pusher (n = 1.547, ρ_0 = 2.65 g/cm^3), and a 250-μm SiO_2 aerogel sample (n = 1.02 to 1.06, ρ_0 = 0.1 to 0.3 g/cm^3). Shock velocity, reflectivity, and radiance were measured using a velocity interferometer for any reflector (VISAR) and a streaked optical pyrometer (SOP).

Brightness temperature of the shocked aerogel was determined by measuring the radiance of the shock front using the SOP. The SOP collects time- and spatially resolved thermal emission from the shock front integrated over wavelengths between 590 and 850 nm, with a peak efficiency at 600 nm. The SOP signal is converted to brightness temperature using an absolute calibration of the OMEGA EP SOP, which follows the procedure described in Ref. 6.

SiO_2 aerogel exhibits behavior that is starkly different from its higher-density counterparts (Fig. 1). Specifically, the exponent of the power law fit a is ~2 with no observed slope change for fused silica, quartz, and stishovite. For SiO_2 aerogel, a is 2 below the change in slope and ~1 above the change in slope. Below the change in slope observed in aerogel, the six T_{bright}–P curves for SiO_2 form a set of parallel lines. Some possible causes for this behavior include: (a) radiative precursor ahead of the shock, (b) a conductive precursor, and (c) shock propagation in aerogel microstructure.

This material was based upon work supported by the Department of Energy National Nuclear Security Administration under Award No. DE-NA0003856, the University of Rochester, and the New York State Energy Re-search and Development Authority. A portion of this work was performed under the auspices of NSF Physics Frontier Center Award No. PHY-2020249, and under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract No. DE-AC52-07NA27344.



E30172JR

Figure 1
Brightness temperature (and integrated radiance in the 590- to 850-nm band) versus inferred pressure for shock compressed SiO_2 aerogel (green, blue, and pink circles) and their two-part power-law fits (green, blue, and pink curves). Shaded regions represent 1σ confidence intervals. Measurements of fused silica (orange circles),[1] quartz (red circles),[1] and stishovite (brown circles)[2] are fit with a single power-law function (orange, red, and brown curves).

1. D. G. Hicks *et al.*, Phys. Rev. Lett. **97**, 025502 (2006).
2. M. Millot *et al.*, Science **347**, 418 (2015).
3. S. Brygoo *et al.*, J. Appl. Phys. **118**, 195901 (2015).
4. J. C. Boettger, Los Alamos National Laboratory NM, New Mexico, Report LA-11488-MS (1989).
5. Ya. B. Zel’dovich and Yu. P. Raĭzer, in *Physics of Shock Waves and High-Temperature Hydrodynamic Phenomena*, edited by W. D. Hayes and R. F. Probstein (Academic Press, New York, 1966), Vol. I, Chap. II, pp. 107–175.
6. M. C. Gregor *et al.*, Rev. Sci. Instrum. **87**, 114903 (2016).