Combined Laser Ultrasonics, Laser Heating and Raman Scattering in Diamond Anvil Cell System

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Abstract

There is widespread interest in the elastic properties of solids at elevated temperatures and high pressures. Much of the impetus for current research in this area has arisen from geophysical and geochemical studies of the Earth's mantle and core.
Laser ultrasonics (LU) combined with a diamond anvil cell (DAC) has been demonstrated to be an appropriate technique to directly determine the acoustical properties of solids under high pressure. In this report, we describe the development of a multi-functional system for high pressure, high temperature measurements. The system is equipped with a LU set up, Raman device, and laser heating system (LU-LH). Laser ultrasonics combined with LH in a diamond anvil cell (LU-LH-DAC) demonstrated to be an appropriate technique for direct determination of the acoustical properties of solids under high pressure and high temperatures. The use of lasers generating nanosecond acoustical pulses in solids allows measurements of the velocities of shear and longitudinal waves in iron up to 50 GPa. The system is unique and allows us to: (a) measure shear and longitudinal velocities of non-transparent materials under high pressure and high temperature (HPHT); (b) measure temperature in a DAC under HPHT conditions using Planck's law; (c) measure pressure in a DAC using a Raman signal; and (d) measure acoustical properties of small flat specimens removed from the DAC after HPHT treatment.

We present results on measurements of shear and longitudinal wave velocities in iron under high pressure up to 52 GPa, and of the behavior of the velocity of a Rayleigh wave in a PtRh alloy at high temperatures up to 1500 K. Finally, we demonstrate, for the first time, that the LU-LH-DAC technique allows measurements of velocities of the skimming waves in iron at 2580 K and 22 GPa. The ability to detect an LU signal at 2600 K was an unexpected surprise. The maximum intensity of the black body radiation at 2600 K is around 1.1 micron. This is very close to the wavelength of the pump laser (1.06 micron) used for the excitation of the acoustical waves in iron. Therefore, excitation and detection of the acoustical waves by the laser ultrasonics technique is possible even for very bright objects.

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