Toward Multi-Grain Brillouin Scattering

Miaki Ishii[1] & Raymond Jeanloz[2]
[1] Department of Earth & Planetary Sciences, Harvard University
[2] Department of Earth & Planetary Science, University of California, Berkeley

Quantitative Brillouin scattering requires single crystals, which restricts the types of samples and conditions under which experiments can be performed. If the single-crystal requirement can be removed, we can obtain acoustic properties of a greater variety of minerals and over much wider ranges of pressures and temperatures than now possible, including for samples and conditions relevant to Earth's deep interior.

The restriction to single-crystal samples arises from the limited polarization and experimental geometry considered in the theory of Brillouin scattering. In particular, the fourth-order Pockel's tensor that describes elasto-optic interaction, i.e., interaction of phonons with the probing light, is examined only under specific circumstances such as horizontal and vertical polarizations with respect to the plane defined by the experiment. In order to avoid this limitation, we have derived a generalized Brillouin scattering intensity equation that includes the effects of two 4th order tensors, the elasticity tensor and Pockel's tensor. In addition to the tensors, the equation depends upon polarization of the incident and scattered light, geometry of the experiment (the orientation of the sample crystal with respect to the directions of incident and scattered light), acoustic wavevector, indices of reflection for incident and scattered light, optical dielectric tensor, and frequency of the scattered light. This generalization of the theory provides a means of predicting results for multi-grain and powdered samples for comparison with experimental results.

For optically and elastically isotropic materials, we obtain a relatively simple analytical expression of scattered light intensity as a function of frequency. Using this expression, as well as the scattered light frequency that depends upon the experiment geometry, we demonstrate how the theory can be taken from single crystal analysis to multi-grain analysis. For the single crystal case, we confirm that the intensity calculated from our analysis is consistent with previous results, such as those of Born & Huang (1954) and Cummins & Schoen (1972). In particular, the Brillouin spectrum peaks at a frequency related to the experimental geometry and the acoustic wave speed of the sample. Our analytical expression also shows how intensity changes with experimental geometry and polarization, a dependence that is key toward considering multi-grain or powder samples. We assume that elastic scattering from grain boundaries alters the polarization and geometry of the probe beam in a multi-grain sample, and that inelastic scattering occurs only once before reaching the observer. Given the distribution of polarization and geometry (e.g., randomized geometry for powder samples), the intensity and scattering frequency can be integrated over that distribution to predict the peak shape and position for a multi-grain relative to a single-crystal spectrum.