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Hypersonic phononic crystals made of poroelastic spheres

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Abstract: Phononic crystals are composite materials consisting of a periodic array of objects (scatterers) with elastic properties (mass density, elastic wave velocities) different from those of the host medium in which they are embedded. This periodic modulation of the elastic parameters leads to the formation of regions of frequency, known as gaps, where elastic waves cannot propagate within the structured medium, whatever the direction of propagation; these composite materials behave as mirrors for the elastic waves, in analogy to crystalline solids where periodicity creates band gaps for the electronic states. Although frequency band gaps are their most known feature, phononic crystals can exhibit a plethora of interesting phenomena such as waveguiding, filtering, negative refraction, etc, which occur in a frequency range directly related to the scatterer size. In the last decade, self-assembly techniques allowed for the fabrication of colloidal crystals in nanoscale, thus leading to hypersonic phononic crystals operating at the GHz range, one of the most typical cases being silica spheres embedded in a water-like fluid. In this frequency range (up to 20 GHz) Brillouin Light Scattering experiments provide evidence that, at this scale, porosity in silica cannot be neglected [1,2]. For this reason, we shall be concerned with multiple scattering of acoustic waves in colloidal crystals of fluid-saturated porous silica spheres embedded in a fluid, involving study of the transition T-matrix for such a single sphere, after formulating the scattering in an appropriate vector spherical-wave basis. We discuss several physical models describing the effective viscosity present in the porous sphere [3] and provide a thorough analysis of the single-scattering based on density-of-state calculations [4]. Next, considering phononic crystals made of such spheres, we calculate the corresponding frequency band structure using layer-multiple-scattering techniques. For this purpose, the existing computer code MULTEL [5] is extended by incorporating the above-mentioned T-matrix.

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