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Normal Modes and Density of States of Disordered Colloidal Solids

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The normal modes and the density of states (DOS) of any material provide a basis for understanding its thermal and mechanical transport properties. In perfect crystals, normal modes take the form of planewaves, but they can be complex in disordered systems. I will show our recent experimental measurements of the normal modes, the DOS and dynamical structure factor (DSF) in disordered colloidal solids: disordered colloidal crystals composed of thermally sensitive micron-sized hydrogel particles at several different particle volume fractions, ϕ. Particle positions are tracked over long times using optical microscopy and particle tracking algorithms in a single two dimensional (2D) [111] plane of a 3D face-centered-cubic single crystal. The dynamical fluctuations are spatially heterogeneous while the lattice itself is highly ordered. At all ϕ, the DOS exhibits an excess of low frequency modes, a so-called boson peak (BP), and the DSF exhibits a crossover from propagating to non-propagating behavior, a so-called Ioffe-Regel (IR) crossover, at a common frequency somewhat below the BP for both longitudinal and transverse modes. As we tune ϕ from 0.64 to 0.56, the Lindemann parameter grows from $\sim$3% to $\sim$8%, however, the shape of the DOS and DSF remain largely unchanged when rescaled by the Debye level. This invariance indicates that the effective degree of disorder and the structure of the underlying normal modes remain essentially unchanged even in the vicinity of melting. This work was supported by NSF through grants DMR-0645596 & DMR-0619424, the Sloan Foundation and American Chemical Society Petroleum Research Fund.