Molecular picture of the transient nature of mesogenic domains

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The investigation of phonon excitations in soft and biological materials at the molecular scale has always been challenging due to limitations of experimental techniques in resolving meV vibrational modes. The understanding of collective mode behavior with a *Q*-dependence is the key to implement heat management based on the control of a sample structure. The latter has great potential for many energy-inspired innovations. As a first step toward this goal, we carried out high contrast IXS measurements on a liquid crystal (LC) sample, D7AOB, which exhibits solid-like dynamic features, such as the coexistence of longitudinal and transverse phonon modes. For the first time, we found that these terahertz phonon excitations persist in the crystal, smectic A, and isotropic phases. Furthermore, I will present data on the intermediate smectic A phase, which was shown to support a van der Waals-mediated nonhydrodynamic mode with an optical-like phonon behavior. Finally, I will show the coexistence of transverse acoustic and optical modes of 5CB LCs at near room temperature which was revealed through the emergent transverse phonon gap and THz light-phonon coupling taking place within the same energy range. The tunability of the collective excitations at nanometer–terahertz scales via selection of the sample mesogenic phase represents a new opportunity to manipulate optomechanical properties of soft metamaterials.