Optomechanical strong coupling in lattices of light fluids and sound

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We introduce polaromechanical crystals, two-dimensional arrays of zero-dimensional traps confining fluids of exciton-polariton condensates (simply polaritons) and 20 GHz phonons within a semiconductor microcavity [1]. The traps with dimensions down to 1x1 μm2 exhibit large coherence times for polariton fluids (ns-long) as for confined phonons (100's ns) with no observable reduction with decreasing trap size. These crystals combine strongly interacting hybrid phonon-polariton oscillators at the lattice sites with inter-site coupling mediated by strong optomechanical interactions. They are, thus, conceptually closer to metamaterials with resonant unit cells rather than to conventional optomechanical crystals based on Bragg co-localisation of light and vibrations in planar structures. The optomechanical character of the inter-site coupling has remarkable consequences. It is observed, for instance, that when a lattice site is locally perturbed through non-resonant continuous wave optical excitation, mechanical self-oscillation develops corresponding to very efficient polariton-driven phonon lasing [2]. In addition, the crystal responds by locking the energy detuning with neighbour sites to integer multiples of the phonon quantum, thus evidencing synchronization blockade and collective behaviour of the polariton and phonon fields. The exciton-mediated strong polariton-phonon interactions make accessible the so-called ultra-strong optomechanical coupling regime. The coherent control of quantum light fluids with hyper-sound and, conversely, the coherent control of extremely-high frequency sound with light, are envisaged based on the proposed scalable semiconductor platform.

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