Nonequilibrium thermodynamics with exciton-polaritons

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Exciton-polaritons are short-lived light-matter excitations in a solid-state microcavity in the strong coupling regime. From the thermodynamics point-of view, polaritons do not meet any criterion of thermodynamical equilibrium: as particles their lifetime is too short to assume a proper equilibration with their solid-state thermostat (i.e. thermal lattice vibrations); as waves, they cannot be considered as a black-body radiation since at the wavelength they display (visible), the electromagnetic vacuum can be considered as T=0K black-body, meaning that the polariton number at equilibrium is zero.

We thus investigate how polaritons, in spite of this nonequilibrium character behave as a heat exchange gas. In a recent experiment we have studied how polaritons could be used as a medium (a refrigerant) to pick up heat from the surrounding thermal lattice vibrations and release it into the electromagnetic vacuum. We found out that by optically exciting "ground-state" polaritons (i.e. zero in-momentum) we could drive a net cooling power for the cavity lattice vibrations, by anti-Stokes scattering with thermal phonons. Although reminiscent of optical cooling [1], this polaritonic cooling has original features inherited from their mixed light-matter nature [2].

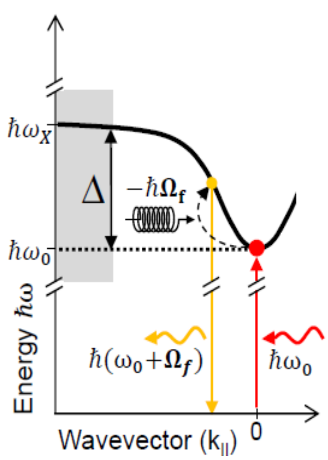

Figure: Principle of polaritonic cooling. The black curve is a typical lower polariton dispersion. The red spot and arrows figure the optically pumped polaritons (of energy $\hbar\omega_0$). Some of the pumped polaritons are scattered by thermal phonons (spring-like arrow) and thus gain an average energy $\hbar\Omega_f(T)$ (i.e. the average thermal phonons energy) and finally recombine by emitting photons (yellow arrows).

Being of integer spin and of very light mass, polaritons fluid are also known to display at high density/low "temperature" a quantum phase transition, sharing key characteristics with Bose–Einstein condensation, and driven partly by the system thermodynamics and partly by its kinetics [3,4]. Close to room temperature, where thermal lattice vibrations have a high interaction rate with polaritons, comparable with the loss rate, the nonequilibrium character of polaritons can result in a strange situation where the polariton condensate is not at full equilibrium with the phononic thermostats (it is rather “cooler”), and yet, the spatial correlations are strongly affected by this thermal noise. Some preliminary measurements characterizing this situation will be presented.

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