Thermal phonon lasing in nanoscopic quantum systems

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With the rapid progress in miniaturization many types of devices have reached the nanoscale where quantum effects become more prevalent, e.g., quantum lasers. On properly designed nanoscopic quantum systems a heat gradient can lead to inversion in parts of it, that could be utilized e.g. for the generation of phonons.

We study a theoretical concept of a nanoscopic quantum system representing the active medium of a thermal phonon emitter. Our model consists of a central three-level system (QS M) interacting with a two-level subunit at each side (QS L/R). Each two-level system is coupled to a heat bath. The different temperatures of the baths impose a heat gradient. The heat gradient leads to a flow of excitation from the hotter to the colder bath. For certain parameters, at the central quantum system, the flow could be accompanied by the emission of a phonon. Our description of the system kinetics is based on the Lindblad form of a Quantum Master Equation and the coupling to the lattice displacement field is described via a semiclassical equation.

In this presentation, we show that a positive inversion within the upper two levels of the central system takes place, which is a requirement to enable phonon lasing.

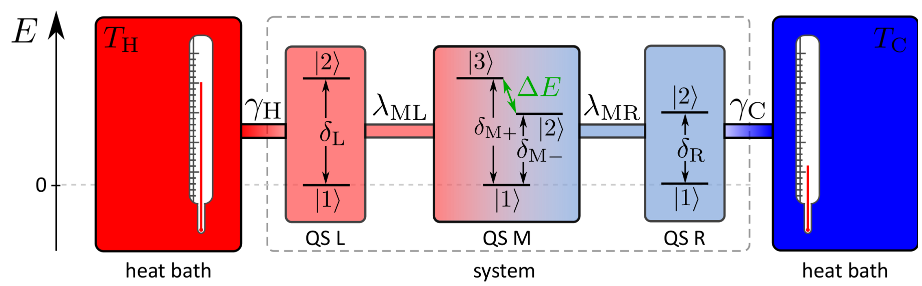

Figure 1: The model system.

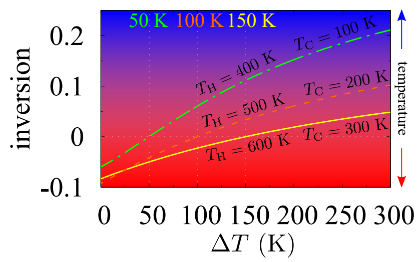

Figure 2: The dependence of temperature in the system on inversion.