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 coherent light or phonons.

We study a theoretical concept of a nanoscopic quantum system representing the active medium of a thermal laser. Our model consists of a central three-level system interacting with a two-level subunit at each side. 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. At the central unit the flow is accompanied by the emission of a photon or phonon. For certain parameters, this transition can generate lasing. Our description of the system kinetics is based on the Lindblad form of a Quantum Master Equation and the coupling to the lasing electromagnetic or 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 lasing. We also discuss how to turn the above concept into reality. We suggest as envisioned nanoscopic quantum system three semiconductor quantum dots stacked upon each other.

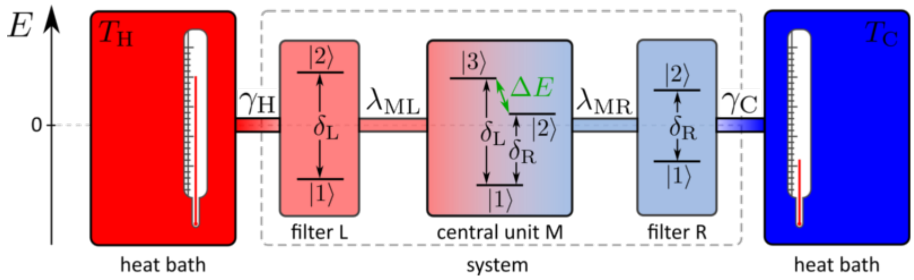

Figure 1: The model system.