Energy conversion in a hybrid optomechanical system: Laser-like behavior and cooling

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A hybrid optomechanical system consists of a two-level system parametrically coupled to a nano-mechanical oscillator (Fig. 1a). Because of this coupling, the transition frequency ω of the two-level system depends on the position of the mechanical oscillator. The ultra-strong coupling regime $g_m \gtrsim \Omega$ is now experimentally reachable [1,2,3] which opens new perspectives, including energy conversion. g_m is the optomechanical coupling strength and Ω the mechanical frequency.

Here we propose to convert electromagnetic energy into mechanical energy by shining a detuned laser on the two-level system. As a result of the optomechanical coupling, the two-level system enters in and out of resonance with the laser. In the case of a blue detuning (Fig. 1b), at each resonance, the two-level system can absorb a high-energy photon and, later, spontaneously emit a photon with a lower energy. The energy difference is provided to the mechanical oscillator in the form of work. We demonstrate that, with this mechanism, a coherent phonon state can be built upon thermal noise and that the system exhibits a laser-like behavior. On the other hand, in the case of a red-detuning, the two-level system absorbs low-energy photons and emits higher-energy ones, resulting in a cooling down of the mechanical oscillator.

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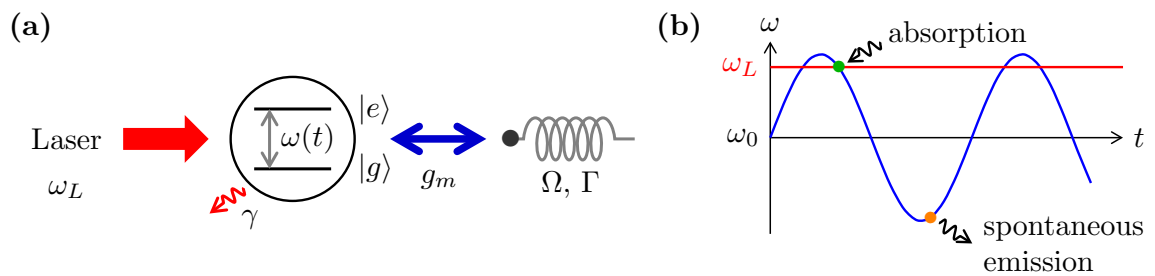
Figure 1: **(a)** Hybrid optomechanical system: a two-level system parametrically coupled to a mechanical oscillator. **(b)** Principle of the energy conversion: frequency of the transition of the mechanical oscillator as a function of time.