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 $\omega$ of the two-level system depends on the position of the mechanical oscillator. The ultra-strong coupling regime $g_m \gg \Omega$ is now experimentally reachable [1,2,3] which opens new perspectives, including energy conversion. $g_m$ is the optomechanical coupling strength and $\Omega$ 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.


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.