Dynamic Brillouin cooling for continuous optomechanical systems

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Cooling a mechanical oscillator to its quantum ground state by overcoming the effects of thermal environment has always attracted great interests [1-3]. Preparing a single mode mechanical oscillator to its ground state has been realized in cavity optomechanics by using sideband cooling. Beyond the cooling of single mode mechanical mode, lots of novel phonon cooling methods for multimode have been proposed recently for extended optomechanical platforms with many degrees of freedom. The intriguing limit of these cases is quantum ground state cooling in continuous optomechanical systems. Brillouin-based technologies provide cooling for groups of phonons in continuous optomechanical systems [4,5]. However, the large mechanical loss, which exceeds optical loss, limits the optomechanical continuum cooling. For general backward Brillouin scattering with higher frequency and thus lower Q-factor, it was thought that it is impractical for ground-state cooling in continuous optomechanical systems.

Here, we demonstrate that by periodically modulating the backward Brillouin interaction with a pulsed pump in the strong coupling regime (Fig. 1a), we can stimulate the swapping cooling process while significantly suppressing the heating process [6]. Figure 1a shows the time evolution of the mean phonon number $N_b(t)$, where the blue dashed (orange solid) curves denote the single pulse (periodic pulse) modulation, where $\tau$ is the pump switch-off time. The upper inset shows the dynamical modulation of $g(t)$ over the time. In Fig. 1b, the Brillouin cooling factor $R$ versus the coupling strength is the depicted.

With such dynamic modulation, a cooling factor with several orders of magnitude compared with the steady-state cooling limit can be realized. It shows that cooling traveling phonons into the quantum ground state by using backward Brillouin scattering is possible in integrated waveguides while mechanical dissipation exceeds optical dissipation. This modulation scheme can also be applied to Brillouin cooling generated by forward intermodal Brillouin scattering.

Fig. 1 (a) Dynamic cooling via pulsed modulation. $N_b$ is the mean phonon number, $g$ coupling strength, $\Gamma$ the acoustic damping time. (b) Brillouin cooling factor $R$ versus coupling strength.

References
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