Engineering long-lived vibrational states for an organic molecule

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Single organic molecules are promising contestants for realizing quantum optical networks in solid-state platforms due to their outstanding coherent properties [1]. Such a high degree of coherence is a result of strong zero-phonon lines that are Fourier-limited linewidths. However, their associated timescales are limited to nanoseconds, which implies a significant challenge for practical implementations of quantum networks with such molecular platforms.

In this theoretical work, we propose exploiting the optomechanical character of single molecules in the solid-state to build a new molecular system with quantum coherences up to millisecond timescales [2]. For such purpose we tailor the host matrix of a single organic molecule to the nanoscale and position it on a structured phononic environment that suppress its phononic decay [3] (see illustrations in Fig. 1). We show that the resulting long-lived vibrational states in these systems facilitate reaching strong optomechanical regimes at single photon level, which can be witnessed from strong anti-stokes scattering in the molecular emission spectrum. We exploit such long optomechanical coherence time of the molecule to store and retrieve optical information with proper pulse excitation up to milliseconds (see Fig. 2). The proposed system shows the prospects of organic molecules for reaching unexplored optomechanical regimes and realizing long-lived quantum memories.

References

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Figures

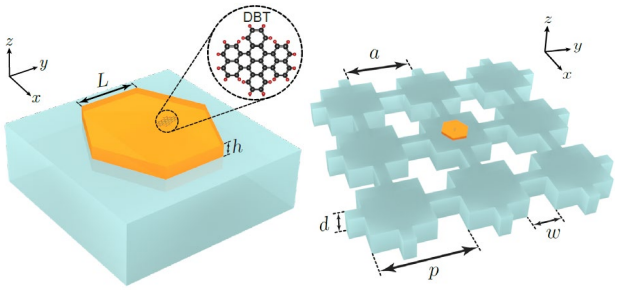

Figure 1: Left: Illustration of an anthracene nanocrystal doped with a single dibenzoterrylene molecule on a substrate. Right: Hybrid cavity formed by the nanocrystal-molecule system on top of a phononic crystal structure with suppressed phonon density of states [3].

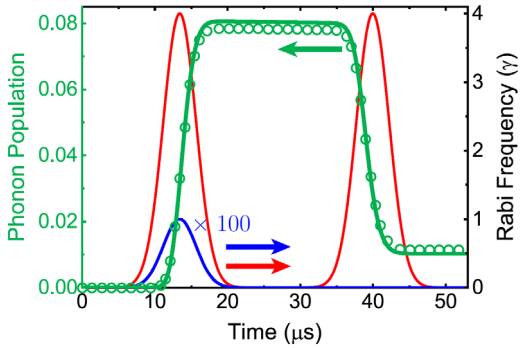

Figure 2: Coherent optical generation of ms-lived phonons by stimulated Raman scattering in the proposed molecular system.