Microscopic Origins of Room Temperature Superradiance In 2D Materials

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Poster

MICROSCOPIC ORIGINS OF ROOM-TEMPERATURE SUPERRADIANCE IN 2D MATERIALS

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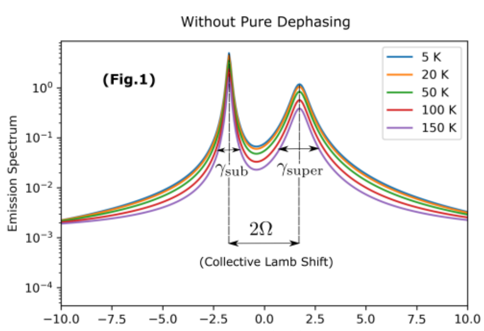
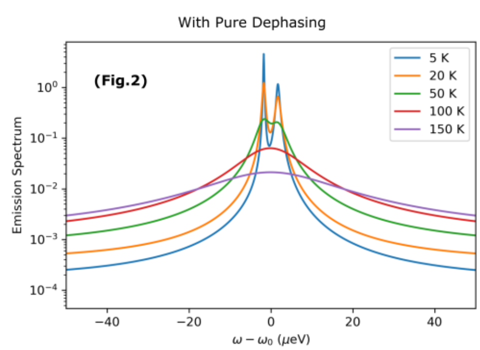
Superradiance is a quantum phenomenon that arises from the collective emission of multiple quantum emitters and promises a plethora of interesting real-life applications. This phenomenon has already been observed in solid-state systems at room temperature [1,2]. Recently color centers in hBN have been identified with a lifetime-limited broadening of the zero-phonon line even at room temperature [3]. This has been explained as being due to mechanical isolation between low-energy phonons and the emitters where the emission of photons is in-plane to the hBN layer orientation. Solid-state emitters with such emission properties may enable the observation of superradiance at room temperature.

For modeling the optical properties of emitters embedded in a solid-state environment, apart from exciton-photon interactions, exciton-phonon interactions should also be included. The phonon bath induces non-Markovian dynamics on a picosecond time scale, affecting coherences in the emitter states without affecting the populations due to a large mismatch between the phonon and the emitter energy splitting. On the other hand, the photon bath leads to the spontaneous decay of the emitters that decay in the nanosecond time scale and can be captured accurately with the help of the Markovian master equation [4]. While Markovian master equations are known for their computational simplicity, non-Markovian master equations are computationally demanding.

Therefore to capture the phonon effects along with an accurate description of photon emission, we make use of the polaron master equation. This allows us to achieve the best of the two worlds, namely the computational simplicity of the Markovian master equation and on the other hand capturing the non-Markovian effects due to phonons in multi-emitter systems. This is possible only because of the different time scales at which the phonon bath correlations and atomic correlations decay. Using this formalism we find that the temperature-dependent effects of phonon absorption and emission that contribute to the phonon sidebands have little effect on the distinct super/subradiant decay ($\gamma_{super}/\gamma_{sub}$) (Fig.1). On the other hand, thermal broadening of the ZPL due to the pure dephasing processes may obscure collective emission by quantum emitters, although sub- and superradiance may be spectrally resolved at low temperatures (Fig.2).





References
[1] M.Biliroglu, et al. Room-temperature superfluorescence in hybrid perovskites and its origins. Nature Photonics **16.4**, 324-329. **2022**
[2] K.Cong , Q.Zhang, Y.Wang, G.T. Noe, A.Belyanin, J.Kono. Dicke superradiance in solids. JOSA B **1**, **33(7)**, C80-101. **2016**
[3] M. Hoese, P. Reddy, A. Dietrich, M.K. Koch, K.G. Fehler, M.W. Doherty, A.Kubanek A. Mechanical decoupling of quantum emitters in hexagonal boron nitride from low-energy phonon modes. Science Advances. **6(40)**,eaba6038. **2020**
[4] Y.C. Cheng, R.J. Silbey. Markovian approximation in the relaxation of open quantum systems. The Journal of Physical Chemistry B. **109(45),**21399-405. **2005**

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