Exciton-phonon interaction in coupled quantum wells: optical refrigeration and optomechanics

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Abstract

Coupled quantum wells (CQWs) confine electrons and holes in spatially indirect regions as shown in Fig. 1, leading to very long radiative lifetimes on the order of 100 ns. We show that this gives sufficient time for relaxation by phonon emission to the excitonic ground state through the excition Mott transition [1]. Since the higher-lying states in the CQW are spatially direct and thus have a much shorter lifetime, CQWs constitute a novel and promising platform for optical refrigeration with cooling efficiencies beyond that of single quantum wells. Finally, we show that the long lifetimes allow matching the timescale of deformation-potential-driven optomechanical interactions to the period of the mechanical resonances, leading to very strong optomechanical forces using free-free membranes as shown in Fig. 2. We find that the carrier-mediated optomechanical forces are 500-fold stronger than radiation pressure [3].

References

[1] Kirsanske, Tighineanu, Daveau, Miguel-Sanchez, Lodahl & Stobbe, Phys. Rev. B **94**, 155438 (2016).

[2] Daveau, Tighineanu, Lodahl, and Stobbe, Opt. Express **23**, 243562 (2015).

[3] Barg, Midolo, Kirsanske, Tighineanu, Pregnolato, Imamoglu, Lodahl, Schliesser, Stobbe & Polzik, arXiv:1708.0588 (2017).

Figures

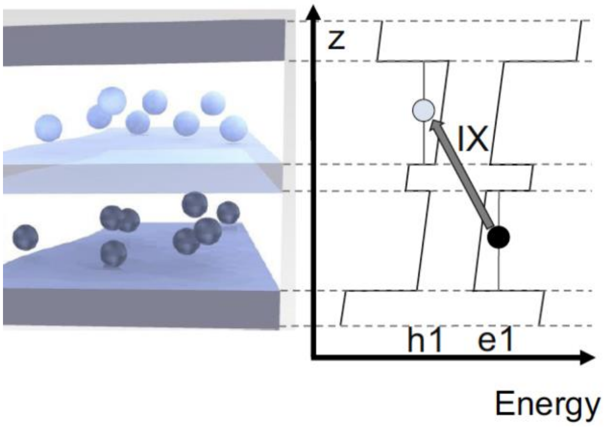

Figure 1: Coupled quantum wells confine electrons (dark blue) and holes (light blue) and the lowest-energy transition connect electrons (e1) and holes (h1) are spatially separated, leading to very long lifetimes [1].

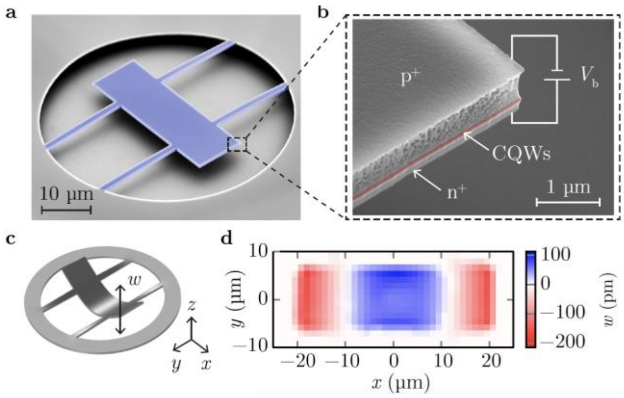

Figure 2: Free-free optomechanical membrane with embedded coupled quantum wells. **a**: Scanning electron micrograph, **b**: Zoom-in showing the doped contact layers, **c**: Simulation and **d**: Measurement of the fundamental mechanical mode of the membrane with the color scale showing the deformation [3].