Electrically driven crossover from repulsive to attractive interactions between dipolar excitons

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Spatially indirect excitons in semiconductor coupled double quantum wells are an ideal system to study cold bosons in solid state materials. This is due to a long radiative lifetime that allows cooling to low lattice temperatures. The electric field driven separation of charges into adjacent quantum wells results in a macroscopic dipole alignment. The repulsive dipolar interactions cause a density dependent blue shift of the emission line. This provides a probe of the exciton-exciton interaction and of the different phases of exciton fluids [1]. The dipole moment is also exploited for excitonic devices [2].

We present calculations of the internal structure of indirect excitons and their dependence on exciton density. Using a multi-sub-level approach [3] we self-consistently solved the exciton Schrödinger equation in real space in three dimensions coupled with Poisson's equation that describes the dipolar interactions in a dense fluid of indirect excitons. Figure 1a shows the blue shift as a function of density and applied electric field F. Of particular interest is the change from increasing to decreasing blue shift with increasing density that happens for $F = 8\,\mathrm{kV/cm}$ where direct and indirect excitons are close in energy. This indicates a crossover from repulsive to attractive interactions above a critical density. We explain this effect in terms of indirect excitons screening the applied electric field which, in turn, causes a decrease in the exciton dipole moment and Bohr radius. As the exciton becomes more tightly bound, energy is effectively absorbed by the modification of its internal structure resulting in a decrease in energy with increasing density. We also examine the reduction in radiative lifetime caused by screening of the applied electric field and its dependence on magnetic field (Figure 1b).

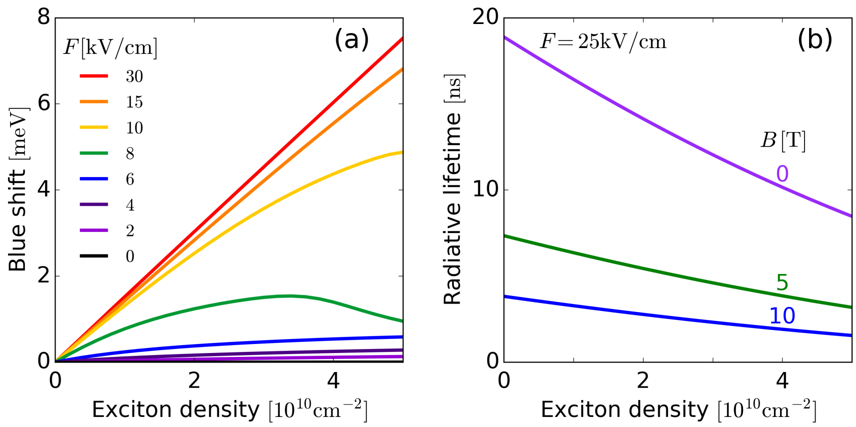

Figure 1: (a) Blue shift of the emission line of 8-4-8 nm GaAs/$Al_{0.3}Ga_{0.7}As$ coupled quantum well excitons as a function of density and applied electric field F. (b) Density dependence of the indirect exciton intrinsic radiative lifetime in magnetic field, B.

[1] K. Cohen *et al.*, *Nano Lett.* **16**, 3726 (2016).
[2] A. G. Winbow *et al.*, *Phys. Rev. Lett.* **106**, 196806 (2011).
[3] J. Wilkes and E. A. Muljarov, *Superlattice. Microst.* [In Press] (2017).