Fast and robust preparation of excitons and biexcitons in a quantum dot even at strong carrier-phonon coupling

M. Glässl[1], A. M. Barth[1], M. D. Croitoru[1], A. Vagov[1], and V. M. Axt [1]

[1] *Institut für Theoretische Physik III, Universität Bayreuth, 95440 Bayreuth, Germany*

Realizing a high-quality, on-demand and robust exciton or biexciton preparation in semiconductor quantum dots is of great importance for many quantum dot based devices such as single or entangled photon sources. While a perfect initiation of the quantum dot to both states can in principle be realized via resonant Rabi flopping, these schemes suffer from a high sensitivity on the dipole moments and the pulse intensity. A robust preparation can be achieved using protocols with frequency swept pulses, that rely on adiabatic rapid passage (ARP). However, the degree of exciton inversion realized in recent ARP-based experiments [1, 2] stayed below the ideal case and theoretical works gave compelling evidence that this reduction can be attributed to acoustic phonons [3, 4, 5].

Here, we present protocols that combine the simplicity of Rabi flopping with the robustness of ARP-based protocols and give the discussion of phonon influences a completely different perspective by demonstrating how one can highly benefit from the otherwise undesired carrier-phonon coupling. Using a numerically exact real-time path-integral approach [6] it is demonstrated how the exciton and the biexciton state of a strongly confined quantum dot can be prepared with high fidelity by applying a strong laser pulse that is circularly polarized and tuned above the exciton resonance for exciton preparation and chosen linearly polarized and in resonance with the exciton transition for biexciton preparation (cf. Fig. 1). Our protocols make active use of the phonon-induced relaxation towards photon dressed dressed states in laser driven quantum dots [7]. The presented schemes result in a fast preparation on a timescale of 10 pico-seconds and perform the better the stronger the carrier phonon coupling is. Thus, they allow for an almost ideal state preparation even in situations with strong system-environment interaction that are usually thought of as making control protocols impossible.

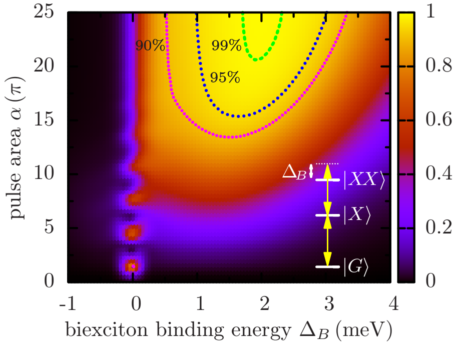

Figure 1: Final biexciton occupation C_{XX} after a Gaussian pulse of 15 ps FWHM at $T = 4$ K as a function of the biexciton binding energy Δ_B and the pulse area α. The laser frequency is chosen in resonance with the ground state to exciton transition and thus, for finite Δ_B, off-resonant to the exciton to biexciton transition (cf. inset). Contour lines show where certain values of C_{XX} are reached.

[1] C. M. Simon et al., Phys. Rev. Lett. **106**, 166801 (2011).
[2] Y. Wu et al., Phys. Rev. Lett., **106**, 067401 (2011).
[3] S. Lüker et al., Phys. Rev. B, **85**, 121302(R) (2012).
[4] K. Gawarecki et al., Phys. Rev. B, **86**, 235301 (2012).
[5] M. Glässl et al., Phys. Rev. B, **87**, 085303 (2013).
[6] A. Vagov et al., Phys. Rev. B, **83**, 094303 (2011).
[7] M. Glässl et al., Phys. Rev. B, **84**, 195311 (2011).