Optically induced exciton generation in quantum dots via adiabatic rapid passage: influence of phonons and detuning

S. Lüker[1], K. Gawarecki[2], M. Glässl[3], D. E. Reiter[1], A. Grodecka-Grad[4], V. M. Axt[3], P. Machnikowski[2] and T. Kuhn[1]

[1]*Institut für Festkörpertheorie, Universität Münster, Wilhelm-Klemm-Strasse 10, 48149 Münster, Germany*
[2]*Institute of Physics, Wroclaw University of Technology, 50-370 Wroclaw, Poland*
[3]*Theoretische Physik III, Universität Bayreuth, 95440 Bayreuth, Germany*
[4]*QUANTOP, Danish National Research Foundation Center for Quantum Optics, Niels Bohr Institute, University of Copenhagen, 2100 Copenhagen Ø, Denmark*

The optical control of quantum dots (QDs) with chirped (frequency-swept) laser pulses, denoted as adiabatic rapid passage (ARP), provides a powerful tool to excite a QD. Recent experiments have demonstrated that a robust occupation of the exciton state is possible using ARP [1, 2]. In a chirped laser pulse the instantaneous frequency of the light field changes with time. Due to this, the laser field is shifted through resonance with the exciton transition energy. This leads to an anti-crossing in the dressed state eigenenergies of the light-matter Hamiltonian. The population inversion is achieved when the system evolves adiabatically along this anti-crossing.

We have recently shown that the coupling to phonons reduces the fidelity of the ARP process [3]. We found that there is only a minor impact of phonons at low temperatures and positive chirps. In contrast, for negative chirps or at higher temperatures the adiabatic evolutuion is strongly affected by interactions with the phonon bath. We model the quantum dot for our calculations in the strong confinement limit as a two level system, consisting of the ground state and the exciton state, which is coupled to longitudinal acoustic phonons via the deformation potential mechanism. The evolution of the system is calculated using a fourth order correlation expansion.

Usually in ARP, the central frequency of the laser pulse, which coincides with the frequency at the pulse maximum, is in resonance with the transition energy. We analyze, how the state preparation fidelity is affected when the central frequency is detuned, i.e., the central frequency at the pulse maximum is not in resonance with the transition energy. Without phonons the population inversion can still be achieved, if the detuning is not too strong and the resonance is passed during the pulse. Again at low temperatures for positive chirps, where the coupling to phonons is very weak, the adiabatic evolution is robust against moderate detunings. For negative chirps on the other hand it is possible to compensate the phonon impact on the carrier dynamics by detuning the central frequency, resulting in an improved efficiency of the ARP process.

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[2] Y. Wu *et al.*, Phys. Rev. Lett. **106**, 067401 (2011).
[3] S. Lüker *et al.*, Phys. Rev. B **85**, 121302(R) (2012).