All-Optical Control of Electron Spins in Quantum Dot Ensembles

(Manfred Bayer)

Abstract :

Electron spins in quantum dots are promising building blocks for semiconductor based quantum information technologies. Due to the unavoidable inhomogeneities in a quantum dot ensemble it is common believe that coherent manipulations ought to be performed on a single dot level. In this contribution we will show that by proper addressing of quantum dots with pulsed laser protocols it might be possible to perform corresponding experiments on dot ensembles, coming along with the related benefits such as a strong spectroscopic response. For our experiments we have primarily used a time-resolved Faraday rotation technique on (In,Ga)As/GaAs self-assembled quantum dots which are singly charged with one electron. Using this methodology we have shown:

(i) Trains of circularly polarized laser pulses are extremely efficient to create spin coherence and to initialize the spins [1].

(ii) Such pulse trains can be also used to synchronize certain spin subsets within the ensemble. From the dependence of the synchronization on the pulse separation the electron spin coherence time can be measured to be 3 μs at cryogenic temperatures [2].

(iii) The spins can be clocked by pulse doublet sequences such that they show periodic coherent responses. The period of these responses can be tailored by the details of the laser excitation protocol [2,3].

(iv) Finally, due to the interaction with the lattice nuclei also the background of electron spins, which does not fulfil the synchronization condition from the start, disappears with time, as illumination-induced spin flip-flop processes between the electrons and the nuclei lead to an effective nuclear magnetic field which contributes to the external field to fulfil the mode locking condition [4].

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