Exploring Spin-Blockade in Deterministic Quantum-Dot Microlenses

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Keywords: *quantum dot, MOCVD, quantum optics, dark exciton, cross-correlation.*

Abstract

In recent years the coherent properties of bright excitons (BE) in self-assembled semiconductor quantum dots (QD) have been explored extensively [1]. However, the use of BEs for quantum information processing tasks is still limited due to their relatively short lifetime - set by its radiative recombination rate. On the other hand, dark exciton states have already proven to constitute an extremely long-lived qubit which is optically accessible via specific biexcitonic states [2].

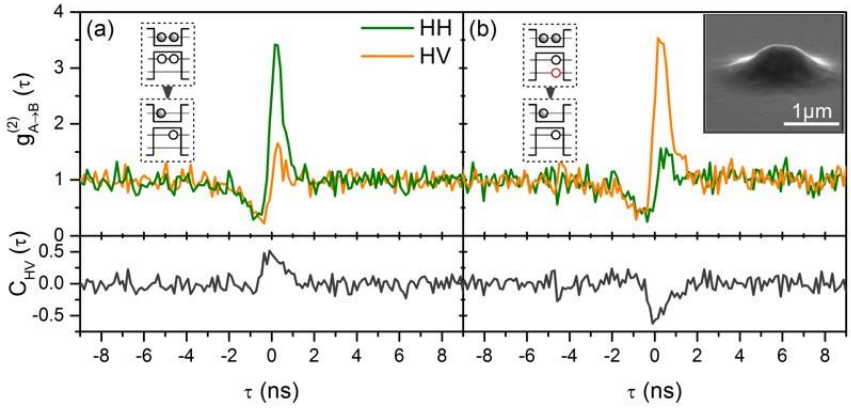

Figure 1: Polarization resolved photon cross-correlation histograms $g^{(2)}_{A\to B}(\tau)$ recorded on the emission of a deterministically fabricated QD microlens (cf. inset) for (a) the biexciton-exciton cascade in spin-singlet configuration and (b) for the spin-blockaded biexciton (spin-triplet).

In this work we report on such biexcitonic triplet states in single InAs QDs grown by metal-organic chemical vapor deposition (MOCVD) integrated deterministically into microlenses (cf. Fig. 1(b), inset) with enhanced photon-extraction efficiency. In contrast to the common spin-singlet biexciton state, the triplet states are constituted of two s-shell electrons and two holes having parallel spins, where one hole must be located in the p-shell due to Pauli exclusion principle. To proof the presence of this so-called spin-blockade in QD-microlenses, we present a detailed analysis of the dynamics of various charge carrier configurations. Figure 1(a) depicts the polarization resolved photon cross-correlation measurements performed on the well-known biexciton-exciton cascade. As a consequence of the direct radiative cascade a pronounced bunching behavior is observed in co-polarized configuration (HH), while cross-polarized correlations (HV) are strongly suppressed. Correspondingly a positive polarization correlation C_{HV} is observed (cf. lower panel). In contrast, the photon cross-correlation measured on the spin-blockaded biexciton triplet state (see Fig. 1(b)) reveals an inverted polarization correlation, where a pronounced bunching effect is observed in cross-polarized configuration (HV). This behavior is due to the underlying modified selection rules and proofs the origin from a spin-blockaded biexciton state. This first observation of spin-blockade in MOCVD grown InAs QDs proofs the robustness of this phenomenon against specific growth conditions and paves the way for the realization of long-lived matter qubits on a deterministic technology platform.

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