Coherence and Degree of Time-Bin Entanglement from Quantum Dots

T Huber\(^1\), L Ostermann\(^2\), M Prilmüller\(^1\), G S Solomon\(^3\), H Ritsch\(^2\), G Weihs\(^1\), and A Predojević\(^1\)

\(^1\)Institute for Experimental Physics, University of Innsbruck, Innsbruck, Austria
\(^2\)Institute for Theoretical Physics, University of Innsbruck, Innsbruck, Austria
\(^3\)National Institute of Standards and Technology, Gaithersburg MD, USA

Contact Email: ana.predojevic@uibk.ac.at

Single semiconductor quantum dots, due to their discrete energy structure, constitute an antibunched single photon source at a well-defined frequency and with inherently sub-Poissonian statistics [1]. Quantum dots generate single photons through recombination of a exciton, a quasi-particle formed by a Coulomb-bound electron from the conduction band and a hole from the valance band. In a more refined operation mode employing biexcitons, the Coulomb-bound four-carrier states containing two electrons and two holes, quantum dots can provide pairs of photons emitted in a fast cascade very similar to the original atomic cascade experiment by Aspect et al. [2]. It has been demonstrated that in the absence of the fine structure splitting of the bright exciton levels, such a cascade exhibits polarization entanglement. Nevertheless, the ability to achieve entanglement of photons from a quantum dot is not limited to polarization. Recently, it has been shown that the biexciton-exciton cascade can also be entangled in its emission time (time-bin) [3].

The requirements to generate this type of entanglement include the suppression of the single exciton probability amplitude in the excitation pulse and the lowest possible degree of dephasing caused by the laser excitation. These conditions constitute contradictory demands on the excitation pulse-length and its intensity. We studied these limitations from an experimental and a theoretical point of view. We find an optimized operation regime for the system under consideration and provide guidelines on how to extend this study to other similar systems. Beyond the generation of time-bin entanglement our study also indicates a generalized method to achieve very high photon pair generation probability from quantum dots [4].

In addition, resonantly excited quantum dots [5] are expected to deliver photons with higher degree of coherence than quantum dots excited above band. Our measurements show agreement with this claim and significant improvement of the indistinguishability of photons emitted from a resonantly excited single quantum dot compared with the photons obtained in above-band excitation.

References

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