Experimentalphysik 1 and SFB 631-Seminar

High-fidelity entangled photons from strain-tunable optoelectronic devices

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Despite the impressive progress achieved in the growth and fabrication of semiconductor nanostructures, real semiconductor quantum dots (QDs) usually do not show any structural symmetry. This induces a coherent coupling of the two bright excitonic states and leads to an energetic separation between them, the well-known fine structure splitting (FSS). When the FSS is larger than the radiative linewidth of the transitions (~ 1 μeV) the fidelity of the entangled photons emitted during the cascade biexciton-exciton-ground state is strongly reduced and the possibility to use QDs in advanced quantum optics experiments is severely hampered. For more than a decade researchers have struggled to find a reproducible way to suppress the FSS and the idea to use external perturbations (such as magnetic, electric, and strain fields) has been explored. However, recent results have raised fundamental doubts about the success of these attempts in QDs with low structural symmetry.

In this presentation, I will first introduce a novel class of QD-based devices, in which diode- like nanomembranes are integrated onto piezoelectric actuators having giant piezoelectric response [1]. This allows the electronic structure and the interaction energies among charged carriers confined in single QDs to be reshaped by the simultaneous application of large strain (up to 0.4%) and electric fields (up to 200 kV/cm) [2]. Then, I will demonstrate experimentally and theoretically that the coupling between the bright excitons, and hence the FSS, can be always suppressed regardless of the QD structural symmetry [3]. Using quantum state tomography, I will show that ideally all the QDs embedded in these novel devices can emit polarization entangled photons [4], with average fidelity as high as 0.81(2). This highlights that absolute control over the FSS is a fundamental prerequisite for the real exploitation of QD in quantum technologies. Finally, new concepts enabling the demonstration of tunable sources of entangled photons will be discussed.

[1] R. Trotta et al., Adv. Mater. 24, 2668 (2012).
[2] R. Trotta et al., to appear in Phys. Rev. B (2013).
[3] R. Trotta et al., Phys. Rev. Lett. 109, 147401 (2012).
[4] R. Trotta et al., in preparation (2013).