Polarization and high-fidelity fiber-integrated quantum dot cavity-QED devices

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A single semiconductor InGaAs quantum dot in a high-quality optical micro cavity is a candidate for high-efficiency single photon sources and photonic quantum gates. We present our recent results on single-mode fiber integration of the devices, and on polarization control and polarization effects in quantum dot cavity QED.
If a quantum dot is placed at the field anti-node of a high-quality microcavity, the Purcell effect enhances the interaction with desired propagating optical modes and can be used to extract single photons with near-unity efficiency. Circular micropillar cavities (Fig. 1 a) enable the coupling to a fundamental Gaussian optical mode, which is ideal for coupling into single-mode optical fibers. We show that by careful design, full polarization control through the fibers can be obtained [1].
A strong Purcell effect requires a small optical mode volume; this strong optical confinement, however, leads to a very strong sensitivity of the optical modes to intrinsic material birefringence by stress and strain, and to form-birefringence or spin-orbit coupling due to fabrication tolerances and deviations from the circular shape of the micro cavity. Even a small polarization splitting of the fundamental cavity mode is problematic for using the photon polarization degree of freedom as a qubit in a photonic quantum gate: First, it leads to a polarization dependent Purcell effect, degrading the gate fidelity. Secondly, it leads to a complex polarization dependent dispersion of the cavity, which can lead to several complications: For instance, it prevents the use of cross-polarization techniques for the extinction of (possibly 10s of GHz broad) pulsed laser light, if the input polarization is not along one of the cavity polarization axes; this choice is sometimes advantageous for single photon sources, see Fig. 1 b and Ref. 2. We demonstrate that, by exploiting the linear electro-optic (Pockels) effect, full polarization degeneracy can be restored (Fig. 1 c) [3]. Finally, we discuss open questions such as polarization-differential loss and surprising quadratic electro-optic effects (visible in Fig. 1 c).

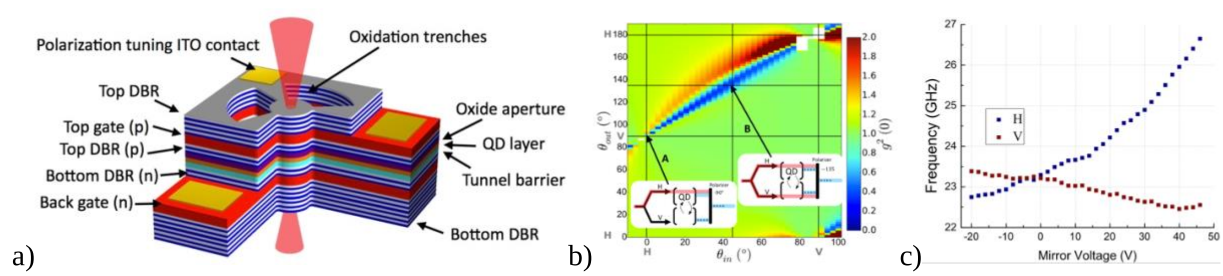

Figure 1: Cartoon of the quantum dot micropillar cavity device (a), photon correlations depending on the input-output polarization choice (b), and recovery of full polarization degeneracy of the cavity modes by electro-optic tuning (c).

References

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