Quantum Dots: Light source for Quantum Information

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Introduction

Semiconductor quantum dots (QDs) belong to the class of structures called "artificial" atoms which exhibit distinct quantum character. Self assembled quantum dot (SAQD) structures with high optical efficiency and relatively stable emission energies as compared to colloidal dot system make them ideal for quantum light generation. Such a single structure can also be suitably selected as a solid state-based platform to mimic quantum optical phenomena involving light matter interaction. Indeed a lot of theoretical and experimental studies in the past decade have focused on the above-mentioned aspects of SAQDs.

Outline

This work will present the summary of our experimental work of spectroscopy on single QDs to evaluate the system for quantum light generation in view of the requirements for quantum information processing (QIP). We demonstrate resonant excitation on single quantum dots where we inexplicably show distinct feature of resonance fluorescence from a single quantum emitter. Photon correlation and indistinguishability measurements on the resonance fluorescence (RF) from single QDs reveal both single and cascaded photon source with high coherence which are both important ingredients of QIP schemes. Excitation of single QDs in optical microcavities also demonstrate the cavity quantum electrodynamics effects typically observed in atom optics as well. At the end, we will briefly outline the effect of the presence of phonons on the operation of QD-based quantum light source. This includes not only the mostly dreaded dephasing processes but also phonon-assisted excitation of cavity as well as quantum emitter which can be used as a resource in QIP.

Resonance Fluorescence from single QDs

Resonant excitation of solid state quantum emitter suffers from the technical problem of separation of excitation laser and sample emission in the collection. We show that relatively high S/N ratio for RF signal from a QD can be achieved [1,2]. High resolution spectroscopy of the RF signal exhibits the appearance of Mollow triplet which is a hall mark of dressed state formation in the coupled laser + emitter system [1]. Photon correlation measurements on the sidepeaks of the triplet demonstrate that individually they consist of well defined single photon states while together they make a pair of photon emitted with a definite order with high fidelity [2].

Cavity Quantum Electrodynamics with QDs

Semiconductor based SAQDs can monolithically be integrated with semiconductor based optical microcavities. Recent advances in this direction have made it possible to routinely achieve strong coupling between the cavity photons and confined excitons of QDs [3]. We study QDs in cavities close to the strong coupling regime achieving reasonably high Purcell factors. We show that cavities indeed help in coherence properties of single photons emitted from QDs [4]. Close-to-Fourier limited single photon emission has been demonstrated with high photon coalescence at a beam splitter [1].

However, resonant excitation of single QD in a cavity exhibits unusual phenomenon of so called “non-resonant QD-cavity coupling” [5]. It demonstrate the even under large detunings the cavity mode is still pumped by the quantum emitter. The non-resonantly excited cavity mode can not only be used for extracting QD properties [5,6] but can also be used as a frequency stable single photon channel.

Phonon effects

The presence of phonons in solid state quantum emitters presents an inherent dephasing channel which decreases the mutual coherence of the emitted single photons from the emitter. We present excitation and detuning dependent studies on resonant excitation of single QDs which shows that both excitation- [7,8] and detuning- [8] induced dephasing is demonstrated by the presence of LA phonons in the system. However we show some unusual effects due to the presence of phonon. One is the presence of laser-QD detuning controlled intensity asymmetric Mollow triplet [8]. The other is the phonon assisted excitation of QD by a non-resonant laser [9] and the non-resonant coupling between a cavity mode and a QD [5,6].

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