Pulsed to continuous wave coherent micropillar cavity-quantum dot dynamics

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Coherently driven two-level systems, such as semiconductor quantum dots, are a versatile source of quantum light [1,2,3]. The quantum dot response is well understood for continuous-wave excitation, where a stream of single photons is produced randomly, i.e. without well-defined time-bins, and the steady-state condition limits the quantum dot population to at most 50% occupation. Under pulsed excitation, using pulses shorter than the relevant quantum dot decoherence times, near-unity population inversion is possible and with this deterministic production of single photons in well-defined time bins [1].

In our experiment, we study a charged InGaAs quantum dot in a p-i-n diode structure embedded in a polarization-split monolithic micro-cavity and we excite it using a custom optical pulse generator enabling pulse lengths from 20 ps to many times the quantum dot lifetime [4]. This programmable pulse generator based on electro-optic modulation of a tunable narrow linewidth continuous-wave laser enables us to investigate how the cavity-quantum dot system behaves under various excitation conditions, from pulsed to continuous-wave. We record the reflected light and its second-order correlation function for various quantum dot and laser detunings.

We find that, as shown in Fig. 1, in the pulsed regime Rabi dynamics dominate the emission characteristics [5], and that by increasing the pulse length a rich dynamics appears that depends sensitively on the detunings, ranging from the production of single photons (orange circle, $g^{(2)}(0) << 1$), photon bundles [3] (green circle, $g^{(2)}(0) > 1$), to the production of photon-subtracted coherent states (blue circle, $g^{(2)}(0) \sim 4$).

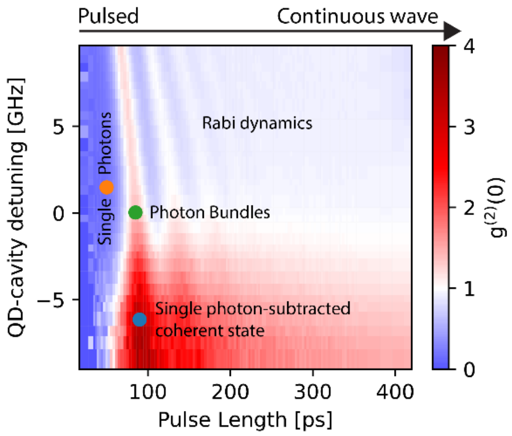

Figure 1: Recorded $g^{(2)}(0)$ of the light collected as the quantum dot transition is Stark shifted around the cavity resonance. For each QD-cavity detuning, the laser frequency is tuned in continuous-wave mode to optimize the amount of collected light. Regions generating photonic states with fundamentally different photon number statistics are highlighted by markers.

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