Wave-particle correlations and quantum-fluctuation asymmetry in multiphoton Jaynes-Cummings resonances

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We discuss the conditional measurement of field amplitudes by a non-classical photon sequence in the Jaynes-Cummings (JC) model under multiphoton operation. We do so by employing a correlator of immediate experimental relevance to reveal a distinct quantum evolution in the spirit of [1], relying on the complementary nature of the pictures obtained from different unravelings of the JC master equation. We demonstrate that direct photodetection entails a conditioned separation of timescales [2], a quantum beat and a semiclassical oscillation, produced by the coherent light-matter interaction in its strong-coupling limit. We single the quantum beat out in the analytical expression for the waiting-time distribution, pertaining to the particle nature of the scattered light, and find a negative spectrum of quadrature amplitude squeezing, relevant to its wave nature for certain operation settings. We then jointly detect the dual aspects of the emitted radiation via the wave-particle correlator, showing an asymmetric regression of fluctuations to the steady state [2, 3] which depends on the quadrature amplitude being measured.

More precisely, the application of quantum trajectory theory in parallel with the master equation and quantum regression formula uncovers various aspects of temporal asymmetry in the quantum fluctuations characterizing the cascaded process through which a multiphoton resonance is established and read out. We also find that monitoring different quadratures of the cavity field in conditional homodyne detection affects the times waited between successive photon counter “clicks”, which in turn trigger the sampling of the homodyne current [3]. The individual realizations thus obtained allow the experimenter to access the distribution and statistics of the light field in a regime of single-atom QED where photon blockade persists for a growing system-size parameter [4].

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