Aharonov-Bohm quantum rings in microcavities

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Progress in nanolithography and epitaxial techniques has resulted in burgeoning developments in the fabrication of semiconductor nanostructures and optical microcavities. Cavity quantum electrodynamics addresses the interaction of an emitter embedded inside a microcavity with the cavity modes and the emission spectrum of the system. The luminescence spectrum of a microcavity coupled to a single quantum-dot-based emitter under incoherent continuous pumping has been studied extensively both theoretically and experimentally. This system possesses a rich spectrum, which maps transitions between quantized photon-dressed states of the light-matter coupling Hamiltonian.

There is a considerable current interest in non-simply-connected nanostructures, quantum rings, which have been obtained in various semiconductor systems [1-3]. The fascination in quantum rings is partially caused by a wide variety of purely quantum-mechanical effects, which are observed in ring-like nanostructures, including the celebrated Aharonov-Bohm effect resulting in magnetic-flux-dependent oscillations of various physical quantities. It has been shown that an external lateral electric field, which is known to reduce the ring symmetry and suppress the energy oscillations for the low-energy states, also modifies optical properties of the ring [4,5]. Namely, the application of a weak electric field leads to magneto-oscillations of frequency and the degree of polarization of optical transitions between the ground and first excited states which are typically in the THz range.

In the present work we examine a microcavity with an embedded quantum ring, which is pierced by a magnetic field and subjected to a lateral electric field. We calculate the luminescence spectrum of the system using the Lindblad master equation approach and demonstrate that it is strongly influenced by the pumping intensity and the quality factor of the cavity [6]. An additional degree of control can be achieved by changing the angle between the polarization plane of the pump and the external electric field. Optical properties of the considered system demonstrate a rich behavior which can be controlled by external electric and magnetic fields. These fields govern the electron spectrum and optical selection rules in a ring, which can be easily tuned to match the cavity modes.

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