Qubit Gate Operations in Elliptically Trapped Polariton Condensates

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We consider bosonic condensates of exciton-polaritons optically confined in elliptical traps [1], *cf.* Fig. 1(a). A superposition of two non-degenerated p-type states of the condensate oriented along the two main axes of the trap [Fig. 1(b)] is represented by a point on a Bloch sphere, being considered as an optically tunable qubit. We describe a set of universal single-qubit gates [2] resulting in a controllable shift of the Bloch vector through an auxiliary laser beam. Moreover, we consider interaction mechanisms between neighboring traps that enable designing two-qubit operations such as CPHASE and CNOT gates [2]. Both the single- and two-qubit gates are analyzed in the presence of error sources in the context of polariton traps, such as pure dephasing and spontaneous relaxation mechanisms, leading to a fidelity reduction of the final qubit states and quantum concurrence, as well as the increase of Von Neumann entropy. We also discuss the applicability of our qubit proposal in the context of DiVincenzo's criteria [3] for the realization of local quantum computing processes. Altogether, the developed set of quantum operations would pave the way to realize a variety of quantum algorithms in a planar microcavity with a set of optically induced elliptical traps.

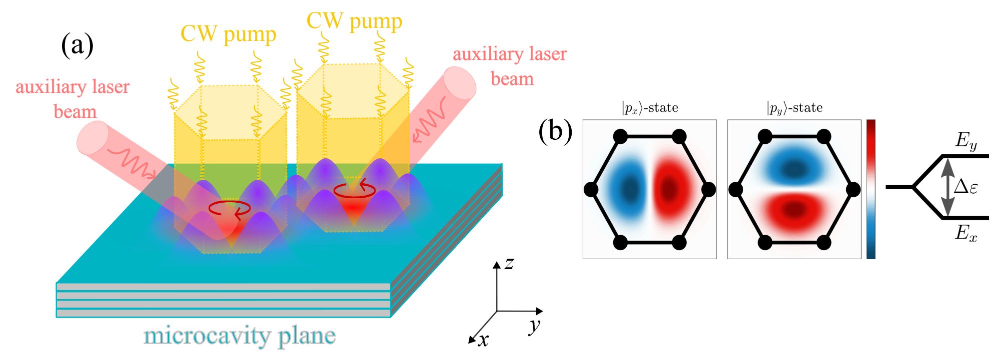

Figure 1: (a) Sketch of the polariton condensate qubit system. Each trap hosts a circular superfluid current state, defined by opposite orbital angular momentum (OAM), shown by red circled arrows. The linear combination of clockwise and anticlockwise OAM states defines the orthogonal $|p_x\rangle$- and $|p_y\rangle$-modes in the optically generated trap and are the basis states for a two-level qubit in each polariton condensate. The initial qubit states and qubit gates for an individual trap can be tuned by the corresponding auxiliary off-resonant laser beams. (b) Spatial representation of the p-modes, corresponding to the qubit basis states, with $\Delta\varepsilon$ being the energy splitting between the modes.

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