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Two-Qubit Motional Gates in Double-Well Optical Lattices

MARK EDWARDS, Georgia Southern University, JAMES PORTO, CHARLES W. CLARK, NIST — A controllable, phase-stable two-dimensional array of double-well optical potentials can be created by crossing two pairs of counterpropagating laser beams. If such a lattice is applied to a gaseous Bose-Einstein condensate and the depth of the lattice is ramped up, it is possible to "freeze" exactly two atoms at the site of each double-well potential. The relative depths of the wells of the potential can be controlled along with the height of the central barrier by applying a phase shift to one of the pairs of counterpropagating beams. We are, therefore, able to adjust the potential so that there are two distinguishable motional states of a single atom on each side of the double-well potential. These pairs of motional states can then be used as qubit states. We have studied the quantum dynamics of two interacting particles moving in this adjustable double-well potential. All of the dynamics can be understood using three separate few-state models (for sufficiently wide band-gap energy spectra) whose individual dynamics can be well understood using Landau-Zener theory. We present these models and analyze the behavior of the two atoms for several different time-dependent changes of the double-well potential. The suitability of these dynamical changes in serving as a two-qubit quantum gate are assessed.

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