Quantum logic in optical lattices via trap-induced resonances in controlled collisions of Cesium atoms

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Controlled collisions of ultracold atoms in optical lattices provide new avenues for quantum control and quantum information processing. Of particular interest is the investigation of controlled collisions of atoms in separated but close wells. In previous research, we showed that for certain well separations, resonances between molecular bound states and trap eigenstates appear. These trap-induced resonances[1] provide a new handle for coherently controlling two-atom ground-state interactions and open up new possibilities for designing robust quantum logic gates. Here, we consider this new type of trap-induced resonance for the case of Cs-133 atoms. The anomalously large scattering lengths and the presence of a very weakly bound molecular state in Cesium, lead to the possibility of creating trap-induced resonances under realistic experimental conditions. Our theoretical studies establish realistic operating conditions under which the trap-induced resonance could be observed and show that this strong and coherent interaction could be used as a basis for high-fidelity two-qubit quantum logic operations in standard and addressable optical lattice systems.

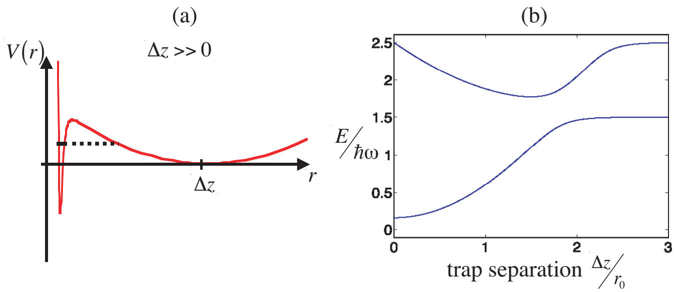

Figure 1: *(a) Schematic of a trap-induced resonance between a molecular bound state and a trap eigenstate in the relative coordinate picture. (b) Calculation of the lowest energy levels as a function of separation Δz for realistic Cs parameters. The energy spectrum shows a large avoided crossing resulting from a trap-induced resonance.*

[1]R. Stock, E. L. Bolda, and I. H. Deutsch, Phys. Rev. Lett. **91**, 183201 (2003).