Robust entangling gate for capacitively coupled few-electron singlet-triplet qubits

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Singlet-triplet (ST_0) qubits remain one of the leading candidates to host quantum computing devices in semiconductor quantum dots. Relative to single-spin qubits, ST_0 qubits feature fast operations, suppressed power dissipation, simplified control systems, and high-fidelity readout. Conventionally, ST_0 qubits are realized in two singly-occupied tunnel-coupled dots ("two-electron ST_0 qubit"). Such setup for ST_0 qubits is limited from performing high-fidelity capacitive gates as dipoles are introduced during the two-qubit operations. Therefore, searching a two-qubit sweet spot, locus in qubit parameters where quantum control is first-order insensitive to charge noises, is key to achieve robust entangling gates in this system.

Recent experiments have demonstrated, when a singly-occupied quantum dot is coupled to a multielectron dot, that exchange energies can depend non-monotonically on the detuning, the control parameter [1,2]. Inspired by these works, we consider ST_0 qubits allowing each dot to host more than one electron, with a total of four electrons in the double quantum dots ("four-electron ST_0 qubit"). We theoretically demonstrate, using configuration-interaction calculations, that sweet spots appear in this coupled qubit system. We further demonstrate that, under realistic charge noise and hyperfine noise, two-qubit operation at the proposed sweet spot could offer gate fidelities (~99%) that are higher than conventional two-electron singlet-triplet qubit system (~90%)

References

[1] F. K. Malinowski, et al., Phys. Rev. B X, 8 (2018) 022045
[2] F. Martins, et al., Phys. Rev. Lett., 119 (2017) 227701
[3] G. X. Chan and X. Wang, arXiv:2201.01583 (2022)

Figures

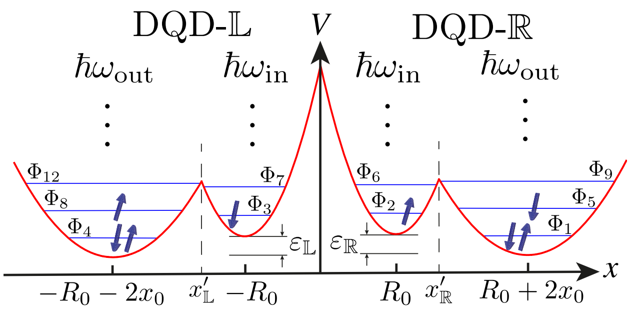

Figure 1: Schematic illustration of a double double-quantum-dot (DQD) device, where DQD-L and -R denote left and right DQD respectively, with x = 0 being the boundary between them.

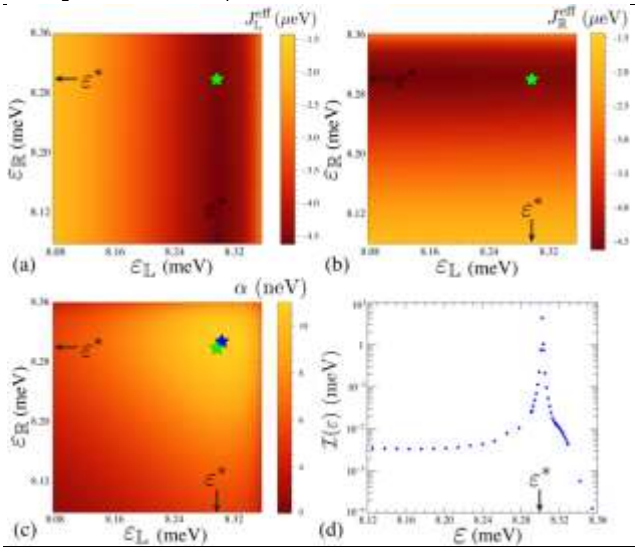

Figure 2: (a, b) Effective exchange energies and (c) capacitive coupling as functions of detunings (d) Insensitivity v.s. symmetric detunings on two DQDs