Spin Qubit Leapfrogging: Dynamics of Shuttling Spin Qubits on top of another

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In recent years spin shuttling has distinguished itself as a promising candidate for achieving high fidelity medium range interactions between spin qubits[1,2] and presents a powerful tool for enabling scalable semiconductor spin quantum computing architectures in the future[3]. A dominant source of errors encountered during spin shuttling in silicon is the spontaneous transition into the excited valley state, which when unnoticed, leads to unaccounted for dephasing and irregular behaviour during gate application[4].

Modelling the process of a shuttled spin qubit encountering a stationary quantum dot, we investigate the dynamics of the (1,1)-(2,0) charge transition in a silicon double quantum dot with non-vanishing inter-valley coupling and find that driving this transition can implement a power-of-SWAP-gate regardless of the shuttled electrons valley state. In particular in the case of a non excited valley state, the electron can coherently pass over the other qubit into a third quantum dot, thereby potentially offering a mechanism to shortcut shuttling routes by having qubits leapfrog over another while simultaneously implementing an entangling gate.

Harnessing this setup, we additionally present a non-demolition valley-state readout scheme utilising a trapezoidal detuning pulse to drive a single diabatic transition while moving adiabatically through others. A consequential valley-to-charge conversion then allows one to assess the valley state of the shuttled qubit.

References

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Figures

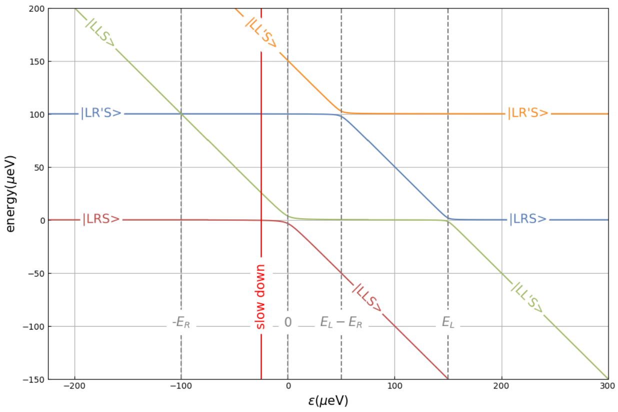

Figure 1: Energy landscape of the (1,1)-(0,2) charge transition with inter-valley coupling for spin singlets. By detuning rapidly at the beginning one can skip over the first anti crossing, leading to a valley to charge conversion of the right spin qubits valley state at the end of the detuning protocol.