Moving electrons as spin qubits

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Quantum dots are one of the most promising physical systems for quantum computation. After reaching experimental values for single qubit manipulation fidelities of more than 99% [1] and two qubit interactions creating CNOT gates [2], the limit of universal computation is as close as ever. However, as ion traps and superconducting qubits did before, the limit of operating with short ranged interactions limits the amount of qubits that quantum computers can operate at the same time. Tackling these issues, the presented system is based on electrons as spin qubits moved by surface acoustic waves (SAWs) [3,4]. GaAs piezoelectric properties allow the creation of SAWs with patterned metallic interdigital transducers (IDTs), as well as 2D electron gases in an interface with AlGaAs, that enables it to control QDs 100 nm below the surface. Extending this experiment by placing other static dots at some known distance from the moving, one can tune the exchange interaction between the triplet and the singlet. In order to avoid the decoherences that the nuclear spin bath in GaAs may cause to spin qubits, an alternative Si/SiGe interface with piezoelectric ZnO on top is has been proposed, where isotopic purification can make spin qubits a more feasible quantum memory.

References

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[2] D. M. Zajac et al., Science, 359 (2018) 439

[3] C. H. W. Barnes, J. M. Shilton and A. M. Robinson, PRB, 62 (2000) 8410

[4] C. J. B. Ford, p.s.s (b), 254 (3) (2017) 1600658

Figures

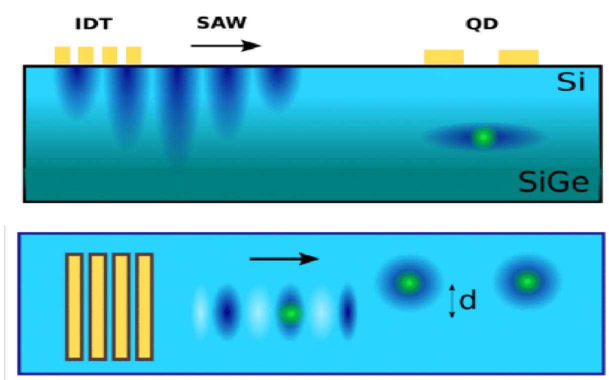

Figure 1: Side and top view of a sketch showing the working process of electron pickup and multiple particle interaction.

$$H = 2\epsilon + \begin{pmatrix} U & X & -\sqrt{2}t_{\mathrm{H}} & 0 \\ X & U & -\sqrt{2}t_{\mathrm{H}} & 0 \\ -\sqrt{2}t_{\mathrm{H}} & -\sqrt{2}t_{\mathrm{H}} & V_{+} & 0 \\ 0 & 0 & 0 & V_{-}\cdot \mathbb{I}_3 \end{pmatrix}$$

Figure 2: Hamiltonian of the interaction between two electrons, showing the singlet triplet decoupling.