Coherent electron spin transport and fault-tolerant semiconductor-based quantum computer architectures.¹
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The recent progress in single atom fabrication techniques for discrete gated donor systems in semiconductors offer new opportunities for coherent quantum technology applications. We review a new scheme for coherent electron spin transport by adiabatic passage (CTAP) particularly suited to atomic and solid-state systems. In a semiconductor implementation, CTAP based transport is a highly robust mechanism for shuttling electron spin states coherently along pathways defined by ionised donors spaced 20-30 nm apart. Such novel discrete transport of electrons may lead to new applications in semiconductor technology, however, as a transport mechanism for spin-encoded quantum information it is an essential development for the successful design of a strongly scalable quantum computer architecture. Using phosphorous donor electron spins in silicon as a model system, the tunnelling rates, transfer times, and effects of decoherence are calculated. The introduction of electron spin transport leads to a scalable 2D quantum computer architecture for Si:P with spatially separated interaction, storage and readout regions and incorporates non-nearest-neighbour interactions between qubits. The transport rails which provide these non-local interactions, also provide alternative pathways to avoid non-functioning regions. The fault-tolerant operation of such an architecture using CTAP for qubit transport is considered in detail.

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