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Spin qubits in quantum dots – beyond nearest-neighbour exchange[1]

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The spin of a single electron is the canonical two-level quantum system. When isolated in a semiconductor quantum dot, a single electron spin provides a well-controlled and long-lived quantum bit. So far, two-qubit gates in this system have relied on the spin exchange interaction that arises when the wave functions of neighbouring electrons overlap. Furthermore, experimental demonstrations of controlled spin-exchange have been limited to 1D quantum dot arrays only. Here we explore several avenues for scaling beyond 1D arrays with nearest-neighbour coupling. First, we show that second-order tunnel processes allow for coherent spin-exchange between non-nearest neighbour quantum dots. The detuning of the intermediate quantum dot controls the frequency of the exchange-driven oscillations of the spins. Second, we demonstrate shuttling of electrons in quantum dot arrays preserving the spin projection for more than 500 hops. We use this technique to read out multiple spins in a way analogous to the operation of a CCD. Finally, we develop superconducting resonators that are resilient to magnetic field and with a predicted tenfold increase in vacuum electric field amplitudes. This makes coupling spin qubits via superconducting resonators in a circuit-QED approach a realistic possibility. [1] F.R. Braakman et al, Nature Nano 8, 432, 2013 [2] T.A. Baart et al, Nature Nano, accepted, see arXiv:1507.07991 [3] T.A. Baart et al, in preparation [4] N. Samkharadje et al, in preparation

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