Spin qubits in silicon with long-distance interactions

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Silicon has become the leading material for semiconductor spin qubits. In order to scale up spin qubits based in semiconductor quantum dots, long-distance qubit interactions can be provided by either circuit quantum electrodynamics (circuit QED) or electron shuttling. Here, we illuminate both of these techniques from the perspective of a theoretical physicist. First we discuss the shuttling of electrons in silicon in the presence of the valley degeneracy in the conduction band of silicon, which leads to interesting extensions of the Landau-Zener model. Second, we turn to spin qubits embedded into a superconducting microwave cavity as a means of realizing long-range interactions via circuit QED. A particularly useful concept in this context is the flopping-mode spin qubit. Finally, we introduce the exchange-only qubit and its coupling to the photons of a quantized cavity field.