Nuclear notch filtering and long-distance spin exchange in GaAs quantum dots

Ferdinand Kuemmeth

Center for Quantum Devices, Niels Bohr Institute, University of Copenhagen, Denmark

Spin qubits based on semiconducting quantum dots are promising candidates for quantum computation, due to their potential for integration and fault tolerance. I will present recent results on how to mitigate nuclear noise in GaAs spin qubits using nuclear notch filtering techniques, and on achieving coherent exchange operations between distant spins using a multielectron quantum dot.

To protect singlet-triplet qubits from nuclear spin fluctuations we apply pulse sequences that dynamically decouple noise both at low frequencies and discrete high frequencies. At high magnetic fields qubit depasing originates from nuclear Larmor precessions, occurring at well-defined frequencies. By implementing notch filters at exactly these "noisy" frequencies we extend qubit coherence times to 0.87 ms, i.e. more than five orders of magnitude longer than the duration of a π exchange gate in the same device.

Further, we use a singlet-triplet qubit implemented in a GaAs double dot to probe the exchange coupling between one of its dots and a nearby multielectron dot. We find that the spin-exchange energy can have opposite sign compared to exchange between singly-occupied dots, indicating the presence of non-trivial electron correlations. By coupling a second qubit to the multielectron dot, we demonstrate several regimes of long-distance spin exchange mediated by the multielectron dot (on-site, direct, and superexchange). Our results show a pathway to implementing fast, non-nearest neighbor two-qubit gates in semiconducting spin qubits.