Towards quantum simulation of a spin ladder in a semiconductor quantum dot array

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Different from other 1D or 2D lattices, two-leg spin ladders can develop a spin gap, which resembles the pseudo-gap present in underdoped high-Tc superconductors. This has motivated extensive theoretical and experimental efforts to study spin ladders [1-3]. Recently, it also attracted the attention from the quantum simulation community. By using ultracold atoms, researchers have investigated the underlying physics of a topological phase and hole pairing in a spin ladder [4, 5]. However, the preparation of low-entropy starting conditions for such system is still a serious challenge for simulating more intricate physics [6].

Semiconductor quantum dots offer an alternative platform for quantum simulation [7-10]. In gate defined GaAs quantum dots, it has been demonstrated that the Fermi-Hubbard model Hamiltonian can be simulated in a well-controlled manner, with tunable inter-site tunnel couplings and on-site potentials [7]. Such systems have enabled the experimental observation of Nagaoka Ferromagnetism in a 2x2 array [9] and of a 4-site Heisenberg antiferromagnetic spin chain [8, 10], using adiabatic and diabatic state preparation methods and pairwise singlet-triplet readout based on Pauli spin blockade.

Here, we scale up the semiconductor quantum dot platform to a 2x4 array to simulate the physics of a spin ladder. First, we show the basic characterization of a 2x4 germanium quantum dot array [11, 12], including single charge occupation in each quantum dot, tunable tunnel coupling and Pauli spin blockade. Ongoing work is focused on the transition from a 2-rung spin ladder to two isolated 1-dimensional spin chains. For infinitely long ladders, this transition is expected to yield a quantum phase transition.

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