Towards coherent control of a spin ladder in germanium quantum dots

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Semiconductor quantum dot lattices are a promising platform for analog quantum simulations of Fermi-Hubbard physics, giving rise to a wealth of physical phenomena. Resent demonstrations include collective Coulomb blockade [1], Nagaoka ferro-magnetism [2], Heisenberg spin chains [3] and resonance-valence-bond physics [4]. A particularly interesting configuration is a spin ladder as it is predicted to exhibit the key ingredients behind high-Tc supercon-ducting behaviour [5].
Here we investigate a 2x4 array of Ge/SiGe quantum dots to simulate the physics of a spin ladder. We show the basic characteri-zation of a 2x4 germanium quantum dot ar-ray (Fig. 1), and demonstrate single charge occupation in each quantum dot, tunable tunnel couplings and Pauli spin blockade.
Motivated by the need for calibrating the spin exchange interactions across the lad-der, we study the coherent two-axis control of all four spin pairs along the rungs of the ladder, which effectively form singlet-triplet qubits. Specifically, we show ST- oscillations around the x-axis of the Bloch sphere and demonstrate rotations around the z-axis that are driven by the exchange coupling. We are able to control the couplings either via detuning of the double dot or via the barrier voltage between two dots (Fig 2).
Experiments demonstrating sequential readout of two or more qubits are under-way, as are measurements geared at two-qubit gates between the ST- qubits.
Next we will probe the expected quantum phase transition between a spin-liquid-like phase and a dimer phase as a function of exchange couplings.

References

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Figures

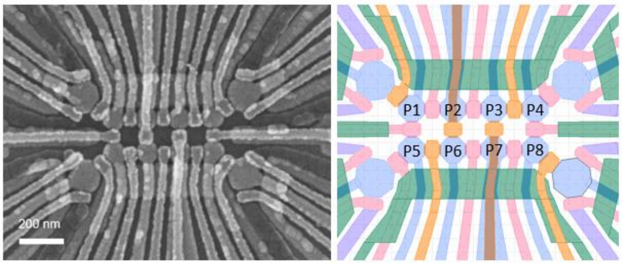

Figure 1: AFM image of the device (on the left). Device design (on the right): plunger/sensor gates are in blue, barrier gates are in pink (first fabrication layer) and orange (top fabrication layer), screening gates are in green, ohmic con-tacts are in purple.

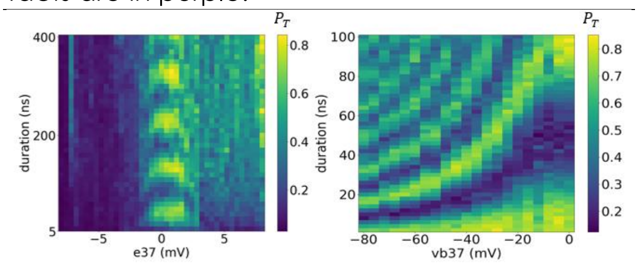

Figure 2: Two axis control of the P3-P7 pair of the device: x-axis control resembling ST- oscillations (on the left), z-axis control resembling exchange oscillations tuned via the barrier voltage (on the right).