Quantum information processing with graphene quantum dots

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Spin qubits in semiconductors have the advantage that the operation and fabrication of gate electrodes are similar to classical transistors. High-quality qubits have been demonstrated on multiple semiconductor platforms including traditional bulk MOSFETs as well as on III-V, silicon- and germanium-based heterostructures. Graphene offers several advantages as a host material for spin qubits, namely naturally low nuclear spin concentrations and weak spin-orbit interactions, similar to Si. In addition, the 2D nature of graphene allows for much smaller and more strongly coupled quantum devices . Furthermore, bilayer graphene quantum dots offer the flexibility of bipolar operation. Here we demonstrate recent advancements toward quantum information processing; we study the one- and two-electron excited state spectra in single and double quantum dots and demonstrate that the spin and valley states can be well manipulated by both electric and magnetic fields [1-2]. The high-tunability allows us to switch controllably between Pauli spin-blockade and valley-blockade physics [3], which are the crucial for qubit readout and two-qubit operations. We then perform an Elzerman-style [4] single-shot readout of the excited spin state with a signal-to-noise ratio of about 7 and find relaxation times to the spin ground state of up to 50 ms with a strong magnetic field dependence, promising even higher values for smaller magnetic fields [5]. The spin relaxation time is a few orders of magnitude longer than typical spin-qubit operation times and competes very well with other group IV elements like silicon.