Ultra-long relaxation of a Kramers qubit formed in a bilayer graphene quantum dot

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Abstract

The intrinsic valley degree of freedom makes bilayer graphene a unique platform for emerging types of semiconducting qubits. The single-carrier quantum dot ground state exhibits a two-fold degeneracy where the two states have opposite spin and valley quantum numbers. By breaking the time-reversal symmetry of this ground state with an out-of-plane magnetic field, a novel type of qubit (Kramers qubit), encoded in the two-dimensional spin–valley subspace, becomes accessible. The Kramers qubit is robust against known spin- and valley-mixing mechanisms, as it requires a simultaneous change of both quantum numbers, potentially resulting in long relaxation and coherence times. We measure the relaxation time of a single carrier in the excited states of a bilayer graphene quantum dot at small (~ mT) and zero magnetic fields. We demonstrate ultra-long spin-valley relaxation times of the Kramers qubit exceeding 30 s, which is about two orders of magnitude longer than the spin relaxation time of 400 ms. The demonstrated high-fidelity single-shot readout and long relaxation times are the foundation for novel, long-lived semiconductor qubits [1].

References

[1] Artem O. Denisov, Veronika Reckova, Solenn Cances, Max J. Ruckriegel, Michele Masseroni, Christoph Adam, Chuyao Tong, Jonas D. Gerber, Wei Wister Huang, Kenji Watanabe, Takashi Taniguchi, Thomas Ihn, Klaus Ensslin, Hadrien Duprez., 10.48550/arXiv.2403.08143

Figures

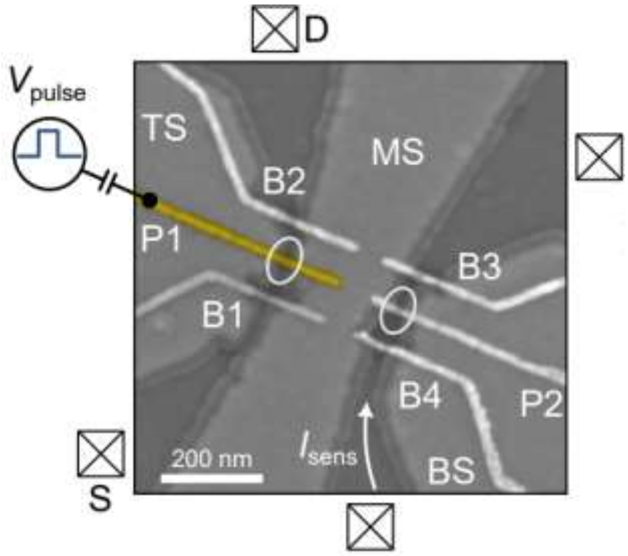

Figure 1: SEM false-colour image of the device. All labelled metallic gates and the graphite back gate (not shown) are DC-biased. The plunger gate P1 is additionally controlled by AC pulses.

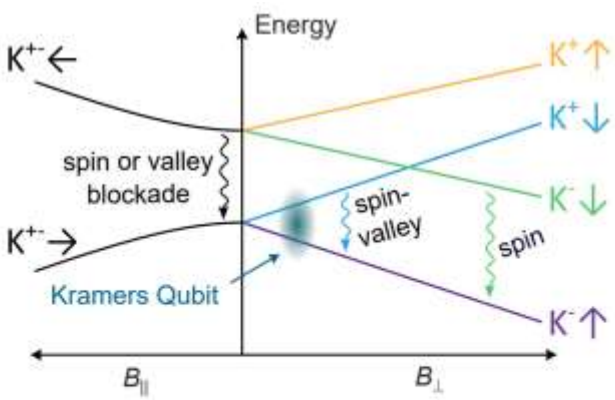

Figure 2: The energy spectrum of a single carrier in the BLG QD plotted as a function of in-plane and out-of-plane magnetic fields.