Charge and spin coherence in Landau-Zener interferometry in quantum dots

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Two-electron spin qubits in a double quantum dot can be coherently manipulated using Landau-Zener-Stückelberg-Majorana (LZSM) transitions at the singlet (S)-triplet (T_+) anti-crossing. The level coupling leading to this anti-crossing originates from a magnetic field gradient which can e.g. be realized by the hyperfine interaction with the nuclear spins of the host material [1,2]. In this case, however, the fluctuations of the nuclear spin bath result in spin dephasing within T_2^*~10–20 ns. As a consequence, the sweep through the anti-crossing would have to be performed on a timescale comparable to T_2^* to achieve LZSM oscillations with near 100% visibility. Moreover, the S-T_+ anti-crossing is located near the (1,1)–(2,0) interdot charge transition, where (n_L,n_R) denotes the charge state with n_L (n_R) electrons on the left (right) quantum dot. As a result, the singlet state involved in the dynamics is a superpostion of (1,1) and (2,0) singlet states. We show that it is possible to increase the oscillation visibility while keeping sweep times less than T_2^* using tailored pulses with a detuning dependent level velocity. These "double-hat" pulses include a slow level velocity portion that is chosen to coincide with the passage through the S-T_+ anti-crossing and two fast level velocity portions. The latter minimize the time spent in regions where spin and charge degrees of freedom are entangled, which renders the qubit susceptible to charge noise. The slow level velocity part of the pulse results in a stronger effective coupling between the spins states, which increases the oscillations visibility [3,4]. This constitutes an important step towards the coherent adiabatic implementation of elementary quantum gates such as the Hadamard gate.

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[2] H. Ribeiro, J. R. Petta, and G. Burkard, Phys. Rev. B **82**, 115445 (2010).
[3] H. Ribeiro, G. Burkard, J. R. Petta, H. Lu, and A. C. Gossard, Phys. Rev. Lett. 110, 086804 (2013).
[4] H. Ribeiro, J. R. Petta, G. Burkard, arXiv:1210.1957 (2012).

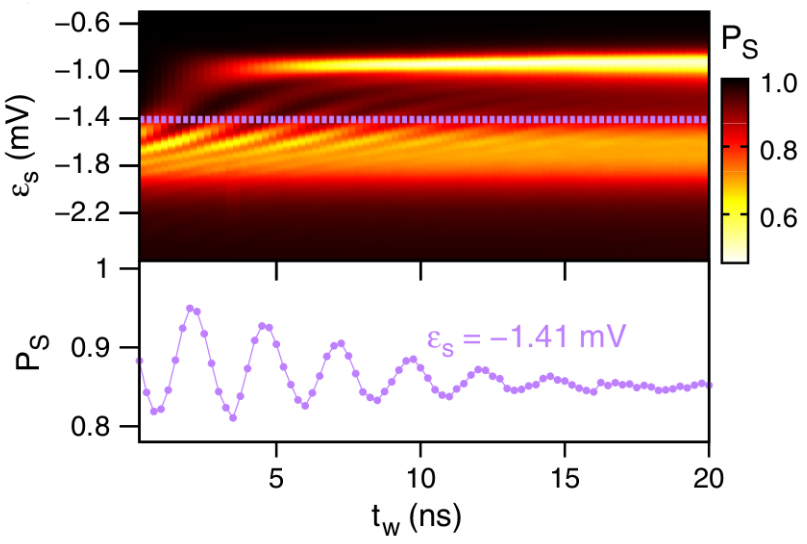

Figure (from [3]): Theoretical calculations of singlet return probability P_S as a function of waiting time t_w and inter-dot bias ε_s for double hat pulses and B=55 mT. Theory is in qualitative agreement with the experimental measurements [3].