

### Spin splitting in open quantum dots

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Recently there has been a lot of interest in the spin properties of semiconductor quantum dots. This is due not only to the new fundamental physics that these devices exhibit but also to possible applications in the emerging fields of spintronics and quantum information. In the case of small symmetric dots these exhibit properties reminiscent of those of real atoms, including the formation of a shell structure filled according to Hund's rule that favours a ground state with maximum possible spin [1].

One method to probe the nature of the spin states in quantum dots is through Coulomb blockade (CB) experiments. The CB regime corresponds to a weak coupling between the dot and the leads, so that the number of electrons in the dot is integer and each peak signals an addition/removal of one electron to/from the dot. In strong contrast to the Coulomb blockade regime in the *open dot* regime electrons can freely enter and exit the dot via leads that support one or more propagating modes. In this case the charge quantization no longer holds and one may expect that the conductance is mediated by two independent channels of opposite spin resulting in a total spin equal to zero in the dot. The degree of spin degeneracy in this regime was probed in [2] for a large chaotic dot where the statistical analysis of the conductance fluctuations indicated that a dot was spin-degenerate at low magnetic fields. Here we present experimental evidence that in small open dots two spin channels are correlated and therefore *the spin degeneracy can be lifted* [3].

Specifically we demonstrate that the magnetoconductance of small lateral quantum dots in the strongly-coupled regime (i.e. when the leads can support one or more propagating modes) shows a pronounced splitting of the conductance peaks and dips which persists over a wide range of magnetic fields (from zero field to the edge-state regime) and is virtually independent of the magnetic field strength, see figure 1 below.

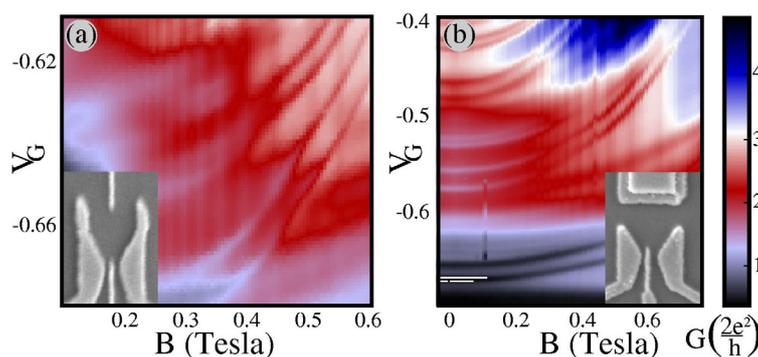


Figure 1: Experimental conductance as a function of magnetic field  $B$  and gate voltage  $V_G$  obtained from different dots. The lithographic size of the dots is  $\sim 450\text{nm}$ . Note the distinct splitting in the conductance.

Our numerical analysis of the conductance based on the Hubbard Hamiltonian demonstrates that this is essentially a many-body/spin effect that can be traced to a splitting of degenerate levels in the corresponding closed dot (see figure 2 on the second page). The above effect in

open dots can be regarded as a counterpart of the Coulomb blockade effect in weakly coupled dots, with the difference, however, that the splitting of the peaks originates from the interaction between the electrons of opposite spin.

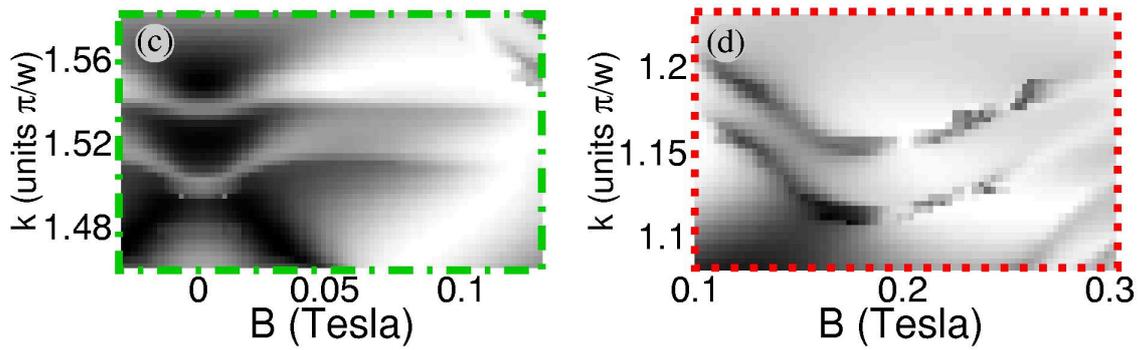


Figure 2: Computed conductance as a function of magnetic field and fermi wave vector  $k$ . The splitting seen appears as the interaction between electrons of different spin is included into the Hubbard Hamiltonian describing the system.

- [1] S. Tarucha *et al.*, Phys. Rev. Lett. **77**, 3613 (1996).
- [2] J. A. Folk *et al.*, Phys. Rev. Lett. **86**, 2102 (2001).
- [3] [arxiv.org/abs/cond-mat/0306327](https://arxiv.org/abs/cond-mat/0306327).