Perfect Zeeman Anisotropy in Rotationally Symmetric Quantum Dots with Strong Spin-Orbit Interaction

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We investigate the magnetic properties of very thin (quasi 2D) quantum dots (QDs) embedded in InAs nanowires formed by crystal phase control. In previous studies, we have shown that ring-like states can form, where the effective Landé *g*-factors can be controlled over a wide range using electric (*E*-) fields [1, 2]. In this work we show that by careful tuning of the rotational symmetry in similar QDs, it is possible to completely suppress orbital interactions of valence electrons, probed by magnetic (*B*-) fields aligned with the ring-symmetry axis ($B_{\|}$).

Due to a high QD electron occupation, the orbital angular momentum of the probed electron states become significant (80 μ_B), which in turn provides a strong (~1 meV) spin-orbit interaction (SOI). In agreement with theoretical predictions for symmetric quantum rings with SOI, Zeeman splitting becomes perfectly suppressed for perpendicular *B*-fields ($B_{\perp}$) where no flux threads the ring. However, when the symmetry is broken through *E*-field detuning, orbital interaction and Zeeman splitting becomes possible, where the effective *g*-factor eventually recovers to the typical value observed for InAs QDs.

For two valence electrons, we find that the *B*-field dependence of ground-excited state transitions show a basically perfect agreement with a 1D quantum ring model that includes electron-electron and spin-orbit interaction. The strong SOI lifts the degeneracy of the triplet ground state, where the orbital configuration of the singlets and triplets determine which states interact via SOI. We probe how interactions are affected by breaking the rotational symmetry, and tilting the *B*-field away from the ring axis.

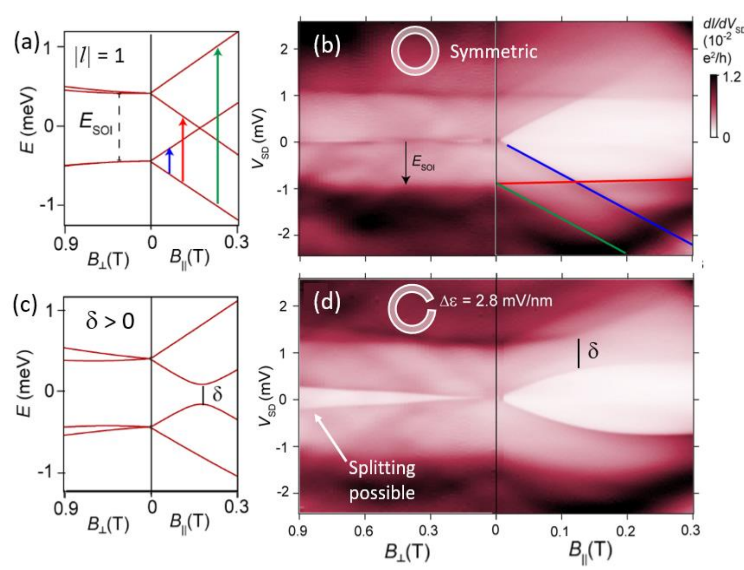

Fig.1. (a) One-electron state energies involving the $l = \pm 1$ orbitals in an ideal 1D quantum ring with SOI, plotted as function of *B*-field. (b) Corresponding experimental transport spectroscopy that probe level differences for a QD with rotational symmetry. (c) Symmetry breaking allows orbital mixing and Zeeman splitting for perpendicular *B*-fields. (d) Corresponding measurement for a non-optimum *E*-field slightly changed relative to panel b.

References

[1] H. Potts *et al.* Nature Communications **10**, 5740 (2019).
[2] R. Debbarma *et al.* Nano Letters **22**, 334 (2022).