Many-Body Renormalization of Hole g-Tensors for Different Occupancies

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Abstract

Hole g-tensors in germanium quantum dots depend on the orbital states occupied by the system. Accessing higher-lying orbitals typically requires loading multiple holes into the dot, making interactions an intrinsic part of the problem. This work sets out to explore how these multi-hole effects influence the g-tensor and to what extent a mean-field description is sufficient. Starting from a microscopic single-particle Hamiltonian, Coulomb interactions are included and treated within a self-consistent Hartree–Fock framework, yielding an effective one-body description.
The aim is to identify regimes in which this approach is expected to capture the relevant physics, as well as situations where it may break down due to stronger correlations or state mixing. By relating the model to available experimental trends, this study seeks to clarify how interactions and orbital filling shape g-tensor behaviour and to assess the scope of mean-field models for multi-hole quantum dot systems.

References

[1] Valvo et al., Electrically Tuneable Variability in Germanium Hole Spin Qubits (2025)
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[3] G.Guiliani and G.Vignale, Quantum Theory of the Electron Liquid (2005)
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Figures

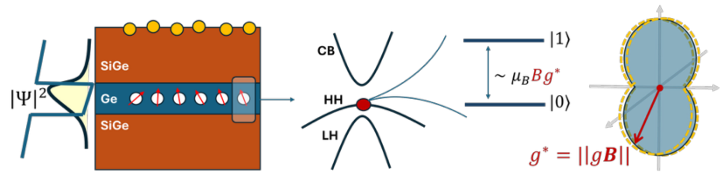

Figure 1: Schematic of a SiGe quantum dot hosting hole states.
Left: confinement leads to predominantly heavy-hole states, with possible mixing from light-hole components. Centre: this mixing gives rise to an anisotropic g-tensor. Right: the resulting Zeeman splitting depends on magnetic field direction, reflecting the heavy-hole character and its anisotropy.

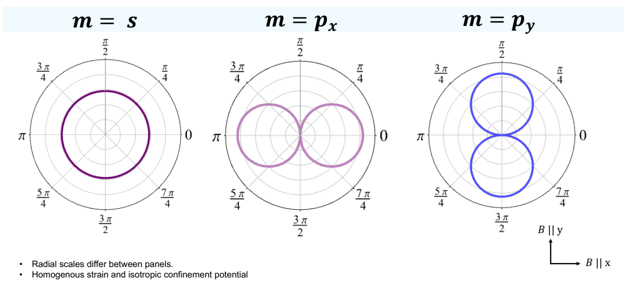

Figure 2: g-tensors for ideal (perfectly symmetric) confinement. From left to right: the isotropic case (s-like state), where the g-tensor is the same in all directions, and the anisotropic cases p-like states, where the g-tensor reflects the orbital symmetry and exhibits directional dependence along orthogonal axes.