Exchange anisotropies in microwave-driven singlet-triplet qubits

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Hole spin qubits are becoming key players in semiconducting quantum processors due to their strong spin-orbit interaction (SOI), enabling fast and all-electric operations. However, this interaction also introduces challenges, such as non-uniform qubit energies and site-dependent anisotropies, which, if uncontrolled, might hinder scalability of semiconducting quantum circuits. Recently, multiple works have focus on studying and exploiting the SOI induced quantization axes tilt between two spins [1-4]. Here, we report on microwave-driven singlet-triplet qubits in planar germanium and use them to investigate the anisotropy of two spins in a double quantum dot. We introduce a simple protocol to explore and harness the anisotropy of spin qubits based on a single magnetic field sweep in a fixed direction, instead of rotating the magnetic field along the azimuthal and polar angles to extract the g-tensors [2-4]. We show two distinct operating regimes depending on the magnetic field direction. For in-plane fields, the two spins are largely anisotropic, and electrically tunable, see Fig. 1, which enables to measure all the available transitions; coherence times exceeding 3 µs are extracted. For out-of-plane fields, they have an isotropic response but preserve the substantial energy difference required to address the singlet-triplet qubit. Even in this field direction, where the qubit lifetime is strongly affected by nuclear spins, we find 400 ns coherence times. Our protocol can be implemented in any large-scale NxN device, facilitating the path towards scalable quantum processors, including those with synthetic SOI due to the presence of micromagnets.

References

[1] van Riggelen-Doelman et al., Nat. Comm., 15, 5716 (2024).
[2] Geyer et al. Nat. Physics 20, 1152–1157 (2024).
[3] Hendrickx et al. Nat. Materials 23, 920–927(2024).
[4] Liles et al. Nat. Comm 15, 7690 (2024).

Figures

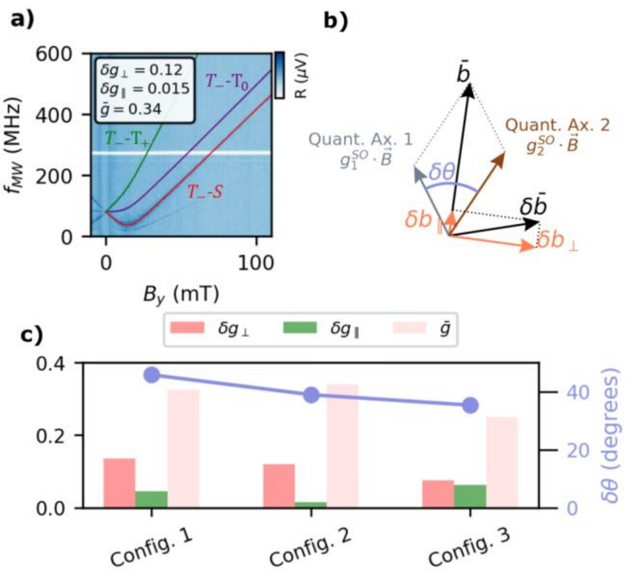

Figure 1: a) In-plane magnetic field spectroscopy. b) Schematic explaining the quantization axes (grey and brown), the addition and difference of the Zeeman vectors (black) as well as the projections δb‖ and δb⊥ (orange). δθ represents the tilt in the quantization axes. c) Components of g-tensor anisotropies for three different voltage configurations, including the misalignment (δθ) between the quantization axes. The results highlight the electrical tunability of the relative tilt between the spins and exchange anisotropy.