Dynamics of hole singlet triplet qubits with large g-factor differences

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Abstract (Century Gothic 11)

Holes in SiGe/Ge quantum wells hold great promise for spin qubits as they possess several favorable qubit properties: a small effective mass, a strong spin-orbit coupling, long relaxation time and an inherent immunity to contact hyperfine interaction [1]. All these characteristics helped Ge hole spin qubits to evolve from a single qubit to a fully entangled four qubit processor in only 3 years [2]. Here, we investigate the singlet-triplet qubit approach leveraging the large out-of-plane g-factors of heavy hole states in Ge quantum dots [3]. We found this qubit to be reproducibly operable at magnetic fields as low as 1 mT and at large rotation frequencies exceeding 600 MHz. This was possible because large differences of g-factors in adjacent dots can be achieved in the out-of-plane magnetic field direction. In the in-plane direction, on the other hand, the heavy-hole g-factors are small and can be altered very effectively by the confinement potentials leading even to a sign change. The resulting g-factor difference drastically influences the dynamics of the system and produces effects typically attributed to a spin-orbit induced spin-flip term (See Figure 1).

Our work gives further insights into the possibilities of holes in Ge but also reveals important properties that need to be considered when designing future spin qubit experiments.

References

[1] Scapucci, G et al., Nature Reviews Materials (2020)
[2] Hendrickx, N. W. et al, Nature, 591 (2021) 580-585
[3] Jirovec, D. et al, Nature Materials, 20 (2021) 1106-1112

Figures

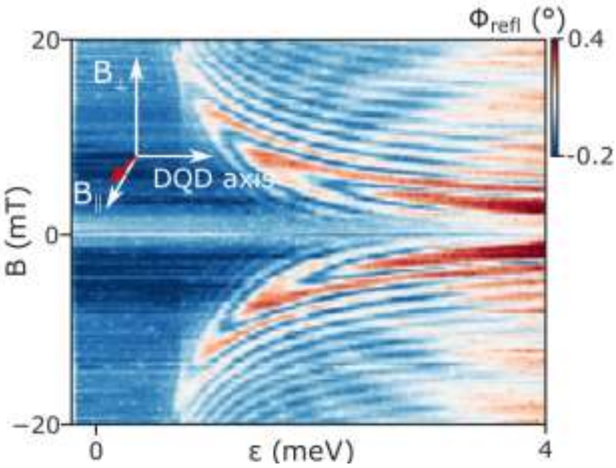

Figure 1: An intriguing butterfly shaped pattern appears when measuring the singlet-triplet degeneracy in the in-plane magnetic field direction. This pattern emerges as a consequence of a large coupling term between these two states. While typically a direct spin-orbit spin-flip term is responsible for this coupling we show that large g-factor differences are the actual cause.