Electrically Tuneable Variability in Germanium Hole Spin Qubits

Edmondo Valvo
Michele Jakob, Patrick Del Vecchio, Stefano Bosco, Maximilian Rimbach-Russ

QuTech and Kavli Institute of Nanoscience Delft, Delft University of Technology, PO Box 5046, 2600 GA Delft
evalvo@tudelft.nl

Hole spin qubits in planar germanium (Ge) heterostructures are frontrunners for scalable semiconductor quantum computing. However, their current performance is mostly limited by large dot-to-dot variability [1-2].

We propose a local method to engineer the spin qubit response by imprinting a controlled anisotropy in the quantum dot (QD) confinement, enabling on-demand electric g-tensor control. We find that both the quantum-dot size and asymmetry allow electrical tuning and suppression of magnitude and angular variability of the spin response for selected magnetic field directions. We confirm this behaviour by simulating statistical ensembles of state-of-the-art strained and unstrained [3-4] germanium channels, showing that the latter provides an optimal path for g-tensor engineering.

Our results provide practical design principles for on-demand control of the spin response and mitigating variability [5], paving the way towards large-scale germanium-based quantum computers.

References

[1] Seidler,I. Et al. arXiv:2510.03125 (2025)
[2] Martinez, B. et al. arXiv:2507.04953 (2025).
[3] Costa,D. et al. arXiv:2506.04724 (2025)
[4] Mauro,L. et al. arXiv:2506.04977 (2025)
[5] Valvo, E. et al. arXiv:2512.12702 (2025)

Figures

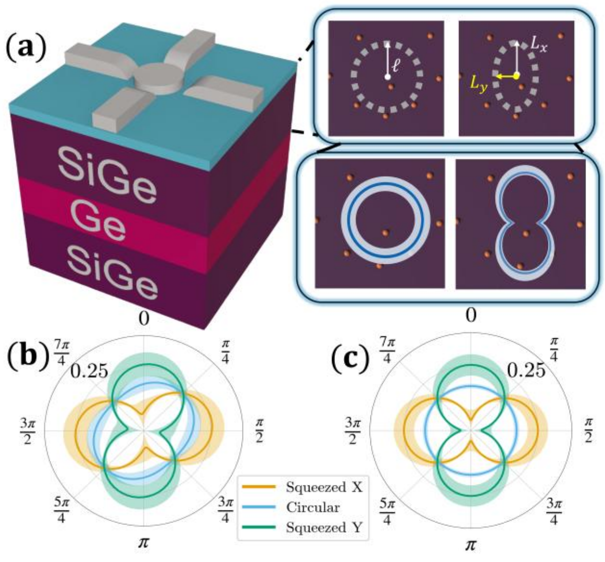

Figure 1: Sketch of planar Ge heterostructures with circular and squeezed QDs, including interface disorder (orange dots). (b)-(c) Simulated g-tensors and standard deviations, for strained (b) and unstrained (c) Germanium

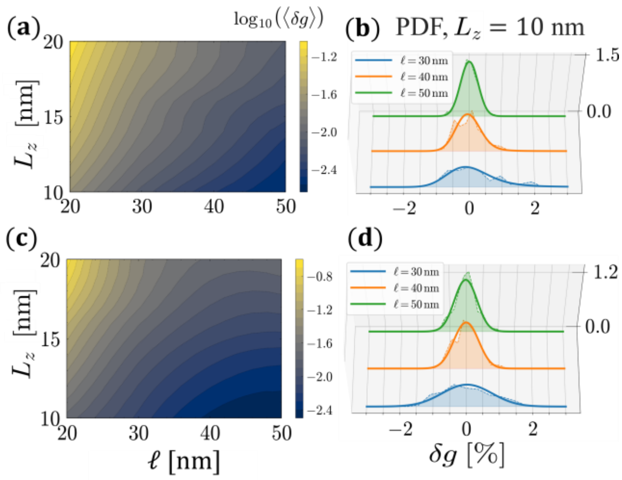

Figure 2: (a)-(b) Standard deviation (a) and probability distribution functions of the relative g-factors variation δg of circular QDs in strained Ge with Lz = 10 nm. (c)-(d) present the results for unstrained Ge. For circular QDs, the variability is generally lower at smoother confinements both in-plane and out-of-plane. Both cases have been computed by averaging over 200 noise realizations.