

A Vertical Spin Qubits Array in Bilayer Ge/SiGe

Dario Denora¹

Pietro Borghi¹, Marion Bassi¹, Merritt P. Losert², Setareh Kazemzadeh¹, Barnaby van Straaten¹, Lucas Stehouwer¹, Justyna P. Zwolak², Giordano Scappucci¹, Menno Veldhorst¹.

[1] *QuTech and Kavli Institute of Nanoscience, Delft University of Technology*
d.denora@tudelft.nl

Quantum dot-based spin qubits have seen rapid developments in device complexity, with qubit scaling remaining a key priority. Approaches towards scaling up spin qubits are primarily based on one- or two-dimensional planar arrays. In the case of Ge/SiGe gate-defined quantum dots, by introducing an additional quantum well, vertically coupled quantum dots can be formed [1].

In recent years, robust control over the charge degree of freedom of multi-layer Ge/SiGe heterostructures has been demonstrated, enabling the realization of three-dimensional quantum dot arrays [2]. Building on these results, we here demonstrate an automated protocol for analyzing charge stability diagrams (CSDs) for bilayer devices [3]. By combining ML, object detection, we can identify different types of transition with otherwise similar features.

This advancement allows us to report the first demonstration of initialization and readout of a vertical 2-by-2 array. By means of intra-layer (horizontal) and inter-layer (vertical) spin shuttling, we fully characterize the single-qubit operation fidelities (>99%) and g-tensor anisotropy (Figure 2). We find that vertically stacked QDs exhibit significantly different out-of-plane g-factors, which range from 6 in the upper layer to 10 in the lower layer.

References

[1] H. Tidjani, et al., *Physical Review Applied* 20.5 (2023).

[2] H. Tidjani*, D. Denora*, et al., <https://arxiv.org/abs/2512.01634> (2025).

[3] L. Merritt PR, D. Denora et al. *arXiv:2601.00067* (2025).

Figures

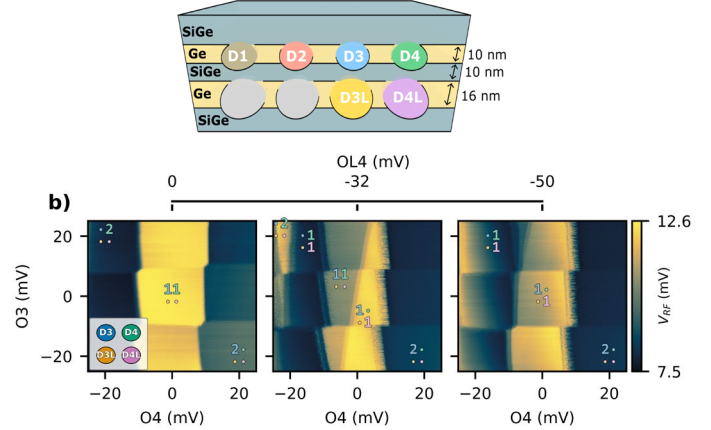


Figure 1: (a) Double-well schematic showing the position of the QDs in the heterostructure. (b) Charge stability diagram (CSD) showing control of the vertically stacked QDs.

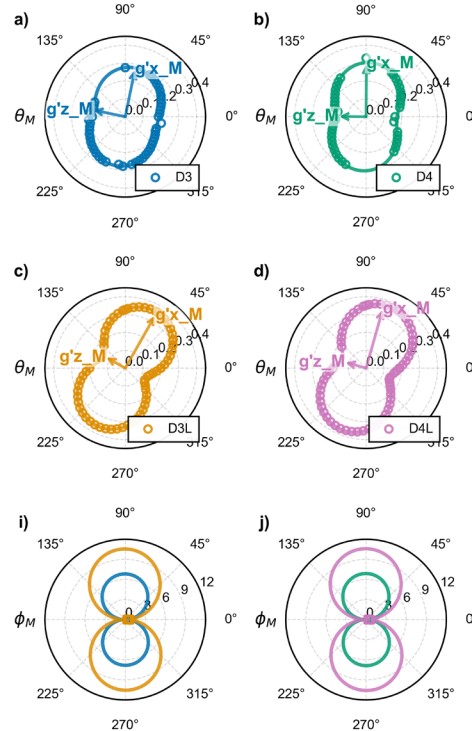


Figure 2: (a-j) g-factors of each QD in the vertical 2x2 array as a function of in-plane and out-of-plane field directions with the corresponding fitting table.