Optimal control for error mitigation on molecular spin qudits

Alonso Hernández Antón[1, 3*]
David Zueco[1]
Fernando Luis[1]
Alberto Castro[2]

[1]Instituto de Nanociencia y Materiales de Aragón, CSIC-Universidad de Zaragoza, 50009, Zaragoza, Spain
[2]Instituto de Blocomputación y Física de Sistemas Complejos, Universidad de Zaragoza, 50009, Zaragoza, Spain
[3]Quantum Device Lab, ETH Zürich, Otto-Stern-Weg 1, 8093 Zürich, Switzerland
* alhernandezanton@gmail.com

Abstract

The most extended approach to fault-tolerant quantum computing is the execution of error correction protocols on multi-qubit devices [1], which requires many physical qubits for few logical information and presents scaling and connectivity issues. Molecular spin qudits have been proposed as a promising alternative [2]. The lifetimes of spins typically outperform other solid-state platforms, and their multi-level character allows for efficient encodings that require less connectivity. Although there exist recent demonstrations of single-spin addressing [3], this technology is typically restricted to spin ensembles, which show shorter T_2 due to the interaction between neighbouring spins. Thus, the coherent control of these systems must be engineered to mitigate errors. Here we apply optimal control techniques to a molecular spin qudit and shape control pulses to maximize the fidelities of certain operations on it [4]. We consider the spin 7/2 of a GdW_{30} molecule, which is coupled to a control field and to the environment (Fig.1), and encode three qubits within its eight energy levels. We model the dynamics as a Lindblad master equation and search for optimal pulses to implement a Toffoli gate. The optimization considers the whole model and therefore accounts for the dissipation. For T_2 = 500 ns [5], we find pulses that implement this unitary in tens of ns with fidelities around 90% (Fig. 2), even in the presence of this strong dephasing.

Figures

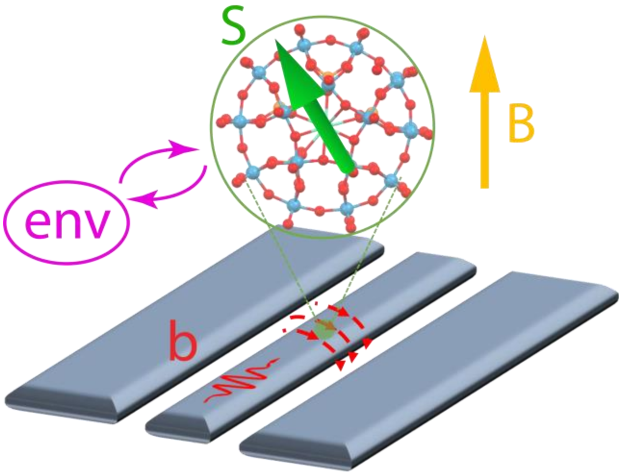

Figure 1: A molecular spin qudit is controlled by superconducting line that routes RF signals to it. The spin level splittings are tuned with an external DC magnetic field. Interaction with surrounding spins yields non-unitary dynamics.

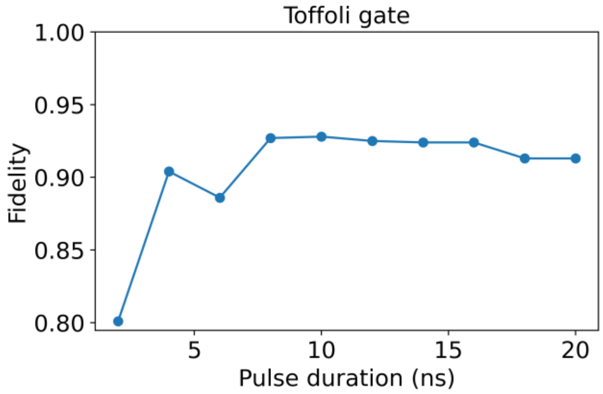

Figure 2: Toffoli gate fidelity, with pulses optimized for different durations up to 20 ns.

References

[1] Google Quantum AI, *Nature* 614 (2023), 676–681
[2] Carretta et al., Appl. Phys. Lett. 118 (2021), 240501
[3] Wang et al., arXiv:2301.02653
[4] Castro et al., Phys. Rev. Applied 17 (2022), 064028
[5] Jenkins et al., Phys. Rev, B 95 (2017), 064423
[6] Jenkins et al., Phys. Rev. B 95 (2017), 064423