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Decoherence of spin chirality qubits

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Molecular nanomagnets represent a varied class of spin clusters, whose physical properties can be extensively engineered by chemical synthesis. This makes them a potential alternative to other spin systems for the implementation of spin-cluster qubits. While most of the attention has been so far focused on the use of the total-spin projection (Sz) as a computational degree of freedom, it has been recently realized that alternative encodings would enable the use of electric—rather than magnetic—fields for the qubit manipulation [1,2]. In particular, transitions between states of opposite spin chirality (Cz) can be induced, with estimated gating times τg in the ns range.

In order to assess the suitability of spin chirality for applications in quantum-information processing, τg has to be contrasted with a characteristic decoherence time τd. Here we theoretically estimate the characteristic time scale of hyperfine-induced decoherence, and investigate its dependence on the qubit encoding within a prototypical spin-cluster qubit, consisting of an antiferromagnetic spin triangle, coupled to a bath of nuclear spins. In particular, we consider three different encodings, based on Sz, Cz, and the partial spin sum S12, whose value—as that of Cz—can be controlled through spin-electric coupling. Values of the decoherence times approaching the ms are found for the spin chirality. S12 is instead characterized by decoherence times comparable to those of the total-spin projection. We conclude that an effective decoupling of the molecular spin cluster from the nuclear spin bath requires the logical states to be indistinguishable both in terms of the total- and of the individual-spin expectation values.

[1] M. Trif, F. Troiani, D. Stepanenko, and D. Loss, Phys. Rev. Lett. 101, 217201 (2008).
[2] M. Trif, F. Troiani, D. Stepanenko, and D. Loss, Phys. Rev. B 82, 045429 (2010).
[3] F. Troiani, D. Stepanenko, and D. Loss, Phys. Rev. B 86, 161409(R) (2012).