Electrical two-qubit gates within a pair of clock-qubit magnetic molecules

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Solid-state nanoelectronic devices can now host single-qubit quantum logic operations with high fidelity and have also demonstrated quantum operations employing the spins of an electron bound to a single-donor atom, introduced in the silicon by ion implantation.[1] Molecules, being much more versatile than atoms, and yet microscopic, are claimed to be the quantum objects with the highest capacity to form non-trivial ordered states at the nanoscale, with their potential therefore deserving exploration.[2] Enhanced coherence in qubits based on Ho^{3+} spin states in a HoW_{10} molecule has been demonstrated by use of Clock Transitions (CTs) at T=5K.[3] More recently it was shown that, while operating at the CTs, it was possible to use an electrical field to selectively address HoW_{10} molecules pointing in a given direction, within a crystal that contains two kinds of identical but inversion-related molecules.[4] Herein we theoretically explore the possibility of employing electric field pulses to effect entangling two-qubit quantum gates among two neighbouring CT-protected HoW_{10} molecular spin qubits within a diluted crystal. We also estimate the thermal evolution of T_1, T_2 in this system, and find that CTs are also optimal operating points from the point of view of phonons, and that even a moderate cooling to T=2 K would significantly increase coherence times in the order of 100 µs. We find that, provided challenging initialization requirements are met, it will be possible to combine a sequence of microwave and electric field pulses to achieve coherent control within a 2-qubit operating space that is protected both from spin-bath and from phonon-bath decoherence. Finally, we found a highly protected 1-qubit subspace resulting from the interaction between two clock molecular qubits.

References

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Figures

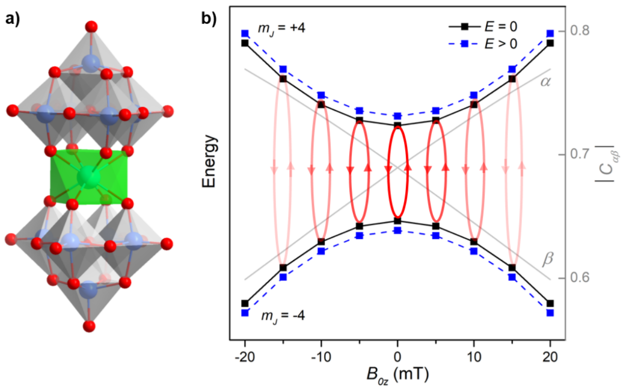

Figure 1: {a) Molecular structure of HoW_{10} b) Spin energy levels evolution (black and blue lines) and admixing of wavefunction for $m_J=\pm4$ with corresponding coefficients (gray lines) upon magnetic field. An external electric field E field affects the anticrossing, thereby regulating the qubit transition energy.