Quantum Spintronic Qubit : first experiments

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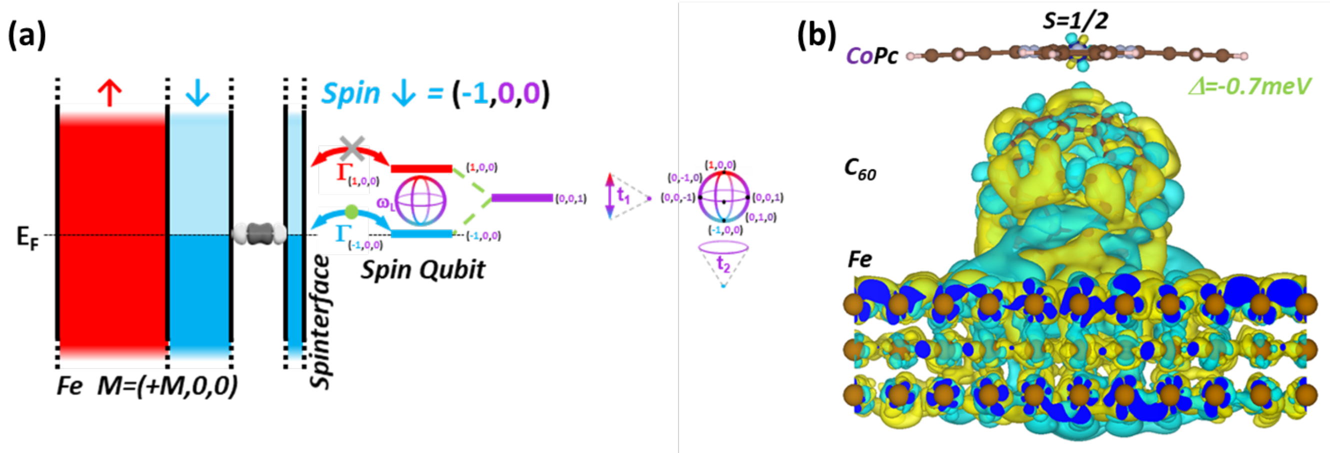

Many hardware platforms exist to implement qubit operations for quantum technologies, but these platforms, although conceptually elegant, do not offer a straightforward path toward consumer applications in terms of energy/resource usage (#QEI) [1]: low/very low temperatures, external magnetic fields, lasers/microwave sources, a room-full of optical/electrical/vacuum/cryogenic equipment, difficulty to entangle qubits... To address this challenge, **we propose a new platform: the quantum spintronic qubit.** It is an atomic paramagnetic atom that electronically interacts with a simple ferromagnetic metal across a fully spin-polarized interface ('spinterface', see panel a). Thanks to its solid-state spintronic implementation, this qubit paradigm offers many advantages: large/built-in magnetic field (panel b), spintronic initialization/manipulation/readout of the qubit along the Bloch sphere [2] (panel a), potential for room-temperature operation [2,3], built-in entanglement [4]. Our prior experiments and theory have identified several qubit candidates, from C atoms in MgO [2,5] (the spintronic reference spacer) to commercially available paramagnetic molecules (CoPc [3,6], see panel b).

Despite first successes in the areas of quantum information [5,6] and energy harvesting [2,3], this quantum spintronic qubit platform remains extremely immature compared to existing quantum technologies. We therefore propose as a PhD project to examine how to implement the di Vicenzo criteria within magnetotransport experiments across a CoPc-borne qubit embedded into a molecular spintronic nanojunction. The project will in particular evaluate the relevant time scales of the qubit's spintronic operational sequences. The PhD candidate will utilize the Molecular Quantum Spintronic team's research chain to grow heterostuctures, craft them into vertical molecular nanojunctions, and perform dc/ac magnetotransport measurements. Additional skill to be acquired include how to intuitively construct experimental measurement protocols based on scientific knowledge and experimental data-driven intuition. This research track thus offers solid training for academic/industrial career opportunities: UHV growth/characterization, clean-room, magneto-transport measurements, thinking outside the box.

[1] A. Auffèves, Quantum Technologies Need a Quantum Energy Initiative, PRX Quantum **3**, 020101 (2022).
[2] K. Katcko et al., Spin-driven electrical power generation at room temperature, Communications Physics **2**, 116 (2019).
[3] B. Chowrira et al., Quantum Advantage in a Molecular Spintronic Engine that Harvests Thermal Fluctuation Energy, Adv. Mater. **34**, 2206688 (2022).
[4] M. C. Arnesen, S. Bose, and V. Vedral, Natural Thermal and Magnetic Entanglement in the 1D Heisenberg Model, Phys. Rev. Lett. **87**, 017901 (2001).
[5] M. Lamblin and et al., Encoding information onto the charge and spin state of a paramagnetic atom using MgO tunnelling spintronics, arXiv:2308.16592 (2023).
[6] K. Katcko et al., Encoding Information on the Excited State of a Molecular Spin Chain, Advanced Functional Materials 2009467 (2021).