Masters 2 Thesis Internship

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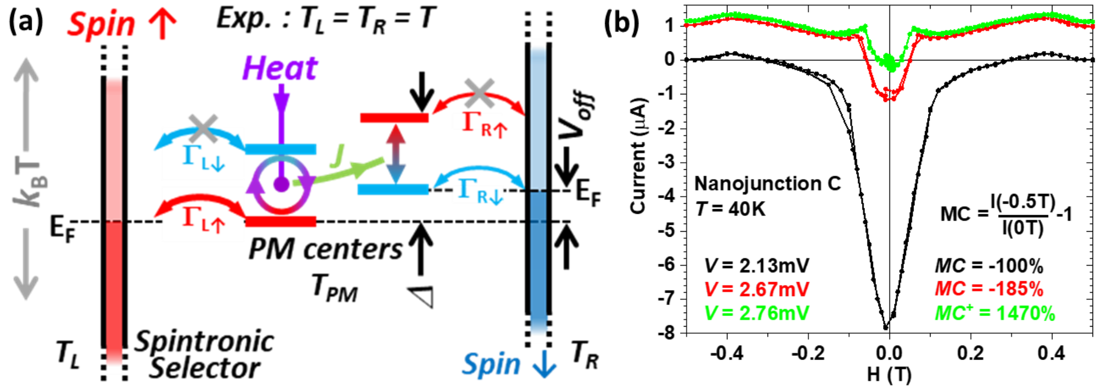
Post-Masters PhD funding : ANR Spin Elec project already secured

Controlling paramagnetic centers within a spintronic quantum engine

Join the budding revolution in quantum technologies, with an energy twist!
Contribute to technological efforts to mitigate the energy/climate crises!

A number of initiatives aim to harvest energy from our environment. These energy sources can be naturally occurring (solar irradiation, wind, thermal gradients due to solar irradiation) or artificially occurring (thermal gradients due to proximity to a heat engine, wifi/GSM emissions, vibrations, etc…). A set of recent experiments have explored, using model optics systems at very low temperature, how thermal fluctuations can drive the operation of **quantum heat and information engines**[1–3]. To enable practical applications, our team is designing these engines using spintronics[4], a green electronics that utilize the electron's quantum spin property (www.spinengine.tech). Spintronics already appears in hard disk drives and next-gen MRAM.



In a spintronic quantum engine (panel a, red is spin ↓, blue is spin ↑), the energy-split spin states of paramagnetic (PM) centers are stochastically occupied by thermal fluctuations (purple arrow, $k_BT>\Delta$). Charge transfer between these states and each fully spin-polarized electrode ('spintronic selector') thus takes place at different energy levels. This results in a spontaneous bias voltage/output electrical power, e.g. a current flow against the applied bias voltage (panel b, from Ref. [5]). By changing the relative orientation of the magnetic electrodes (in panel b with a magnetic field), the spin engine also acts as a switch of current flow, and of its direction. Underscoring this operation is the presence of several so-called quantum resources (squeezed bath, injection of quantum coherence, quantum entanglement, phase transition, quantum information readout…) that are thought to confer available work to the engine to asymmetrically shuffle electrons (arrows) between the coupled spin qubits and the spintronic selectors[1–3].

Our design not only enables room-temperature operation, but also outclasses other forms of energy harvesting[6]. So far, we have experimentally tested this spin engine using C PM centers in MgO barriers[6], and using Co PM centers in CoPc molecules (panel b). We propose as an experimental internship to establish a separate protocol to assess the properties (effective spin, coupling) of the paramagnetic centers that we use in our experimental devices. In collaboration with B. Vileno of the POMAM team, Institut de Chimie, Strasbourg, the candidate will assist with sample growth and perform electron spin resonance studies on appropriate CoPc-based samples. The bright candidate will integrate a sizeable research team that includes two PhD students already working on related aspects of the engine. The candidate will take part in magnetotransport measurements on nanofabricated devices. PhD funding is already available for this topic.

Starting References:

1. Klatzow, J. *et al. Experimental Demonstration of Quantum Effects in the Operation of Microscopic Heat Engines*. *Phys. Rev. Lett.* **122**, 110601 (2019).
2. Josefsson... *Double quantum-dot engine fueled by entanglement between electron spins.* PRB **101**, 081408 (2020).
3. Bresque, L. *et al. Two-Qubit Engine Fueled by Entanglement and Local Measurements*. *PRL.* **126**, 120605 (2021).
4. Kent & Worledge, *A new spin on magnetic memories*. *Nature Nanotech.* **10**, 187 (2015).
5. Chowrira, B., Kandpal, L. & et al. *Quantum advantage in a molecular spintronic engine that harvests thermal fluctuation energy* arXiv:2009.10413.
6. Katcko, K. et al. *Spin-driven electrical power generation at room temperature*. *Communications Physics* **2**, 116 (2019). *CNRS News. Unistra News.*