PhD Position: Insight into quantum spintronic energy harvesters using operando electron spin resonance

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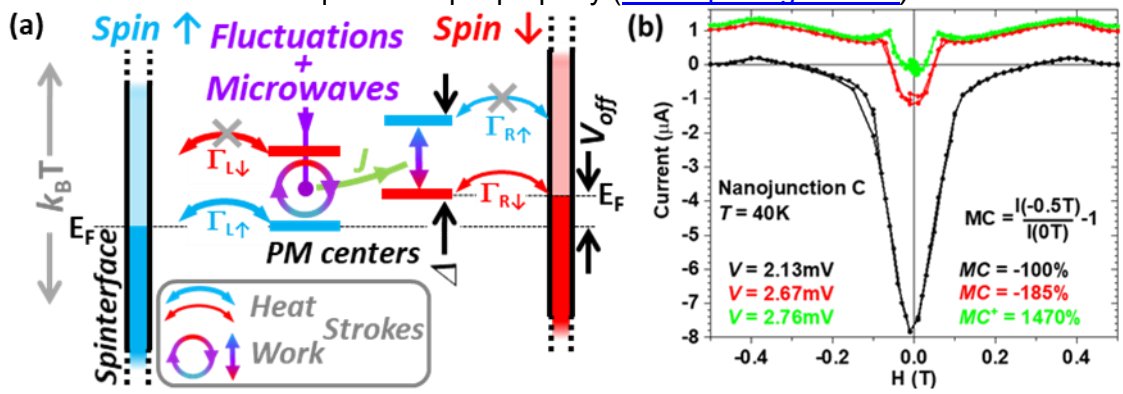
A number of initiatives aim to harvest energy from our environment. These energy sources can be naturally occurring (e.g. solar irradiation) or artificially occurring (e.g. wifi/GSM emissions). Model systems at very low temperature can reveal how thermal fluctuations can drive the operation of **quantum heat and information engines** [1]. To enable practical applications, our team is designing these engines using spintronics [2], a green electronics that utilize the electron's quantum spin property (www.spinengine.tech).



In **a spintronic engine** (panel a, red is spin ↓, blue is spin ↑), the energy-split spin states of paramagnetic centers are stochastically occupied by thermal fluctuations (purple arrow, $k_BT>\Delta$) that can be magnetically coupled (J). Charge transfer between these states and each fully spin-polarized electrode ('spinterface') thus takes place at different energy levels. **These spintronic operations convey quantum resources to the engine**, thus enabling its efficiency to surpass that of a classical engine [3].This results in a spontaneous bias voltage/output electrical power, e.g. a current flow against the applied bias voltage (panel b, from Ref. [4]). By changing the relative orientation of the magnetic electrodes (in panel b with a magnetic field), the spintronic engine also switches the flow and direction of current.

We recently reported [5] (CNRS News, Unistra News) on a spintronic engine with C atoms acting as the PM centers in the MgO barrier, and using the Co site of Co phthalocyanine molecules as the PM center [4] with up to ~100x more power output at RT. To better understand the role of spin fluctuations in the engine's operation, we propose to drive them using microwaves. The PhD candidate, based in Strasbourg, will grow CoPc-based heterostructures, synthesize nanopillar [6] devices and measure their energy generation properties, followed by campaigns of operando microwave experiments in Stuttgart.

Starting References:

[1] *Quantum & Information Thermodynamics: A Unifying Framework Based on Repeated Interactions*, Phys. Rev. X 7, 021003 (2017).

[2] *A New Spin on Magnetic Memories*, Nat. Nanotechnol. 10, 187 (2015).

[3] *Experimental Demonstration of Quantum Effects in the Operation of Microscopic Heat Engines*, Phys. Rev. Lett. 122, 110601 (2019).

[4] *Spintronic Harvesting of Thermal Fluctuations on Paramagnetic Molecular Centers around a Phase Transition*, ArXiv:2009.10413

[5] *Spin-Driven Electrical Power Generation at Room Temperature*, Commun. Phys. 2, 116 (2019).

[6] *Encoding Information on the Excited State of a Molecular Spin Chain*, Adv. Funct. Mater. 2009467 (2021).