Quantum spintronic energy harvesters

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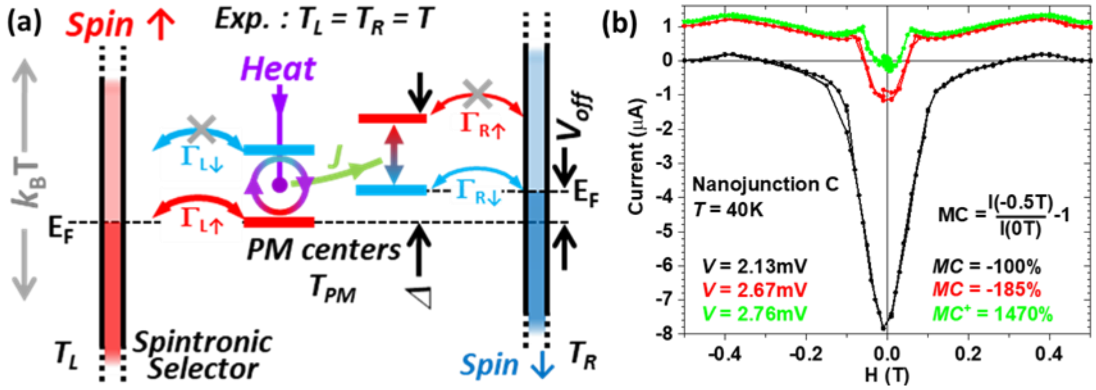
A number of initiatives aim to harvest energy from our environment. These energy sources can be naturally occurring (solar irradiation, wind, thermal gradients due to solar irradiation) or artificially occurring (thermal gradients due to proximity to a heat engine, wifi/GSM emissions, vibrations, etc…). A set of recent experiments have explored, using model systems at very low temperature, 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 ('spintronic selector') thus takes place at different energy levels. **These spintronic operations convey quantum ressources 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.

This PhD proposal aims to develop **this new paradigm of harvesting thermal fluctuations using quantum spintronic engines**. We recently reported [5] (CNRS News, Unistra News) how to achieve this effect at room temperature (RT) using the prototypical, industrialized MgO magnetic tunnel junction. There, C atoms acted as the PM centers in the MgO barrier. To confirm our conceptual description, we studied solid-state nanojunctions in which the Co site of Co phthalocyanine molecules is the PM center. These experiments reveal ~100x more power output at RT than previously. Within a team of researchers and engineers, the PhD candidate will execute the research chain of growing CoPc-based heterostructures, synthesizing CoPc-based and MgO-based (collab. IJL Nancy) nanopillar devices using the STNano technological platform, and measuring their energy generation properties.

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).