Master 2: ***International Centre for Fundamental Physics***

INTERNSHIP PROPOSAL

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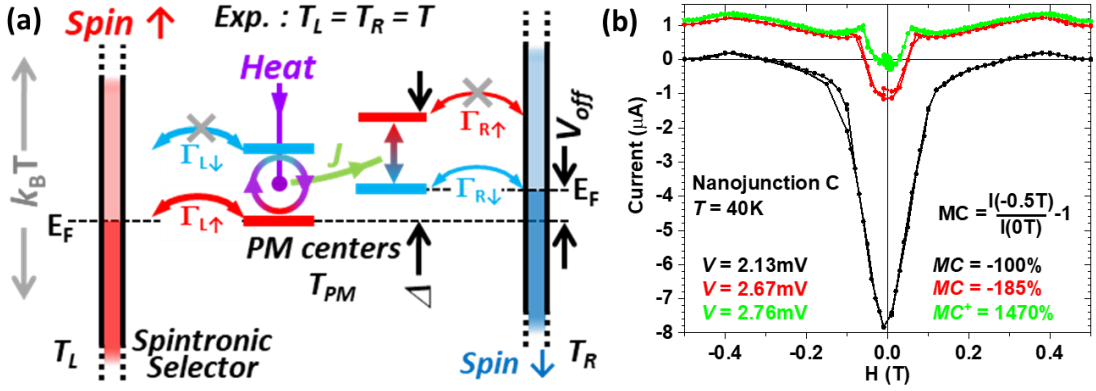
Internship location: Strasbourg, France
Thesis possibility after internship:YES Funding: YES, from French Government

Harvesting thermal fluctuations using spintronics

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 spin 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, $k_BT>\Delta$). 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. 3). 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.

Our design not only enables room-temperature operation, but also outclasses other forms of energy harvesting[4]. We have tested this spin engine using C PM centers in MgO barriers[4], and using Co PM centers in CoPc molecules (panel b). The exchange coupling J (panel a) between PM centers plays an important role in this spintronic energy harvesting[3], but several origins of the spin engine's thermodynamical imbalance remain to be tested[3].

We propose as an experimental internship to study whether spintronic energy harvesting alters the temperature of the spintronic selectors in vertical molecular nanojunctions. The bright candidate will integrate a sizeable research team and acquire expertise in cleanroom techniques and magnetotransport measurements.

Starting References:

1.Strasberg, P. et al, *Quantum and Information Thermodynamics: A Unifying Framework Based on Repeated Interactions*. *Phys. Rev. X* **7**, 021003 (2017).
2. Kent & Worledge, *A new spin on magnetic memories*. *Nature Nanotech.* **10**, 187 (2015).
3. Chowrira, B., Kandpal, L. & et al. *Record spintronic harvesting of thermal fluctuations using paramagnetic molecular centers*. *arXiv:2009.10413.*
4. Katcko, K. et al. *Spin-driven electrical power generation at room temperature*. *Communications Physics* **2**, 116 (2019). *CNRS News*. *Unistra News.*

Condensed Matter Physics: YES Macroscopic Physics and complexity: NO
Quantum Physics: YES Theoretical Physics: NO