Masters 2 Experimental Research Internship
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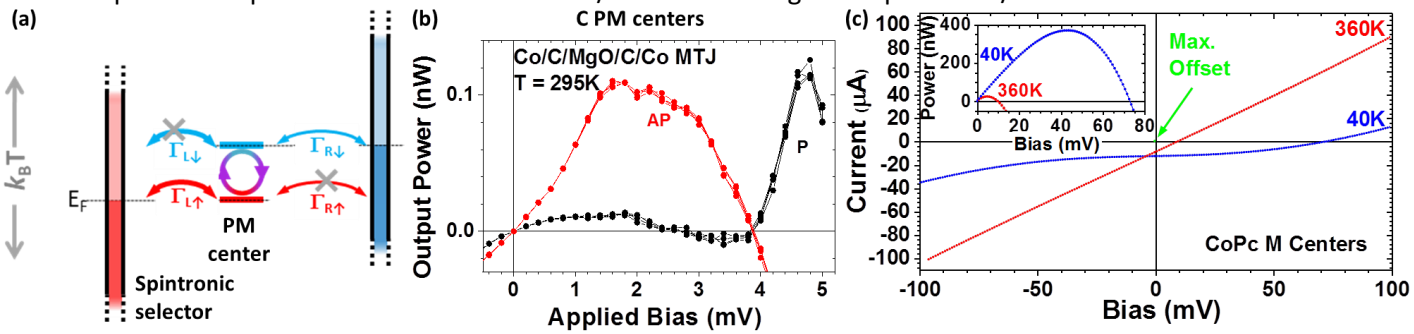
Energy generation using spintronics and quantum physics/thermodynamics

Today's energy-hungry society is struggling with how to mitigate the effects of man-made climate change, and under what conditions of voluntary/coercive adaptation[1]. Present fossil-fuel free technologies appear inadequate/insufficient to meet this daunting challenge. Any technological solution to this challenge will therefore require the maturation of **bold new physical concepts**.

Our team has fortuitously discovered[2] one such concept at the poorly understood/documented intersection between two otherwise disjointed research fields. 1) **Spintronics**[3] is a next-generation electronics that utilize the electron's quantum spin property to, for example, enable read heads in hard drives, non-volatile RAM (MRAM), microwave emitters/receivers and neuromorphic computing. It is thus mostly concerned with information storage/communication technologies. 2) **Quantum physics/thermodynamics**[4] aims to reexamine the rules of thermodynamics when matter is confined at the nanoscale to exhibit quantum properties. Proposals & experiments on nanoscale heat/information engines exploit brief/local violations of the 2nd law[5,6].



Our just published experiments/analysis show that a **spin-based engine can harvest thermal fluctuations on paramagnetic (PM) centers** in MgO to generate current flow at room temperature, thanks to a suitable spin potential landscape (panel a). Output power (panel b) could, if integrated into chips at present MRAM MgO-based device densities, lead to always-on areal power densities 3 times greater than solar irradiation on Earth. Preliminary results show that this spin engine works not only with C PM centers in MgO, but also with Co PM centers in CoPc molecules (panel c), leading to ~100x more output power at room temperature.

To accelerate research on this new paradigm of energy generation, we are looking for a motivated, bright candidate to perform an experimental internship with possible PhD follow-up. The M2 intern will assist PhD candidate B. Poovanna in executing the research chain of growing CoPc-based heterostructures, synthesizing CoPc-based and MgO-based (collab. IJL Nancy) nanopillar devices through access to the STNano technological platform, and measuring their energy generation properties.

Starting References:

1. Dans la lutte climatique, les Français poussent à des contraintes. *Libération.fr* (2019)
2. Katcko, K. & et al. Spin-driven electrical power generation at room temperature. *Communications Physics* in press (2019).
3. Hoffmann, A. & Bader, S. D. Opportunities at the Frontiers of Spintronics. *Phys. Rev. Applied* **4**, 047001 (2015).
4. Strasberg, P., Schaller, G., Brandes, T. & Esposito, M. Quantum and Information Thermodynamics: A Unifying Framework Based on Repeated Interactions. *Physical Review X* **7**, 021003 (2017).
5. Thierschmann, H. *et al.* Three-terminal energy harvester with coupled quantum dots. *Nature Nanotechnology* **10**, 854–858 (2015).
6. Koski, J. V., Kutvonen, A., Khaymovich, I. M., Ala-Nissila, T. & Pekola, J. P. On-Chip Maxwell's Demon as an Information-Powered Refrigerator. *Physical Review Letters* **115**, 260602 (2015).