UNIVERSITY OF MIAMI
COLLEGE of
ARTS & SCIENCES

University of Miami, Physics Department Seminar

Date: Friday, Oct 27, 2023
Time: 4:00 pm – 5:00 pm
Location: Physics Library, Knight Physics Building

Spintronic Implementations of Quantum Information Engines to Harvest Ambient Thermal Energy: Experiment and Theory

Dr. Martin Bowen
Institut de Physique et Chimie des Materiaux de Strasbourg, U. de Strasbourg CNRS

Abstract

As areas of frontier research in energy, mesoscopic quantum thermodynamics (QTD) offer on-chip (i.e. applicative) solutions to harvest thermal energy with fast (~10GHz) electronic engine strokes, but operate at very low temperature and below the classical Carnot limit[1]. Atomic QTD at room temperature (RT) can exceed the Carnot limit [2] if out-of-equilibrium quantum resources, such as coherent states and non-thermal baths, are involved, but utilize slower (~10MHz) engine strokes and require auxiliary equipment, i.e. remain model experiments.

We propose a novel spintronic implementation of QTD that utilizes the generation and manipulation of electrical currents based on the electron spin[3]. Rather than implement classical thermodynamics (e.g. spin Seebeck across the MTJ's interfaces[4], [5], or harvesting (artificial) RF power[6] from Wifi/GSM signals), we combine spintronics and quantum thermodynamics at an atomic/mesoscopic intersection to harvest thermal fluctuations as a natural source of energy.

Our quantum engine implements THz spintronic interactions between fully spin-polarized interfaces and paramagnetic centers that, ultimately, rectify thermal fluctuations on the latter to produce a dc electrical current. I will present our first report[7] of a spintronic engine implementation using an industrially mature device platform: the MgO magnetic tunnel junction (MTJ) that, as a device class, is used in next-generation magnetic memories[3]. We have also studied an implementation using Co phthalocynanine molecules[8], and developped several analytical/computational models[9] that describe how to power such a quantum spintronic engine using either quantum vacuum fluctuations or a phonon bath.

References

[1] M. Josefsson et al., "A quantum-dot heat engine operating close to the thermodynamic efficiency limits," Nat. Nanotechnol. 13, 920 (2018).
[2] J. Klatzow et al., "Experimental Demonstration of Quantum Effects in the Operation of Microscopic Heat Engines," Phys. Rev. Lett., 122, 110601 (2019).
[3] S. Bhatti, et al. "Spintronics based random access memory: a review," Materials Today, 20, 530 (2017).
[4] A. Boehnke et al., "Large magneto-Seebeck effect in magnetic tunnel junctions with half-metallic Heusler electrodes," Nat. Commun., 8, 1626 (2017).
[5] S. Tu et al., "Record thermopower found in an IrMn-based spintronic stack," Nat Commun, 11, (2020).
[6]A. A. Tulapurkar et al., "Spin-torque diode effect in magnetic tunnel junctions," Nature,438 339 (2005).
[7] K. Katcko et al., "Spin-driven electrical power generation at room temperature," Communications Physics 2, 116, (2019).
[8] B. Chowrira et al., "Quantum Advantage in a Molecular Spintronic Engine that Harvests Thermal Fluctuation Energy," Adv. Mater., 34 2206688, (2022).
[9] M. Lamblin and M. Bowen, "The Quantum Measurement Spintronic Engine: Using Entanglement to Harvest Vacuum Fluctuations." 10.48550 / arXiv.2304.13474.