Quentin Bouton - Single-atom coupled to an ultracold gas

Rapport sur les contributions

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Individual atoms immersed into a superfluid form a paradigm of quantum physics. It lies at the heart of many models exploiting the quantum nature of individual atoms to understand quantum phenomena or to open novel routes to local probing and engineering of quantum many-body systems. In the talk, I will present our approach of controlled immersion of individual, localized neutral Cesium (Cs) atoms into a Rubidium (Rb) ultra-cold bath [1].

The first part of my talk is dedicated to local probing: I will present our experimental realization of single-atom quantum probes for local thermometry based on the spin dynamic of the Cs atoms immersed into the Rb ultracold gas. By controlling microscopic atomic collisions, we map thermal information about the gas onto the quasi-spin population of the probe. Our probe is not restricted to measure temperature, but it allows sensing any mechanism affecting the total collisional energy in a spin-exchange collision such as the magnetic field, realizing also local magnetometry. In particular, I will show that having access to the dynamics of the microscopic process of motion-spin mapping allows us optimizing the information flow. Quantifying the sensitivity of our probe by the Quantum Fisher information, we find that it can outperform the steady-state limits setting the Cramér-Rao bound by roughly one order of magnitude [2].

The second part of my talk will be focused on the realization of a heat engine where the working fluid is embodied by the Cs atoms and the bath by the cloud of ultracold Rb atoms. Specifically, our engine is based on the quantum Otto cycle. Heat transfer is realized by spin-exchange collisions between the working fluid and the bath, while work is performed by changing the energy-level spacing of the engine with an external magnetic field. Thanks to the ability to follow the populations of individual atomic levels of a cesium atom in real time, we have performed precise characterization of the engine including the fluctuations of its power [3].

[1] F. Schmidt et al, Phys. Rev. Lett. 121, 130403 (2018).
[2] Q. Bouton et al., Phys. Rev. X 10, 011018 (2020).
[3] Q. Bouton, arXiv:2009.10946 (2020).

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