A 43: Cold atoms VII - micromachines (joint session A/Q)

Time: Friday 10:30–11:50 Location: K 0.011

Group Report A 43.1 Fri 10:30 K 0.011

Thermodynamics of single-ion machines

— •Ulrich Poschinger[1], David von Lindenfels[1], Oliver Gräb[1], Martin Wagener[1], Vidyut Kaushal[1], Jonas Schulz[1], Alexander Friedenberger[2], Eric Lutz[2], and Ferdinand Schmidt-Kaler[1] — [1]QUANTUM, Institut für Physik, Universität Mainz, D-55128 Mainz, Germany — [2]Department of Physics, Friedrich-Alexander-Universität Erlangen-Nürnberg, D-91058 Erlangen, Germany

The thermodynamic behaviour of small machines, ultimately far from the thermodynamic limit, is currently attracting much interest. We present the realization of a single-ion 'heat engine' [1]. The working medium is the spin degree of freedom of a single ^{40}Ca^{+} ion, positioned in an optical standing optical wave[2], which couples the spin to the ion motion. The ion is subjected to alternating optical pumping pulses. This gives rise to an effective resonant force mediated by the standing wave, which leads to the onset of oscillations of the ion position, ranging from the motional ground state to some tens of motional quanta. We analyze the work fluctuations occuring while the thermal energy from the laser reservoirs is transferred to the ion motion, and quantify the extractable work.

We also present ongoing work on the experimental study of the performance of an autonomous single-ion 'wall-clock', which is, according to recent theoretical work[3], tied to its waste heat production.

[1] Rossnagel et al., Science **352**, 325 (2016)
[2] Schmiegelow et al., PRL **116**, 033002 (2016)
[3] Erker et al., PRX **7**, 031022 (2017)

A 43.2 Fri 10:50 K 0.011

Unifying paradigms of quantum refrigeration: how resource-control determines fundamental limits

— •Fabien Clivaz[1], Ralph Silva[1], Géraldine Haack[1], Jonatan Bohr Brask[1], Nicolas Brunner[1], and Marcus Huber[2] — [1]Department of Applied Physics, University of Geneva, 1211 Geneva 4, Switzerland — [2]Institute for Quantum Optics and Quantum Information (IQOQI), Austrian Academy of Sciences, Boltzmanngasse 3, A-1090 Vienna, Austria

In classical thermodynamics the work cost of control can typically be neglected. On the contrary, in quantum thermodynamics the cost of control constitutes a fundamental contribution to the total work cost. Evaluating this contribution is an important but non-trivial problem. Here, focusing on quantum refrigeration, we show how the level of control determines the fundamental limits to cooling. We compare coherent versus incoherent operations, and derive the minimal achievable temperature and associated work cost. We discuss both the single-shot and asymptotic regimes. Our work provides a unified picture of the different approaches to quantum refrigeration developed in the literature, including algorithmic cooling, autonomous quantum refrigerators, and the resource theory of quantum thermodynamics.

A 43.3 Fri 11:05 K 0.011

Is a Stern-Gerlach splitter possible with an ion beam?

— •Carsten Henkel[1], Georg Jacob[2], Felix Stopp[2], Ferdinand Schmidt-Kaler[2], Yonathan Japha[3], Mark Keil[3], and Ron Folman[3] — [1]Universität Potsdam — [2]J. Gutenberg-Universität Mainz — [3]B Gurion University of the Negev, Beer Sheva

The Stern-Gerlach effect for free electrons has been discussed since the advent of quantum mechanics and was found to be challenging due to the uncertainty in the Lorentz force [1,2]. We propose realising a spin filter for a pulsed ion beam using the Stern-Gerlach force of a magnetic micro-grating. The field gradient is created by an array of wires integrated into a microchip. In distinction to the standard setup, both the spin and the magnetic field rotate along the beam path [3]. The Ca^{+} ions are laser cooled and released from a Paul trap, giving a pulsed beam of approximately 1eV with high brightness and very narrow velocity distribution [4]. Due to the large ion/electron mass ratio, the Lorentz force does not prevent the spin splitting. It can even be put to use, in conjunction with a bias field, in order to balance the image charge interaction and to prevent the ions from crashing onto the chip surface. We discuss semiclassical techniques to simulate the ion trajectories and estimate the spin-dependent splitting of the beam.

[1] B. M. Garraway and S. Stenholm, Contemp. Phys. 43 (2002) 147
[2] H. Batelaan, Am. J. Phys. 70 (2002) 325
[3] E. Enga and M. Bloom, Can. J. Phys. 48 (1970) 2466
[4] G. Jacob & al, Phys. Rev. Lett. 117 (2016) 043001

A 43.4 Fri 11:20 K 0.011

Neural Network States: an alternative description of quantum many body states.

— •Jose Nahuel Freitas and Giovanna Morigi — Theoretische Physik, Universität des Saarlandes, D-66123 Saarbrücken, Germany

As is well known, an exponentially large amount of information is needed to describe general quantum states of quantum many body systems. Thus, in order to simulate quantum systems in classical computers, it is important to identify efficient descriptions of physically relevant states. Typical examples of such efficient descriptions are Matrix Product States (MPS), Projected Entangled Pairs States (PEPS) or, in general, Tensor Network States. These parametrizations of quantum states have been employed with high success to study both the ground state and dynamical properties of quantum lattice models in one and two dimensions. However, the amount and range of the quantum correlations (entanglement) that they can capture is severely limited. Recently, it was proposed to leverage the representational power of Neural Networks in order to describe many body quantum states[Science, 355(6325), 602-606]. The family thus obtained, called Neural Network States, seems to be a promising alternative to study systems that are not tractable with usual methods based on TNS. In this talk, we will describe and review the main properties of these states, possible generalizations, and discuss new techniques to manipulate them.

A 43.5 Fri 11:35 K 0.011

Probing quantum dynamical pair correlation functions

— •Salvatore Castrignano and Jörg Evers — Max-Planck-Institut für Kernphysik, Heidelberg, Germany

The space-time correlations among particles in e.g. condensed matter systems can be experimentally studied via the so-called Time Domain Interferometry proposed in [1]. In particular the dynamical couple correlation function [2] can be obtained from the recorded interferogram. This scheme has sofar been theoretically studied and successfully tested for target systems whose dynamics can be safely described by classical mechanics.

With the growth of interest toward higly correlated quantum materials, the development of experimental techniques for measuring quantum dynamical correlations is getting more and more interest. In this project we then ask if extensions of the above interferometric setup are capable of accessing the quantum dynamical couple-correlation function of a quantum target. The classical and quantum correlations have different properties and through a theoretical analysis of the setup in a full quantum framework it is shown that these differences are experimentally accessible. Moreover, using elements of measurement theory in classical and quantum frameworks [3], we give a heuristic criterion to understand when to expect quantum or classical behaviour of generic correlation functions.

[1] A. Q. R. Baron et al., Phys. Rev. Lett. 79, 2823 (1997)
[2] L. Van Hove, Phys. Rev. 95, 249 (1954)
[3] P. Uhrich et al., Phys. Rev. A 96, 022127 (2017)