QI 4: Quantum Thermodynamics and Open Quantum Systems

Time: Tuesday 14:00–16:00 Location: H3

Invited Talk QI 4.1 Tue 14:00 H3

Principles of quantum functional testing — Nadia Milazzo[1,2], Olivier Giraud[2], and •Daniel Braun[1] — [1]Institute for theoretical physics, University Tübingen — [2]LPTMS, Université Paris-Saclay

With increasing complexity of quantum-information-processing devices, testing their functionality becomes a pressing and difficult problem. In contrast to quantum-process tomography, quantum functional testing refers to the decision problem of accepting or rejecting a device based on specifications provided by the producer and limited experimental evidence. The decision should be reached as quickly as possible, yet with as high confidence as possible. Here we review and propose several tools and principles for quantum functional testing, ranging from the formalism of truncated moment sequences, over coherent enhancement of deterministic errors, to automated experimental design for maximum information gain and non-greedy Bayesian parameter estimation. We demonstrate their usefulness at the hand of frequently encountered quantum states and channels.

QI 4.2 Tue 14:30 H3

Necessary structure of a thermodynamic bath for entanglement generation via bath engineering — •Steffen Wilksen, Frederik Lohof, and Christopher Gies — Institut für Theoretische Physik, Universität Bremen, Otto-Hahn-Allee, 28334 Bremen

Interaction of a quantum mechanical system with the environment is usually considered to be an obstacle when preparing entangled states, because this interaction induces decoherence and destroys the entanglement. This does not have to be the case, as coupling the system to a carefully engineered thermal bath can help to create entanglement and even stabilize it indefinitely.

First we consider a non-interacting two-qubit Hamiltonian, where the entanglement is solely created by the system-bath interaction. Specifically, we look at the strength of entanglement as a function of different system parameters. We then generalize our results for a Hamiltonian of arbitrary size and examine the requirements of the Hamiltonian and thermal bath to create entangled states. In particular, we find necessary conditions for the structure of the system-bath interaction that give rise to the occurrence of bath mediated entanglement generation.

QI 4.3 Tue 14:45 H3

Thermodynamic information erasure with computational limitations — •Naga B. T. Kothakonda[1,2], Jonas Haferkamp[2,3], Nicole Yunger Halpern[4], Jens Eisert[2,3], and Philippe Faist[2] — [1]University of Cologne — [2]Freie Univ. Berlin — [3]HZB Berlin — [4]Harvard Univ., MIT, Univ. of Maryland

The role of information entropy in thermodynamics is epitomized by the example of Landauer erasure: To reset a quantum state ρ to a standard pure state, there is a minimum dissipation of $kT \ln(2)\, H(\rho)$, where $H(\rho)$ is the information entropy of the quantum state. Here, we determine the energy cost of resetting a quantum state on a memory register to a standard state under an additional computational restriction: The agent cannot apply more than a given number of unitary gates from a given gate set. The cost is given by a new entropy measure, the *complexity-effective entropy*, which accounts for the complexity of the state. The effective entropy is consistent with known results in the regime where the agent can perform arbitrarily many gates. The effective entropy provides a direct link between complexity and entropy, by quantifying the trade-off between complexity cost and work cost for Landauer erasure. On a conceptual level, the effective entropy generalizes the approach in statistical mechanics whereby a system is studied via the properties of its local observables. Along with our recent results on the linear growth of complexity in random circuits, we believe that the effective entropy can be a powerful tool to understand the physical properties of quantum systems that are chaotic, as well as in quantum gravity, where complexity is believed to play a major role.

QI 4.4 Tue 15:00 H3

Controlled Dephasing and Unequal Time Correlations in Rydberg Qubits — •Andre Salzinger[1], Kevin Geier[2], Titus Franz[1], Sebastian Geier[1], Robert Ott[3], Annika Tebben[1], Clement Hainaut[1], Gerhard Zürn[1], Martin Gärttner[1], Philipp Hauke[2], and Matthias Weidemüller[1] — [1]Physikalisches Institut Heidelberg — [2]University of Trento — [3]Institut für Theoretische Physik Heidelberg

Engineering open system dynamics relies on implementing restrictions on the degrees of freedom of a larger system. We present experimental results for simple Qubit rotations subjected to random phase walks, which are sampled from 1D Brownian motion. The observed ensemble and realization average follows a Lindblad description with a decay parameter given by the variance of sampled phase walks. We show how this technique can be used to extract unequal-time correlation functions in the driven two-level system by coupling to an ancilla level, and how this procedure can be extended to colored noise and larger spin systems.

QI 4.5 Tue 15:15 H3

Entanglement and work fluctuations in composite quantum systems — •Satoya Imai, Otfried Gühne, and Stefan Nimmrichter — Universität Siegen Department Physik Emmy-Noether-Campus Walter-Flex-Straße 3 57068 Siegen Germany

We investigate the role of quantum correlations in the thermodynamics of composite quantum systems by comparing the work cost of unitary operations for separable and entangled states. In a limited control scenario, quantum correlations between interacting, high-dimensional two-particle systems can be characterized by monitoring the average energy change and its fluctuations due to random local or global unitary operations. These operations can represent isentropic strokes as part of a thermodynamic protocol. We derive a hierarchy of bounds based on the Schmidt rank of the quantum state and thereby show that higher work fluctuations can verify the presence of stronger entanglement in the system.

Invited Talk QI 4.6 Tue 15:30 H3

Noncommuting conserved quantities in thermodynamics — •Nicole Yunger Halpern — National Institute of Standards and Technology, College Park, Maryland, USA — Joint Center for Quantum Information and Computer Science, College Park, Maryland, USA — Institute for Physical Science and Technology, College Park, Maryland, USA

In statistical mechanics, a small system exchanges conserved quantities—heat, particles, electric charge, etc.—with a bath. The small system may thermalize to the canonical ensemble, the grand canonical ensemble, etc. The conserved quantities are represented by operators usually assumed to commute with each other. But noncommutation distinguishes quantum physics from classical. What if the operators fail to commute? This question of truly nonclassical thermodynamics has gained substantial attention in quantum-information-theoretic thermodynamics recently. I will discuss recent advances and what noncommutation of conserved quantities may buy for a thermodynamic agent, including the possibility of hindering thermalization to preserve information in memories. Applications include atomic, molecular, and optical physics; condensed matter; and potentially lattice gauge theories.

References:

1) NYH, Beverland, and Kalev, Phys. Rev. E 101, 042117 (2020).
2) NYH and Majidy, arXiv:2103.14041 (2021).
3) NYH, Faist, Oppenheim, and Winter, Nat. Comms. 7, 12051 (2016).