QI 6: Trapped Ion and Atom Qubits

Time: Monday 15:00–16:15 Location: HFT-FT 131

Invited Talk QI 6.1 Mon 15:00 HFT-FT 131

Heat engine and force sensing with trapped ions — •Kilian Singer[1], Bo Deng[1], Moritz Göb[1], Max Masuhr[2], and Daqing Wang[2] — [1]Institute of Physics, University of Kassel, Heinrich-Plett-Straße 40, 34132 Kassel, Germany — [2]Institut für Angewandte Physik, University of Bonn, Wegelerstr. 8, 53115 Bonn, Germany

Thermodynamic machines can be reduced to the ultimate atomic limit [1], using a single ion as a working agent. The confinement in a linear Paul trap with tapered geometry allows for coupling axial and radial modes of oscillation. The heat-engine is driven thermally by coupling it alternately to hot and cold reservoirs, using the output power of the engine to drive a harmonic oscillation. From direct measurements of the ion dynamics, the thermodynamic cycles for various temperature differences of the reservoirs can be determined and the efficiency compared with analytical estimates. I will describe how the engine principle can be exploited to implement a differential probe for non-classical baths [2] and to amplify zeptonewton forces [3] using non-linear features of the tapered trap design.

[1] J. Rossnagel et al., "A single-atom heat engine", Science 352, 325 (2016).

[2] A. Levy, M. Göb, B. Deng, K. Singer, E. Torrontegui and D.Wang "Single-atom heat engine as a sensitive thermal probe." New Journal of Physics, 22, 093020 (2020).

[3] B. Deng, M. Göb, B. Stickler, M. Masuhr, K. Singer, and D. Wang Phys. Rev. Lett. 131, 153601 (2023).

QI 6.2 Mon 15:30 HFT-FT 131

Simulation and optimization methods for collision gates with ultra-cold atoms — •Jan Reuter[1,2], Tommaso Calarco[1,2,3], Felix Motzoi[1,2], and Robert Zeier[1] — [1]Peter Grünberg Institute - Quantum Control (PGI-8), Forschungszentrum Jülich GmbH, Wilhelm-Johnen-Straße, 52428 Jülich, Germany — [2]Institute for Theoretical Physics, University of Cologne, Zülpicher Straße 77, 50937 Cologne, Germany — [3]Dipartimento di Fisica e Astronomia, Università di Bologna, 40127 Bologna, Italy

Atoms in an optical lattice can be used for various applications of quantum technologies, including quantum simulators or quantum computers. In our study, we simulate fermionic ^{6}Li atoms in an optical lattice using a split-step method to solve the Schrödinger equation in up to three dimensions. We analyze the behavior of one, two or three atoms in a double-well potential in a 1D-confinement under the influence of a SWAP- or $\sqrt{\text{SWAP}}$-gate. For this task, we optimize our time-dependent controls by simulating the gradient and the Hessian matrix of the quantum state with respect to these controls. Furthermore, we can verify our results by showing that the simulation of a two-atom collision in a 1D-confinement agrees with the result of a corresponding simulation assuming a 2D-confinement with a tight potential in one of these dimensions.

QI 6.3 Mon 15:45 HFT-FT 131

Atom transport optimization: theoretical frameworks, control algorithms, and experimental integration. — •Cristina Cicali[1,2], Robert Zeier[1], Felix Motzoi[1,2], and Tommaso Calarco[1,2,3] — [1]Forschungszentrum Jülich,Peter Grünberg Institute, Quantum Control (PGI-8), 52425 Jülich, Germany — [2]Institute for Theoretical Physics, University of Cologne, 50937 Köln, Germany — [3]Dipartimento di Fisica e Astronomia, Università di Bologna, 40127 Bologna, Italy

Ultracold atoms constitute a promising platform for quantum computing and quantum simulation. We study the transport of individual atoms in optical tweezers using methods of optimal control. As part of the BMBF project FemiQP, we are developing a theoretical framework for numerically optimizing atom transport trajectories, including strategies aimed at maximizing the transport fidelity, velocity, and robustness against experimental imperfections. Quantum control algorithms such as the dressed-CRAB (d-CRAB) and Gradient Ascent Pulse Engineering (GRAPE) are compared with regard to their utility to effectively optimize the atom transport. In collaboration with the group Christian Groß, optimized control protocols are adapted to the experimental platform in Tübingen.

QI 6.4 Mon 16:00 HFT-FT 131

Fiber cavities for enhancement of comb-assisted microscopy and spectroscopy — •Stephan Fraundienst[1,2], Franziska Haslinger[1,2], Maerpreet Arora[1,2], Tom Schubert[1,2], Bingxin Xu[3], Thomas Udem[1,3], Thomas Hümmer[1,2], Nathalie Picqué[3], and Michael Förg[1,2] — [1]Fakultät für Physik, Ludwig-Maximilians-Universität Munich, Germany — [2]Qlibri GmbH, Munich, Germany — [3]Max-Planck-Institut für Quantenoptik, Garching, Germany

Tunable, open, scanning fiber-based microcavities spanning 100 μm and longer offer a compelling platform for light-matter interactions, such as single trapped ion coupling or frequency comb enhanced spectroscopy and microscopy. However, fabricating the concave mirrors at the tip of an optical fiber for long microcavities proves challenging. We provide a method for fabricating fiber mirrors with high finesse and sufficient free spectral range to couple a frequency comb into a microcavity.