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COLLOQUIUM „OPTICS AND CONDENSED MATTER“

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Trapped ion implementations of quantum computing, quantum thermodynamical processes and quantum optics

Quantum technologies allow for fully novel schemes of hybrid computing. We employ modern segmented ion traps. I will sketch architectures, the required trap technologies and fabrication methods, control electronics for quantum register reconfigurations, and recent improvements of qubit coherence and gate performance. Currently, gate fidelities of 99.995% (single bit) and 99.8% (two bit) are reached. We are implementing a reconfigurable qubit register and have realized multi-qubit entanglement [1] and fault-tolerant syndrome readout [2] in view for topological quantum error correction [3], since current aim is to leave the noisy area of quantum computing. Complementary to gate tomography, we employ thermodynamically-inspired methods within the frameworks of global passivity and passivity deformation where system qubits undergoing unitary evolution but may optionally be coupled also to an unobserved environment qubit, resulting in a heat leak [4]. Trapped single ions feature several assets for investigating the interaction with vortex laser beams [5], and we report the optical super-resolution sensing of a trapped ion's wave packet, inspired by the STED microscopy technique. Scanning a vortex beam spatially over a single trapped Ca ion, we sense the wave packet size of about 39nm for the near-to-ground state cooled ion, reaching a resolution σ=30nm, enhanced by a factor of x12 as compared to the non-saturated situation [6]. Eventually, we will take benefit of the few nm resolution limit and aim for imaging Fock states e.g. $|n=1\rangle$, non-classical matter wave packets. Also, we verify that the vortex light orbital angular momentum can either be transferred to the center of mass motion of the ion or to the internal electron [7]. In our case, out of the two units of angular momentum from the beam one is transferred to the valence electron and the other to the movement of ion, featuring coherent oscillations governed by a new kind of Lamb-Dicke parameter [8].

[1] Kaufmann er al, Phys. Rev. Lett. 119, 150503 (2017)
[2] J. Hilder, et al., Phys. Rev. X.12.011032 (2022)
[3] Bermudez, et al, Phys. Rev. X 7, 041061 (2017)
[4] D. Pijn, et al., Phys. Rev. Lett. 128 110601 (2022)
[5] Schmiegelow, Schmidt-Kaler, Euro. Jour. of Phys. D 66, 157 (2012)
[6] M. Drechsler et al., Phys. Rev. Lett. 127, 143602 (2021)
[7] Schmiegelow, et al., Nat. Comm. 7, 12998 (2016)
[8] Stopp et al., arXiv:2206.04894

July 5th, starting with discussion at 16:45 h, talk at 17:15 h, live IAP lecture hall and via Zoom
https://uni-bonn.zoom.us/j/98441612025?pwd=a01SSjlkY1Q3SDFhL09JQk1qc1V6dz09
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