Q 4: Quantum Information (Concepts and Methods) I

Time: Monday 14:00–16:00 Location: Q-H12

Q 4.1 Mon 14:00 Q-H12

Electromagnetic Modelling of a Surface-Electrode Ion Trap for High Fidelity Microwave Quantum Simulations — •Axel Hoffmann[1], Florian Ungerechts[2], Rodrigo Munoz[2], Teresa Meiners[2], Brigitte Kaune[2], Dirk Manteuffel[1], and Christian Ospelkaus[2] — [1]Institut für Hochfrequenztechnik und Funksysteme, Leibniz Universität Hannover, Appelstr. 9A, 30167 Hannover, Germany — [2]Institut für Quantenoptik, Leibniz Universität Hannover, Welfengarten 1, 30167 Hannover, Germany

Surface-electrode ion traps with integrated microwave conductors for near-field quantum control are a promissing approach for scaleable quantum computers. The goal of the QVLS-Q1 Project is to realize the first scalable 50-qubit quantum computer based on surface-electrode ion traps. Designing a multi-layer ion trap with surface-electrodes for electromagntic near-field operations comes with high demands on the design of the electrical components, such as impedance matching of the surface electrodes to the microwave and radio frequency sources. The near field had to be designed considering the necessary conditions to trap $^{9}Be^{+}$- Ions in a multi layer trap. This process will be presented in this talk, emphasising on the constraints of the electrically small chip size compared to the length of the applied electromagnetic waves. In electromagnetic full-wave simulations we can show that a properly desinged electrode combined with an efficient impedance matching accounts for a significant decrease of electrical losses. The design of the meander-like microwave guide will be discussed including the simulation methods and approaches.

Q 4.2 Mon 14:15 Q-H12

Distinguishability and mixedness in multiphoton interference — •Shreya Kumar[2], Alex E Jones[1], Simone D'Aurelio[2], Matthias Bayerbach[2], Adrian Menssen[3], and Stefanie Barz[2] — [1]QET Labs, H. H. Wills Physics Laboratory and Department of Electrical and Electronic Engineering, University of Bristol, Bristol BS8 1FD, UK — [2]Institute for Functional Matter and Quantum Technologies & IQST, University of Stuttgart, 70569 Stuttgart, Germany — [3]Research Laboratory of Electronics, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139, USA

Quantum interference of photons is central to many applications in quantum technologies such as generating entangled states, quantum metrology, quantum imaging and photonic quantum computing. One of the fundamental prerequisites for these applications is that the photons are indistinguishable and have high purity. The visibility of the Hong-Ou-Mandel (HOM) interference dip is usually used to deduce the nature of the photons. In case of two photons, this visibility is reduced by distinguishability, and by mixedness in the same way. However, here, we show that that when scaling up to three photons, despite having similar HOM interference visibilities, one can differentiate between distinguishability and mixedness of the photons by observing the count statistics after interference at a tritter. This shows that the visibility alone is inadequate to discriminate between distinguishability and mixedness of the photons and that it becomes important to characterize photon state purity, in order to study interference effects at larger scales.

Q 4.3 Mon 14:30 Q-H12

Quantum Frames and Distance Measures — •Moritz Ferdinand Richter and Heinz-Peter Breuer — Institute of Physics, University of Freiburg, Hermann-Herder-Straße 3, D-79104, Germany

Based on Informationally Complete Positive Operator Valued Measures (IC-POVM) the poster will introduce a decomposition of generally mixed quantum states - given by their density operators - in a fixed set of pure quantum states, i.e. rank-one projection operators (quantum frame). This decomposition allows a vector like representation for arbitrary quantum states which can be linearly connected to the probability distribution generated by the IC-POVM - underlying the quantum frame - applied to the quantum state at hand. Both the probability distribution and the quantum frame decomposition can be used to define certain distance measures for quantum states which provide a lower and upper bound for the trace distance between quantum states.

Q 4.4 Mon 14:45 Q-H12

Exact approach to strong-coupling quantum thermodynamics in open systems — •Alessandra Colla[1] and Heinz-Peter Breuer[1,2] — [1]Institute of Physics, University of Freiburg, Hermann-Herder-Straße 3, D-79104 Freiburg, Germany — [2]EUCOR Centre for Quantum Science and Quantum Computing, University of Freiburg, Hermann-Herder-Straße 3, D-79104 Freiburg, Germany

The formulation of a solid and consistent thermodynamic theory in the quantum regime has proven to be extremely challenging. Particularly in the case of strong system-reservoir interactions, agreement on how to properly define thermodynamic quantities such as work, heat, and entropy production has yet to be reached. Using the exact time-local quantum master equation for the reduced open system states, we develop an exact theory describing the thermodynamical behavior of open quantum systems coupled to thermal baths [1]. We define an effective energy operator for the reduced system using a recent principle of minimal dissipation, which gives a unique prescription for decomposing the master equation into a Hamiltonian part (coherent evolution) and a dissipator part (decoherence). From this, we derive the first two laws of thermodynamics and investigate the relationship between violations of the second law and quantum non-Markovianity.

[1] A. Colla and H.-P. Breuer, arXiv:2109.11893 [quant-ph] (2021)

Q 4.5 Mon 15:00 Q-H12

Thermomajorization in Quantum Control — •Frederik vom Ende[1,2], Gunther Dirr[3], and Thomas Schulte-Herbrüggen[1,2] — [1]Department of Chemistry, Technische Universität München, Garching, 85737, Germany — [2]Munich Centre for Quantum Science and Technology & Munich Quantum Valley, Schellingstr. 4, 80799 München, Germany — [3]Department of Mathematics, University of Würzburg, Würzburg, 97074, Germany

Based on the recent description of thermomajorization – known in the mathematics literature as d- or relative q-majorization – as a convex polytope (arXiv:1911.01061) we visualize the constraints coming from thermomajorization for a qutrit as a parameter of the temperature. It is known that one of the extreme points of this polytope majorizes every element from the polytope clasically; this extreme point is of particular interest in quantum control systems where one of the controls is to couple the system to a bath of finite temperature (arXiv:2003.06018). Thus this graphical approach allows us to highlight some critical temperatures for when this maximal extreme point changes its behaviour. Finally, we point to a recently drawn connection to Markovian thermal operations (arXiv:2111.12130) and its possible implications for control systems of the above type.

Q 4.6 Mon 15:15 Q-H12

Quantum simulations in a linear Paul trap and a 2D array — •Florian Hasse, Deviprasath Palani, Apurba Das, Lennart Guth, Ingolf Kaufmann, Ulrich Warring, and Tobias Schaetz — Physikalisches Institut, University of Freiburg

Trapped ions present a promising platform for quantum simulations [1]. In our laboratory in Freiburg, we are performing experiments on multiple ions trapped in a linear or a surface RF-trap. In our linear Paul trap, we switch the trapping potential sufficiently fast to induce a non-adiabatic change of the ions' motional mode frequencies. Thereby, we prepare the ions in a squeezed state of motion. This process is accompanied by the formation of entanglement in the ions' motional degree of freedom and can be interpreted as an experimental analogue to the particle pair creation during cosmic inflation in the early universe [2]. Furthermore, we will transfer entanglement of the motional degree of freedom to the external degree of freedom. In our basic triangular array of individually trapped ions with 40 um inter-site distance, we realize the coupling between ions at different sites via their Coulomb interactions. We demonstrate its tuning in real-time and show interference of coherent states of currently large amplitudes [3]. In addition, we employ the individual control for local modulation of the trapping potential to realize Floquet-engineered coupling of adjacent sites [4].

[1] T. Schaetz et al., New J. Phys. 15, 085009 (2013).
[2] M. Wittemer et al., Phys. Rev. Lett. 123, 180502 (2019).
[3] F. Hakelberg et al., Phys. Rev. Lett. 123, 100504 (2019).
[4] P. Kiefer et al., Phys. Rev. Lett. 123, 213605 (2019).

Q 4.7 Mon 15:30 Q-H12

Broadband detection of a 200 MHz squeezing comb — •Dennis Wilken[1,2], Jonas Junker[1,2], and Michèle Heurs[1,2] — [1]Institut für Gravitationsphysik, Leibniz Universität Hannover, Germany — [2]Max-Planck Institut für Gravitationsphysik, Hannover, Germany

Non-classical continuous-variable states such as squeezed vacua are promising resources in the field of quantum information. One common technique to generate such states relies on optical parametric oscillators, which produce squeezed states in a frequency comb structure. These combs usually have two limitations: first, the tooth separation (free-spectral range) is often larger than GHz, strongly limiting the number of accessible sidebands. Second, only one frequency can be measured at a given time. Here, we present a broadband measurement of our 200 MHz squeezing comb allowing simultaneous access to 18 sidebands. We have detected more than 9 dB of squeezing at a frequency of 3.6 GHz. To achieve this, we have designed a GHz photodetector with close to unity quantum efficiency. It turned out that a balanced detection scheme was not feasible. Therefore, our homodyne detection is based on a 99:1 beam splitter. Our method significantly simplifies the detection process and allows the simultaneous measurement of multiple squeezed states at different frequencies. This flexibility makes our approach an ideal cornerstone on the way to quantum computation with frequency encoded continuous-variable cluster states.

Q 4.8 Mon 15:45 Q-H12

Joint measurability in non-equilibrium quantum thermodynamics — •Konstantin Beyer[1], Roope Uola[2], Kimmo Luoma[3], and Walter Strunz[1] — [1]TU Dresden, Dresden, Germany — [2]University of Geneva, Geneva, Switzerland — [3]University of Turku, Turku, Finland

Quantum work and fluctuation theorems are mostly discussed in the framework of projective two-point measurement (TPM) schemes. According to a well known no-go theorem, there is no work observable which satisfies both (i) an average work condition and (ii) the TPM statistics for diagonal input states.

Projective measurements are an idealization and difficult to implement in experiments. We generalize the TPM scenario to arbitrary measurements and ask if the no-go theorem still holds. The answer is twofold. If the initial and the final measurement are incompatible for at least some intermediate unitary evolution, a work observable cannot be constructed. However, if the measurements in the TPM scheme are jointly measurable for any unitary, the no-go theorem does not hold anymore. Then, a (noisy) work observable that satisfies (i) and (ii) can exist.