Q 33: Quantum Information (Quantum Computing) II

Time: Wednesday 14:00–16:00 Location: S HS 001 Chemie

Invited Talk Q 33.1 Wed 14:00 S HS 001 Chemie
Topological Quantum Error Correction: From Concepts to Experiments with Trapped Ions — •Markus Mueller — Swansea University, Swansea, United Kingdom

To date, the construction of large-scale fault-tolerant quantum computers remains a fundamental scientific and technological challenge, due the influence of unavoidable noise. In my talk, I will focus on quantum error correction in trapped-ion quantum processors. After briefly introducing basic concepts of topological quantum error-correcting codes, I will discuss resource-efficient and fault-tolerant protocols to control single and coupled logical qubits of increasing size and robustness. Specifically, I will discuss protocols to fight qubit loss, as caused e.g. by particle loss or electronic leakage processes, in topological color codes. Here, I will show that determining the corresponding qubit loss error threshold is equivalent to a new generalised classical percolation process. Finally, I will comment on recent experimental implementations of quantum error correction building blocks with trapped ions.

Q 33.2 Wed 14:30 S HS 001 Chemie
Non-Markovianity from a mixture of unitaries: implementation on IBM's quantum computer platforms — •Giulio Amato[1,2,3], Filip Wudarski[1], Panagiotis Kl. Barkoutsos[4], Bassano Vacchini[3,5], Heinz-Peter Breuer[1], and Andreas Buchleitner[1] — [1]Albert-Ludwigs-Universität Freiburg — [2]Universitá degli Studi di Parma — [3]Istituto Nazionale di Fisica Nucleare — [4]IBM Research, Zurich Research Laboratory — [5]Universitá degli Studi di Milano

Can a convex combination of quantum Markovian processes lead to a non-Markovian one? Indeed this is the case. It has been shown that also mixing two unitary evolutions can generate quantum memory effects, due to the build up of correlations between the system of interest and an ancillary degree of freedom [1]. We devise a protocol to experimentally resolve and monitor this phenomenon, by controlled transformations on a composite quantum system. We implement this approach on IBM's quantum computers.

[1] H.-P. Breuer, G. Amato & B. Vacchini, *Mixing-induced quantum non-Markovianity and information flow*, New J. Phys. **20**, 043007 (2018)

Q 33.3 Wed 14:45 S HS 001 Chemie
Entangling gate in a surface-electrode Paul trap with microwave near-fields — •Giorgio Zarantonello[1,2], Henning Hahn[1,2], Marius Schulte[3], Amado Bautista-Salvador[2,1], Klemens Hammerer[3], and Christian Ospelkaus[1,2] — [1]Institut für Quantenoptik, Leibniz Universität Hannover, Welfengarten 1, 30167 Hannover — [2]PTB, Bundesallee 100, 38116 Braunschweig — [3]Institut für Theoretische Physik, Leibniz Universität Hannover, Appelstr. 2, 30167 Hannover

Surface-electrode ion traps are a scalable platform for quantum information processing based on the quantum charge-coupled device (QCCD) architecture [1-2]. A large-scale device would offer different traps, interconnected through transport, used e. g. for loading, storage, single- and multi-qubit operations. Here, the implementation of gate operations with near-field microwaves [3] can be advantageous because the gate drive mechanism can be an integral, scalable part of the device. We present an approach where tailored microwave conductors have been embedded into a surface-electrode trap, allowing the realization of an entangling multi-qubit gate with a fidelity exceeding 98%. We discuss the gate error budget and ongoing efforts to further increase the fidelity.

[1] D.J. Wineland *et al.*, J. Res. NIST. **103**, 259-328 (1998)
[2] D. Kielpinski *et al.*, Nature **417**, 709-711 (2002)
[3] C. Ospelkaus *et al.*, Nature **476**, 181 (2011).

Q 33.4 Wed 15:00 S HS 001 Chemie
Vorschlag für ein Quantengatter durch schnelle Transporte von Rydbergionen — •Jonas Vogel[1], Arezoo Mokhberi[1], Weibin Li[2], Igor Lesanovski[2] und Ferdinand Schmidt-Kaler[1] — [1]Johannes Gutenberg-Universität Mainz, 55128 Mainz, Deutschland — [2]Universität Nottingham, Nottingham, NG7 2RD, Vereinigtes Königreich

Rydbergionen zeichnen sich durch ihre hohe elektrische Polarisierbarkeit im Einschlusspotential der Paulfalle aus [1]. Bei einer schnellen Bewegung mittels elektrischer Kontrollfelder der Fallenkontrollelektroden greifen diese daher nicht allein an deren Ladung an, sondern Ionen in Rydbergzuständen erlangen eine zusätzliche geometrische Phase bei einem schnellen Hin- und Rücktransport in einer segmentierten linearen Ionenfalle [3]. Bemerkenswerterweise benötigt man kein zusätzlich eingestrahltes Laserlichtfeld. Wir schlagen die Erzeugung von Spin-Bewegungs-Verschränkung für ein einzelnes Ion in der Überlagerung von Grund- und Rydbergzustand und quantenlogische Operationen an Ionenkristallen vor.

Literatur:
[1] Feldker et al, Phys. Rev. Lett. 115, 173001 (2015)
[2] A. Walther et al., Phys. Rev. Lett. 109, 080501 (2012)
[3] W. Li and I. Lesanovsky, Appl. Phys. B 114 (1), 37 (2014)

Q 33.5 Wed 15:15 S HS 001 Chemie
Imperfect Quantum Gates in Real Hardware — •Andreas Woitzik[1], Filip Wudarski[1], Panagiotis Barkoutsos[2], Marc Ganzhorn[2], Daniel Egger[2], Stefan Filipp[2], Ivano Tavernelli[2], and Andreas Buchleitner[1] — [1]Albert-Ludwigs-Universität Freiburg, Freiburg im Breisgau, Deutschland — [2]IBM Research - Zurich, Rüschlikon, Schweiz

Recent theoretical and experimental progress in superconducting qubits has equipped us with small scale quantum computers. However, limited control and connectivity, together with the inevitable interaction with the environment still hamper the computational performance of currently available devices. Therefore, it is important to understand the limiting factors for the action of quantum gates, in order to improve their functionality. We elaborate on the description of quantum gates subject to various imperfections, such as to mimic quantum gates implemented on an IBM quantum computing platform.

Q 33.6 Wed 15:30 S HS 001 Chemie
Universal Uhrig dynamical decoupling for bosonic systems — •Margret Heinze and Robert König — Zentrum Mathematik, Technische Universität München, 85748 Garching, Germany

We construct efficient deterministic dynamical decoupling schemes protecting continuous variable degrees of freedom. Our schemes target decoherence induced by quadratic system-bath interactions with analytic time-dependence. We show how to suppress such interactions to N-th order using only N pulses. Furthermore, we show to homogenize a 2^m-mode bosonic system using only $(N+1)^{2m+1}$ pulses, yielding - up to N-th order - an effective evolution described by non-interacting harmonic oscillators with identical frequencies. The decoupled and homogenized system provides natural decoherence-free subspaces for encoding quantum information. Our schemes only require pulses which are tensor products of single-mode passive Gaussian unitaries and SWAP gates between pairs of modes.

Q 33.7 Wed 15:45 S HS 001 Chemie
Efficient Qubit Initialization using Quantum Optimal Control — •Daniel Basilewitsch[1], Francesco Cosco[2], Nicola Lo Gullo[2], Christiane Koch[1], and Sabrina Maniscalco[2,3] — [1]Theoretical Physics, University of Kassel, D-34132 Kassel, Germany — [2]QTF Centre of Excellence, Turku Centre for Quantum Physics, Department of Physics and Astronomy, University of Turku, FI-20014 Turun yliopisto, Finland — [3]QTF Centre of Excellence, Department of Applied Physics, Aalto University, FI-00076 Aalto, Finland

Qubit reset is a key requirement for any quantum technology as it enables reusable qubits. Since the reset process implies purification of the qubit state, coupling to an environment, which serves as entropy dump, is necessary. As a consequence, the reset duration is primarily determined by the environmental coupling strength, respectively the decay rates induced by it. Here we consider a qubit coupled to an engineered and tunable environment allowing to tune the decay rates over several orders of magnitude. Based on a proposed initialization protocol for this setup [1], we use quantum optimal control theory in order to derive optimized field shapes improving the protocol duration and error. We find that for best reset, coherent and dissipative part of the evolution have to be carefully balanced and we are able to identify the quantum speed limit for the given setup.

[1] J. Tuorila et al., npj Quantum Inf. 3, 27 (2017)