Q 27: Quantum Information (Concepts and Methods) II

Time: Wednesday 10:30–12:30 Location: S HS 001 Chemie

Group Report Q 27.1 Wed 10:30 S HS 001 Chemie
Quantum Dynamics Taken to the Limit by Optimal Control — •Thomas Schulte-Herbrüggen[1], Ville Bergholm[1], Witlef Wieczorek[2], and Michael Keyl[3] — [1]Dept. Chem., TU Munich — [2]Dept. Microtechnology, Chalmers University, Gothenburg, Sweden — [3]Dahlem Centre for Complex Quantum Systems, FU Berlin

Optimal control methods are often key to achieving high fidelity implementations in actual experiments. Examples meanwhile pertain to quantum information processing, quantum simulation, and quantum sensing.

First, we exemplify how adding a steerable atom on top of a cavity coupled to a mechanical oscillator gives (approx.) full controllability on the oscillator side and allows for preparing any state of the oscillator subsystem from any initial state. Thus, the extension overcomes limitations of previous designs of a cavity coupled to an oscillator only, where linear feedback from homodyne detection then is limited to interconverting *within* equivalence classes of Gaussian oscillator states or states with constant Wigner negativity. Adding an interacting atom opens the way to controlled dynamics including interchange *between* different equivalence classes.

The results build upon our optimal-control platform dynamo also extended to allowing for fast switchable noise on top of coherent controls.

We round up by showing how to use these features as internal cooling device in superconducting qudits (GMons) with tunable coupling to an open transmission line.

Q 27.2 Wed 11:00 S HS 001 Chemie
Quantum rifling: how to protect the state of a qubit from unwanted collapse — •Daniel Szombati[1], Alejandro Gomez[1], Tyler Jones[1], Clemens Muller[2], and Arkady Fedorov[1] — [1]ARC Centre of Excellence for Engineered Quantum Systems, The University of Queensland, St Lucia, Queensland, Australia — [2]IBM Research, Ruschlikon, Switzerland

The Stern-Gerlach experiment exemplifies properties of quantum measurement: a spin with random orientation is shot through a magnetic field, which acts as a classical detector of the spin state, by selectively deflecting the spin towards one of only two possible trajectories (up or down) depending on the spin orientation. But what happens to the spin flying through the field if it is also spinning fast, like a bullet fired from a rifled gun barrel?

We implement such a scenario in a Circuit QED system, where a superconducting qubit acts as the spin and a coupled coplanar waveguide resonator as the classic measurement apparatus. When our spin is rifled fast enough, the spin is not deflected but flies in a straight line, with no backaction of the detector on the spin. We demonstrate our protocol*s usefulness on a system of two qubits coupled to the same cavity: by rifling one qubit, it can be protected from decoherence caused by the measurement photons in the cavity while we read out the other qubit.

Although the presented experiments were performed in a circuit QED system, such a protocol can be performed for any qubit coupled to a classical detector.

Q 27.3 Wed 11:15 S HS 001 Chemie
Compatibility of quantum effects and inclusion of free spectrahedra — •Andreas Bluhm[1] and Ion Nechita[2] — [1]Zentrum Mathematik, Technische Universität München, Garching, Deutschland — [2]Laboratoire de Physique Théorique, Université Paul Sabatier, CNRS, Toulouse, Frankreich

One of the defining properties of quantum mechanics is the existence of incompatible observables, of which the observables of position and momentum are a well-known example. In this talk, we will connect the problem of determining whether a given set of measurements is compatible to the inclusion of free spectrahedra. Free spectrahedra are objects arising in convex optimization. We show how results from algebraic convexity can be used to quantify the degree of incompatibility of binary quantum measurements. In particular, this new connection allows us to completely characterize the case in which the dimension of the quantum system is exponential in the number of measurements.

Q 27.4 Wed 11:30 S HS 001 Chemie
Single-shot holographic compression from the area law — •Henrik Wilming[1] and Jens Eisert[2] — [1]Institute for Theoretical Physics, ETH Zurich, 8093 Zurich, Switzerland — [2]Dahlem Center for Complex Quantum Systems, Freie Universität Berlin, 14195 Berlin, Germany

The area law conjecture states that the entanglement entropy of a region of space in the ground state of a gapped, local Hamiltonian only grows like the surface area of the region. We show that, for any quantum state that fulfills an area law, the reduced quantum state of a region of space can be unitarily compressed into a thickened surface of the region. If the interior of the region is lost after this compression, the full quantum state can be recovered to high precision by a quantum channel only acting on the thickened surface. The thickness of the boundary scales inversely proportional to the error for arbitrary spin systems and logarithmically with the error for quasi-free bosonic systems. Our results can be interpreted as a single-shot operational interpretation of the area law. The result for spin systems follows from a simple inequality showing that probability distributions with low entropy can be approximated by distributions with small support, which we believe to be of independent interest. We also discuss an emergent approximate correspondence between bulk and boundary operators and the relation of our results to tensor network states.

Q 27.5 Wed 11:45 S HS 001 Chemie
Graph approach to quantum contextuality for projectors of nonunit rank — •Zhen-Peng Xu, Matthias Kleinmann, and Xiao-Dong Yu — University of Siegen, D-57068 Siegen, Germany

Quantum contextuality is the property of quantum theory that, in general, the outcome for a projector cannot be predicted without specifying the measurement context, i.e., which other projectors are measured alongside this projector. In this formulation of quantum contextuality, it is usually assumed that the measurements are composed of projectors of rank one, since the maximal amount of quantum contextuality can already be obtained under this restriction. However, measurements with high rank still can be beneficial, in particular they might allow for simpler examples of state-independent contextuality (SIC) than it is possible in the rank-one case. We develop methods to exhaustively search for SIC with projectors with nonunit rank, using a modification of the graph approach to contextuality. We find that for a low number of projectors there is no example for SIC with rank two projectors, but we also provide examples where SIC can only be realized by using nonunit rank projectors.

Q 27.6 Wed 12:00 S HS 001 Chemie
On Phase-Space Representations of Spin Systems and Their Relations to Infinite-Dimensional Quantum States — •Bálint Koczor[1], Robert Zeier[1], Steffen J. Glaser[1], Frederik vom Ende[1], and Maurice A. de Gosson[2] — [1]Technische Universität München, Garching, Germany — [2]University of Vienna, Vienna, Austria

Classical phase spaces have been widely applied in physics, engineering, economics or biology.

I will give an overview of our recent works considering phase spaces of quantum systems, which have become a powerful tool for describing, analyzing, and tomographically reconstructing quantum states. We provide a complete phase-space description of (coupled) spin systems including their time evolution, tomography, large-spin approximations and their infinite-dimensional limit, which recovers the well-known case of quantum optics.

Finally, Born-Jordan distributions of infinite-dimensional quantum systems are discussed. Refer to the recent preprints arXiv:1808.02697 and arXiv:1811.05872.

Q 27.7 Wed 12:15 S HS 001 Chemie
Entanglement of truncated quantum states — •Giacomo Sorelli[1], Vyacheslav N. Shatokhin[1], Filippus S. Roux[2], and Andreas Buchleitner[1] — [1]Physikalisches Institut, Albert-Ludwigs-Universität Freiburg i. Br. — [2]National Metrology Institute of South Africa, Pretoria

Entanglement is a fundamental resource for many quantum information protocols. While many studies have been dedicated to bipartite entanglement of qubits, that of high-dimensional systems (qudits) is much less studied. Yet, qudits have higher information capacity and can enhance the security of quantum communication. In many practical cases, qudits are encoded in finite-dimensional subspaces of higher-dimensional Hilbert spaces. Then, after the dynamics populates the entire Hilbert space, the final state is often projected onto the encoding subspace. If the coupling between states inside and outside the encoding subspace is strong, such truncation can strongly affect the output state, and hence its entanglement.

We discuss the effect of truncation on the bipartite entanglement of n-level systems. They are initially prepared in a maximally-entangled state of m-dimensional subspaces $\mathcal{H}^m \otimes \mathcal{H}^m$ of their total Hilbert spaces $\mathcal{H}^n \otimes \mathcal{H}^n$, and subsequently subjected to entanglement-preserving dynamics that populate all the n levels of each subsystem. We consider the truncation of this output state in a specific subspace $\mathcal{H}^s \otimes \mathcal{H}^s$ $(s < m)$ of the total Hilbert space. For random local unitary dynamics, we present simple expressions for the output state entanglement as a function of n, m and s.