Q 33: Quantum information: Concepts and methods II

Time: Tuesday 14:00–16:00 Location: E 214

Q 33.1 Tue 14:00 E 214

Stabilizer states are spherical 3-designs – with applications to quantum state discrimination — •Richard Kueng and David Gross — Universität Freiburg

A *complex spherical k-design* is a configuration of vectors which is "evenly distributed" on a sphere in the sense that it reproduces Haar measure up to kth moments. Here, we show that the set of all n-qubit stabilizer states forms a complex spherical 3-design in dimension 2^n. Stabilizer states had previously only been known to constitute 2-designs. The problem is reduced to the task of counting the number of stabilizer states with pre-described overlap with respect to a reference state. This, in turn, reduces to a counting problem in discrete symplectic vector spaces for which we find a simple formula.

We use the finding to answer an open problem posed by in [Matthews, Wehner, Winter, CMP 291 (2008)]: There, the loss of distinguishability suffered by quantum states as a result of a POVM measurement was analyzed. It had been shown that 4-designs (seen as POVMs) perform almost optimally, while 2-designs fall significantly short of this. The performance of 3-designs was left open. Using our explicit example, we find that, unfortunately, 3-designs do not outperform 2-designs.

Q 33.2 Tue 14:15 E 214

The Power of Combining Coherent Control with Switchable Noise — •Thomas Schulte-Herbrüggen[1] and Ville Bergholm[1,2] — [1]Dept. Chem., TU-München (TUM) — [2]Institute for Scientific Interchange Foundation (ISI), Torino

Adding bang-bang switchable noise on a single qubit (out of a total of n) on top of unitary control seems magic: this simple add-on suffices for transforming *any* initial quantum state into *any desired target state*.

We have extended our open-loop optimal control algorithm (dynamo) by such degrees of incoherent control so that these unprecedented reachable sets can systematically be exploited in experiments [1]. As illustrated for an ion trap experimental setting, open-loop control with noise switching can accomplish all state transfers one can get by the more complicated measurement-based closed-loop feedback schemes [2,3] requiring a resettable ancilla qubit.

[1] V. Bergholm and T. Schulte-Herbrüggen, arXiv/1206.4945 (2012)
[2] S. Lloyd and L. Viola, Phys. Rev. A **65**, 010101 (2001)
[3] J. Barreiro et al., Nature **470**, 486 (2011)

Q 33.3 Tue 14:30 E 214

Approximate Quantum Error Correction: optimal codes for independent and correlated errors — •Sol H. Jacobsen and Florian Mintert — Freiburg Institute for Advanced Studies, Albert-Ludwigs-University of Freiburg, Albertstr. 19, 79104 Freiburg, Germany

The reversibility of open system dynamics in practice depends on a separation of probability regimes in which high-probability errors are corrected at the expense of leaving lower-probability errors uncorrected whenever these occur, i.e. correcting only errors on single qubits in a quantum code. However, several important quantum information processing scenarios are not describable by a neat separation of probability regimes, and we investigate codes for optimal information protection when this is the case. We use entanglement dynamics to compare and evaluate the performance of different codes and present optimal codes for full noisy quantum channels in terms of minimum deviation from perfect correctability. We present N-qubit inequalities governing optimal codes for different probability regimes of errors and give explicit examples of significant improvement for some standard cases.

Q 33.4 Tue 14:45 E 214

Scalable Reconstruction Schemes for Quantum State Tomography — •Tillmann Baumgratz[1], Marcus Cramer[1], David Gross[2], and Martin B. Plenio[1] — [1]Institut für Theoretische Physik, Albert-Einstein-Allee 11, Universität Ulm, D-89069 Ulm, Germany — [2]Physikalisches Institut, Hermann-Herder-Straße 3, Albert-Ludwigs Universität Freiburg, 79104 Freiburg i.Br., Germany

The ability to store and manipulate interacting quantum many-body systems, such as linearly arranged ions in ion traps, photonic implementations, and cold atoms in optical lattices, enhanced rapidly during the last years. By now, the number of controllable particles in such systems has reached sizes for which conventional methods of quantum tomography fail due to both, experiment time and post-processing resources. We discuss applications of recently developed strategies [1,2] to reconstruct state representations which are fully determined by a small fraction of the informationally complete measurements. Experimentally relevant examples for ion-trap, photonic, and cold-gases setups will be presented.

[1] M. Cramer, M.B. Plenio, S.T. Flammia, R. Somma, D. Gross, S.D. Bartlett, O. Landon-Cardinal, D. Poulin and Y.-K. Liu, Nat. Commun. 1, 149 (2010).
[2] T. Baumgratz, D. Gross, M. Cramer and M.B. Plenio, arXiv:1207.0358.

Q 33.5 Tue 15:00 E 214

Quantum optical state reconstruction using weak values — •Joachim Fischbach and Matthias Freyberger — Institut für Quantenphysik, Universität Ulm, D-89069 Ulm, Germany

Reconstructing the state of a given system is a fundamental problem in quantum mechanics. We show that the special form of weak values, first introduced by Aharonov, Albert, and Vaidman, can be elegantly used to reconstruct the quantum state of a mode of light. Particularly simple reconstruction relations are found for modulus and phase of the wave function. Finally, we present a numerical simulation of a possible experimental setup, that basically consists of a modified eight-port interferometer, and discuss the limitations of the scheme [1].

[1] J. Fischbach and M. Freyberger, Phys. Rev. A **86**, 052110 (2012)

Q 33.6 Tue 15:15 E 214

Progress on compressed sensing tomography — •Carlos Riofrio[1], Steven T. Flammia[2], David Gross[3], Yi-Kai Liu[4], and Jens Eisert[1] — [1]Dahlem Center for Complex Quantum Systems, Freie Universität Berlin, Germany — [2]School of Physics, University of Sydney — [3]Institute of Physics, University of Freiburg, Germany — [4]National Institute of Standards and Technology, Gaithersburg, MD, USA

Quantum tomography allows us to estimate the state of a quantum system by measuring different observables on identically prepared realizations. This is a time-consuming task that requires a large number of measurements. In practice, however, one is usually concerned with estimating the state of systems that are well described by pure or almost pure states, which are represented by fewer parameters than arbitrary states. In this context, special interest has been growing to develop more efficient methods to address system identification when the states are generically described by low rank density matrices. Such techniques, commonly known as compressed sensing, provably accomplish this task under the low rank assumption. In this talk, I will report on recent progress of the novel tomographic technique of compressed sensing and give examples of its application.

Q 33.7 Tue 15:30 E 214

Continuous time limit of repeated quantum observations — •Bernhard Neukirchen — Leibniz Universität Hannover, Institute of Theoretical Physics, Germany

We look at the continuous time evolution of open quantum systems in the Markovian approximation. The goal is to describe all the information we can obtain about the System by measurements of the environment.

Since this problem is very well understood for discrete time, we set up the continuous time description as a refinement limit of the discrete approach in the step length. This construction can be used to obtain a full quantum description of the field emitted by a driven isolated system, e.g. a cavity or quantum dot.

Q 33.8 Tue 15:45 E 214

Directly probing correlatedness in optical lattices — •Janina Gertis, Matthias Ohliger, and Jens Eisert — Freie Universität Berlin, Germany

Full tomography of a quantum state usually requires a large number of measurements. However, often times, one is mostly interested in some characteristics of the quantum state. In this context, we present a method to directly estimate a lower bound on the degree of correlatedness in a system of cold atoms in an optical lattice. We achieve this goal resorting only to minimal a-priori assumptions on the quantum state of the system. By using density distribution data from time of flight measurements, which is available with current technology in this type of systems, we calculate the second and fourth moments of the quantum state. We minimize the relative entropy between an arbitrary quantum state, with the same estimated moments, and an uncorrelated Gaussian reference state. As a result of the minimization, we obtain a lower bound for the actual relative entropy between the state of the system and the closest Gaussian reference state. We can thus detect strong correlations without having to do a full tomographic reconstruction on the quantum state of the system.