Q 11: Quantum Information: Concepts and Methods II

Time: Monday 16:30–19:00 Location: E 214

Q 11.1 Mo 16:30 E 214

Practical methods for witnessing genuine multi-qubit entanglement in the vicinity of symmetric states — •Geza Toth[1,2,3], Witlef Wieczorek[4,5], Roland Krischek[4,5], Nikolai Kiesel[4,5,6], Patrick Michelberger[4,5], and Harald Weinfurter[4,5] — [1]Theoretical Physics, The University of the Basque Country, E-48080 Bilbao, Spain — [2]IKERBASQUE, Basque Foundation for Science, E-48011 Bilbao, Spain — [3]Research Institute for Solid State Physics and Optics, H-1525 Budapest, Hungary — [4]Max-Planck-Institut für Quantenoptik, D-85748 Garching, Germany — [5]Fakultät für Physik, Ludwig-Maximilians-Universität, D-80799 Garching, Germany — [6]Institute for Quantum Optics and Quantum Information (IQOQI), A-1090 Vienna, Austria

We present general numerical methods to construct witness operators for entanglement detection and for the estimation of the fidelity. Our methods are applied to detecting entanglement in the vicinity of a six-qubit Dicke state with three excitations and also to further entangled symmetric states. All our witnesses are designed to keep the measurement effort small thus they are useful in many-qubit experiments. We present also general results on the efficient local decomposition of permutationally invariant operators, which makes it possible to measure projectors to symmetric states efficiently.

Q 11.2 Mo 16:45 E 214

Separability criteria for genuine multiparticle entanglement — •Otfried Gühne[1] and Michael Seevinck[2] — [1]Institut für Quantenoptik und Quanteninformation, Österreichische Akademie der Wissenschaften, A-6020 Innsbruck, Austria — [2]Institute of History and Foundations of Science, Utrecht University, P.O Box 80.010, 3508 TA Utrecht, Netherlands

The characterization of genuine multiparticle correlations is an important problem in the field of quantum information theory. However, no systematic way to derive multiparticle entanglement criteria is known.

In this talk, we present a method to derive separability criteria for the different classes of multiparticle entanglement, especially genuine multiparticle entanglement. The resulting criteria are necessary and sufficient for certain families of states. Further, the criteria are superior to all known entanglement criteria for many other families; also they allow the detection of bound entanglement. We next demonstrate that they are easily implementable in experiments and discuss applications to the decoherence of multiparticle entangled states.

Q 11.3 Mo 17:00 E 214

Accuracy of the lower bound approximation for three-qubit concurrence — •Michael Siomau[1] and Stephan Fritzsche[2,3] — [1]Max-Planck-Institut fuer Kernphysik, Postfach 103980, D-69117 Heidelberg, Germany — [2]Department of Physical Sciences, P.O.Box 3000, Fin-90014 University of Oulu, Finland — [3]Frankfurt Institute for Advanced Studies, D-60438 Frankfurt am Main, Germany

A proper measure for the entanglement of a mixed state is the convex roof extension to the concurrence. Unfortunately, however, the computational complexity of this entanglement measure increases with the rank r of a given density matrix with as r^3 [1]. Certain approximations, such as the lower bound approximation for the concurrence [2], can significantly simplify the computations. We here investigate on particular examples the relation between the accuracy of the lower bound approximation and the rank of the density matrix. We show that for a density matrix $r < 4$ the lower bound for the concurrence can describe the entanglement of the state for all times. For density matrices with higher rank, in contrast, the lower bound approximation can be applied only to describe the dynamics of quasi-pure states.

[1] F. Mintert *et al.*, Phys. Rep. **415**, 207 (2005).
[2] M. Li, S.-M. Fei, Z.-X. Wang, J. Phys. A **42**, 145303 (2009).

Q 11.4 Mo 17:15 E 214

Structure factors and entanglement witnesses — •Hermann Kampermann[1], Philipp Krammer[2], Dagmar Bruss[1], Reinhold A. Bertlmann[2], Leong Chuang Kwek[3], and Chiara Macchiavello[4] — [1]Institut für Theoretische Physik III, Heinrich-Heine-Universität Düsseldorf — [2]Faculty of Physics, University of Vienna, Austria — [3]Centre for Quantum Technologies, National University of Singapore, Singapore — [4]Dipartimento di Fisica "A. Volta", University of Pavia, Italy

We construct multi-qubit entanglement witnesses whose expectation value has a direct link to the static structure factor, and thus to diffractive properties. These "collective" witness operators are composed of two-point correlation operators. The general construction of these witnesses allows to detect different classes of multi-partite entangled states like Dicke states. The robustness of the entanglement detection with respect to noise is discussed.

Q 11.5 Mo 17:30 E 214

Estimates for the three-tangle from incomplete information — •Andreas Osterloh[1] and Philipp Hyllus[2] — [1]FB Physik, Universität Duisburg-Essen, Lotharstrasse 1, 47048 Duisburg, Germany. — [2]BEC-INFM, Dipartimento di Fisica, Università di Trento, Via Sommarive 14, I-38050 Povo, Italy.

We investigate the lower bound obtained from experimental data of a quantum state ρ, as proposed independently by Gühne et al. and Eisert et al. [1] and apply it to mixed states of three qubits. The measure we consider is the convex-roof extension of the three-tangle [2]. Our findings highlight an intimate relation to lower bounds obtained recently from so-called characteristic curves of a given entanglement measure [3]. For an unstructured admixture to a GHZ state the non-vanishing lower bound is obtained if the GHZ-fidelity of the produced states is larger than 3/4, which reproduces the result obtained from witnesses. We apply the bounds to estimate the three-tangle present in recently performed experiments aimed at producing a three-qubit GHZ state.

[1] O. Gühne, M. Reimpell, and R.F. Werner, PRL **98**, 110502 (2007); J. Eisert, F.G.S.L. Brandão, and K. Audenaert, NJP **9**, 46 (2007).
[2] V. Coffman, J. Kundu, and W.K. Wootters, PRA **61**, 052306 (2000).
[3] A. Osterloh, J. Siewert, and A. Uhlmann, Phys. Rev. A **77**, 032310 (2008).

Q 11.6 Mo 17:45 E 214

Mutually unbiased bases generated by a single unitary operator — •Kedar Ranade[1], Oliver Kern[2], and Ulrich Seyfarth[2] — [1]Institut für Quantenphysik, Universität Ulm — [2]Institut für Angewandte Physik, Technische Universität Darmstadt

In this talk, we discuss a method for constructing unitary operators which generate mutually unbiased bases on Hilbert spaces $\mathcal{H} = \mathbb{C}^d$ for d being a power-of-two dimension (i. e. $d = 2^m$, $m \in \mathbb{N}$). Such operators U have order $d + 1$, and the columns of U, U^2, ..., $U^{d+1} = 1$ define mutually unbiased bases. The construction is based on finding a maximal commuting unitary operator basis of the matrix algebra associated to the Hilbert space and a Clifford group unitary transformation which maps the equivalence classes of a partition of this operator basis onto another. We explicitly construct unitary operators which generate mutually unbiased bases in all dimensions $d = 2^m$ for $m \leq 22$.

Q 11.7 Mo 18:00 E 214

Simple adaptive measurement strategies for estimation of d-dimensional quantum states — •Christof Happ and Matthias Freyberger — Institut für Quantenphysik, Universität Ulm, D-89069 Ulm

Adaptive methods improve the quality of state reconstruction when estimating unknown pure d-level-states (qu*d*its), of which only a limited amount of copies is available. Using information from previous measurements, the adaption steps construct measurement bases for further measurements, which improve the estimation quality more than further measurements with fixed or random measurement bases. We present adaptive strategies for arbitrary finite dimensions d and discuss Monte-Carlo simulation results for complete reconstruction of the quantum state.

Q 11.8 Mo 18:15 E 214

Entanglement between Atoms in a Diatomic Molecule — •Nathan Harshman[1,2] and William Flynn[1] — [1]Department of Physics, American University, Washington, DC, USA — [2]Institut für Quantenphysik, Universität Ulm, D-89069 Ulm, Germany

Entanglement between atoms in an idealized diatomic molecule in one-dimension is investigated. Trapped and free molecules and homonuclear and heteronuclear molecules are considered. The entanglement between the atoms for coherent states, number states, and superpositions of number states can be calculated analytically from the position wave function in atomic coordinates. Entanglement between atoms occurs in the ground state and other coherent states unless the molecular frequency and the trap frequency are the same. In number states, the exact functional dependence of entanglement depends in a complicated way on the ratio of the frequencies and the ratio of the masses. Generally, states with high numbers, large frequency differences, and equal masses have increased entanglement. While the interatomic entanglement can be quite large even in the coherent states, the covariance in position observables can be entirely explained by a classical model with appropriately chosen statistical uncertainty.

Q 11.9 Mo 18:30 E 214

Anderson Localization in Disordered Quantum Walks — •Volkher Scholz, Albert Werner, and Andre Ahlbrecht — Institut für Theoretische Physik, Leibniz Universität Hannover

We study a Spin-$\frac{1}{2}$-particle moving in a one dimensional lattice subjected to disorder induced by a random space dependent coin. The discrete time evolution is given by a family of random unitary quantum walk operators, where the shift operation is assumed to be non-random. Each coin is an independent identically distributed random variable with values in the group of two dimensional unitary matrices. We find that if the probability distribution of the coins is absolutely continuous with respect to the Haar measure, then the system exhibits localization. That is, every initially localized particle remains on average and up to exponential corrections in a finite region of space for all times.

Q 11.10 Mo 18:45 E 214

Area laws for thermal free fermions — •Holger Bernigau and Jens Eisert — University of Potsdam, 14476 Potsdam, Germany

Physical interactions in quantum many-body systems are typically local: Individual constituents interact mainly with their few nearest neighbors. This locality of interactions is inherited by a decay of correlation functions, but also reflected by scaling laws of correlation or entanglement measures: They satisfy an "area law" if the they merely grow like the boundary area of the subregion, and not like its volume, in sharp contrast with an expected extensive behavior. In this talk, we will investigate the scaling of the mutual information for thermal states of free fermionic lattice systems, and will discuss an exact formula for the asymptotic scaling, including all prefactors. Ideas of Toeplitz determinants applied to thermal states will be mentioned. We will finally briefly discuss implications of such results to the simulatability of such quantum systems.