Q 64: Quantum information: Concepts and methods V

Time: Friday 14:00–16:00 Location: Kinosaal

Q 64.1 Fri 14:00 Kinosaal

Experimental test of a four-party GHZ-theorem — •Marie-Christine Röhsner, Chiara Greganti, Stefanie Barz, and Philip Walther — Faculty of Physics, University of Vienna, Boltzmanngasse 5, 1090 Vienna, Austria

Nonlocality - the fact that quantum mechanical objects can exhibit correlations that cannot be explained by assigning local hidden variables to each object - plays a major role in quantum information science. Whereas two-party nonlocality has already been thoroughly investigated in the last decades of research, the multiparticle case is a more complex subject and still holds some open questions. The Greenberger-Horne-Zeilinger (GHZ) theorem allows us to experimentally test the predictions of quantum mechanics against those of local hidden variable theories using multiparticle states. Here we present an experimental test of a GHZ-theorem for 4-qubit states using an irreducible set of mutually commuting observables. We use sets of measurements in which every single-qubit observable appears an even number of times. Therefore the overall product of the measurement outcomes will always be +1 in any local hidden variable theory. On the contrary quantum mechanics predicts an outcome of -1. [1] The experiment is realized by using an entangled 4-qubit photonic cluster state. We measure five different 4-qubit-observables which allows us to demonstrate genuine 4-party irreducible nonlocality.

[1] M. Waegell, arXiv:1307.6264 [quant-ph].

Q 64.2 Fri 14:15 Kinosaal

Construction of Cyclic Mutually Unbiased Bases with Different Entanglement Structures — •Ulrich Seyfarth[1], Luis L. Sánchez-Soto[1,2], and Gerd Leuchs[1,3] — [1]Max-Planck-Institut für die Physik des Lichts, Günther-Scharowsky-Straße 1, Bau 24, 91058 Erlangen, Germany — [2]Departamento de Óptica, Facultad de Física, Universidad Complutense, 28040 Madrid, Spain — [3]Department für Physik, Universität Erlangen-Nürnberg, Staudtstraße 7, Bau 2, 91058 Erlangen, Germany

In the context of quantum state tomography, complete sets of mutually unbiased bases provide an attractive set of measurement bases as they achieve the minimal number of required different measurement setups. For qubit systems mutually unbiased bases can be constructed in a cyclic way which facilitates their implementation. In a recent article it has been shown that the entanglement structures of the bases play an important role concerning error distributions for certain properties of the physical system [1]. In order to find optimal cyclic sets subjected to this ascpect, we will show how an existing construction scheme [2] can be generalized for this purpose [3].

[1] J. Řeháček et al., Phys. Rev. A 88, 052110 (2013)
[2] U. Seyfarth and K. S. Ranade, Phys. Rev. A 84, 042327 (2011)
[3] U. Seyfarth, PhD Thesis (2013)

Q 64.3 Fri 14:30 Kinosaal

Systematic errors in current quantum state tomography tools — Christian Schwemmer[1,2], Lukas Knips[1,2], Daniel Richart[1,2], •Tobias Moroder[3], Matthias Kleinmann[3,4], Otfried Gühne[3], and Harald Weinfurter[1,2] — [1]Max-Planck-Institut für Quantenoptik, Garching — [2]Department für Physik, Ludwig-Maximilians-Universität München — [3]Theoretische Quantenoptik, Universität Siegen — [4]Departamento de Matematica, Belo Horizonte

In this work we investigate the systematic errors of commonly employed tools used in quantum state tomography to estimate the full density operator or key figures of merit like its entanglement or the fidelity with respect to the intended target state. We show that techniques such as maximum likelihood or free-least-squares—used nearly in all experiments within the last decade—suffer from a rather large systematic error for current experimental samples sizes, which leads to strong deviations of the estimated fidelity or wrong conclusion about the presence of entanglement. These errors do not occur due to some mismatch between the real experimental setup and the associated model, but are inherent to the used analysis tools, which in statistics is called the bias. As a solution in order to avoid this we exemplify a linear evaluation of the data which does not suffer from this effect, show how even non-linear quantities like entanglement measures can easily be accessed, and finally equip it with directly computable confidence intervals which do not rely on large sample properties.

Q 64.4 Fri 14:45 Kinosaal

Minimal Quantum Gate Characerisation and its Applications to Fidelity Estimation — •Daniel Reich[1], Giulia Gualdi[1,2,3], and Christiane Koch[1] — [1]Theoretische Physik, Universität Kassel, Heinrich-Plett-Str. 40, 34132 Kassel — [2]Dipartimento di Fisica e Astronomia, Università di Firenze, Via Sansone 1, 50019 Sesto Fiorentino, Italy — [3]QSTAR, Largo Enrico Fermi 2, 50125 Firenze, Italy

Assessing how well a quantum device implements a desired operation is one of the greatest obstacles towards the development of quantum technologies. Current protocols to determine the gate error scale strongly exponential in the number of qubits. We have derived an algebraic framework to identify the minimal information required to perform this task. It is based on characterising only the unitary part of an open system's evolution, reducing the number of required input states to two, independent of the system's size. [1] While this minimal set is impractical for device characterisation, we can construct different reduced sets of states which allow for determining numerical and analytical bounds respectively. We apply these concepts to provide a classification of efficient strategies to determine the average gate error of a quantum gate in terms of the number of required experimental settings, average number of actual measurements, and classical computational resources. [2]

[1] D.M. Reich, G. Gualdi, and C.P. Koch, Phys. Rev. A 88, 042309 (2013)
[2] D.M. Reich, G. Gualdi, and C.P. Koch, Phys. Rev. Lett. 111, 200401 (2013)

Q 64.5 Fri 15:00 Kinosaal

The necessity of entanglement for improved phase sensitivity — •Simon Laibacher und Matthias Freyberger — Institut für Quantenphysik, Universität Ulm, D-89069 Ulm, Germany

It is well known that the exploitation of non-classical properties of light in optical interferometry allows for a phase sensitivity that surpasses the classical limit [1,2]. Most of the approaches apply entangled states of light [3]. However, in quantum optics this is, in contrast to atom interferometry, not the only way to introduce non-classical correlations and indeed not necessary to improve phase sensitivity [4]. We present an interferometric measurement scheme based on homodyne detection which allows us to easily determine the influence of the presence or absence of entanglement in otherwise identical states on phase sensitivity. As we show, in both cases basically the same scaling of the phase uncertainty can be achieved.

[1] C. M. Caves, Phys. Rev. D **23**, 1693 (1981).
[2] V. Giovanetti et al., Nature Photon. **5**, 222 (2011).
[3] C. C. Gerry and J. Mimih, Contemp. Phys. **51**, 497 (2010).
[4] P. M. Anisimov et al., Phys. Rev. Lett. **104**, 103602 (2010).

Q 64.6 Fri 15:15 Kinosaal

Optimized state independent entanglement detection — •Christian Schwemmer[1,2], Wieslaw Laskowski[3], Daniel Richart[1,2], Lukas Knips[1,2], Tomasz Paterek[4,5], and Harald Weinfurter[1,2] — [1]Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Straße 1, D-85748 Garching, Germany — [2]Department für Physik, Ludwig-Maximilians-Universität, D-80797 München, Germany — [3]Institute of Theoretical Physics and Astrophysics, University of Gdańsk, PL-80-952 Gdańsk, Poland — [4]School of Physical and Mathematical Sciences, Nanyang Technological University, Singapore — [5]Centre for Quantum Technologies, National University of Singapore, Singapore

Entanglement lies in the very heart of quantum mechanics and is considered a key resource for many promising quantum information tasks like quantum cryptography or quantum computing. Therefore, tools for the rapid detection of entanglement are highly desirable. Here, we present two schemes [1,2] that are based on a simple entanglement criterion using accessible correlations between the measurement results and the principle of correlation complementarity. The first one essentially implements Schmidt decomposition of pure two-qubit states but without requiring a shared reference frame. The second one uses a decision tree to detect entanglement with as few measurements as possible and can also be generalized to multi-qubit states. We demonstrate their experimental applicability for mixed and multi qubit states.

[1] Laskowski et al., Phys. Rev. Lett. **108**, 240501 (2012)
[2] Laskowski et al., Phys. Rev. A **88**, 022327 (2013)

Q 64.7 Fri 15:30 Kinosaal

Bounding Temporal Quantum Correlations — •Costantino Budroni[1], Tobias Moroder[1], Matthias Kleinmann[1], Otfried Gühne[1], and Clive Emary[2] — [1]Naturwissenschaftlich-Technische Fakultät, Universität Siegen, SIegen, Germany — [2]Department of Physics and Mathematics, University of Hull, Kingston-upon-Hull, United Kingdom

Sequential measurements on a single particle play an important role in experimental tests of the Kochen-Specker theorem and in Leggett-Garg inequalities. We provide a general method to analyze temporal quantum correlations, which allows to compute the maximal correlations in quantum mechanics. For the case of dichotomic measurements, we present the full characterization of temporal correlations in the simplest Leggett-Garg scenario as well as in the most fundamental proof of the Kochen-Specker theorem.

Moreover, the above method shows that the quantum bound for temporal correlations in a sequential measurement scenario strongly depends on the number of levels that can be accessed by the measurement apparatus via projective measurements. For the simplest Leggett-Garg scenario, we provide exact bounds for small N, that exceed the known bound for the Leggett-Garg inequality, and show that in the limit of an infinite number of levels the Leggett-Garg inequality can be violated up to its algebraic maximum.

Q 64.8 Fri 15:45 Kinosaal

A universal set of qubit quantum channels — •Daniel Braun[1,2], Olivier Giraud[3], Ion Nechita[1], Clément Pellegrini[4], and Marko Znidaric[5] — [1]Laboratoire de Physique Théorique, Université Paul Sabatier and CNRS, 31062 Toulouse, France — [2]Institut für theoretische Physik, Universität Tübingen, 72076 Tübingen, Germany — [3]LPTMS, UMR8626, Université Paris-Sud, CNRS, 91405 Orsay, France — [4]Institut de Mathématiques de Toulouse, Université Paul Sabatier, 31062 Toulouse, France — [5]Department of Physics, Faculty of Mathematics and Physics, University of Ljubljana, Ljubljana, Slovenia

We investigate the set of quantum channels acting on a single qubit. We provide a compact generalization of the Fujiwara-Algoet conditions for complete positivity to non-unital qubit channels, which we then use to characterize the possible geometric forms of the pure output of the channel. We provide universal sets of quantum channels for all unital qubit channels as well as for all extremal (not necessarily unital) qubit channels, in the sense that all qubit channels in these sets can be obtained by concatenation of channels in the corresponding universal set. We also show that our universal sets are essentially minimal.