QI 25: Quantum Entanglement II

Time: Thursday 11:00–13:00 Location: B302

QI 25.1 Thu 11:00 B302

Quantifying multiparticle entanglement with randomized measurements — Sophia Ohnemus[1], Heinz-Peter Breuer[1,2], and •Andreas Ketterer[1,2,3] — [1]Physikalisches Institut, Albert-Ludwigs-Universität Freiburg, Hermann-Herder-Straße 3, 79104, Freiburg, Germany — [2]EUCOR Centre for Quantum Science and Quantum Computing, Albert-Ludwigs-Universität Freiburg, Hermann-Herder-Straße 3, 79104, Freiburg, Germany — [3]Fraunhofer Institut für Angewandte Festkörperphysik IAF, Tullastr. 72, 79108 Freiburg, Germany

Randomized measurements constitute a simple measurement primitive that exploits the information encoded in the outcome statistics of samples of local quantum measurements defined through randomly selected bases. In this work we exploit the potential of randomized measurements in order to probe the amount of entanglement contained in multiparticle quantum systems as quantified by the multiparticle concurrence. We further present a detailed statistical analysis of the underlying measurement resources required for a confident estimation of the introduced quantifiers using analytical tools from the theory of random matrices. The introduced framework is demonstrated by a series of numerical experiments analyzing the concurrence of typical multiparticle entangled states as well as of ensembles of output states produced by random quantum circuits under the influence of noisy gate operations.

QI 25.2 Thu 11:15 B302

Highly entangled graph states — •Zahra Raissi — Department of Physics, Virginia Tech, Blacksburg, VA 24061, USA

Multipartite entanglement is at the very heart of quantum information theory. Among all possible entangled states, k-uniform and absolutely maximally entangled (AME) states, have attracted much attention for a wide range of tasks such as measurement-based quantum computing, quantum networking and quantum error correction. Moreover, many efforts have also focused on showing if the relevant sets of states are also graph states.

The connection between classical codes and k-uniform states has been shown to provide a systematic method of constructing a large set of k-uniform states. In our work, we first show that a much larger class of k-uniform states can be obtained by starting from the graph state representation and asking what is the most general form of the adjacency matrix that is consistent with k-uniformity? With this, we uncover a large class of graph states that are maximally multipartite entangled. At least some of these are inequivalent under stochastic-local-operations and classical communication.

In the second part of our work, we propose and analyze deterministic protocols to generate them. We propose and evaluate deterministic methods to generate multi-photon qudit graph states from multi-level quantum emitters. We present several different explicit protocols that can produce various states either using a single emitter together with time-delayed feedback, or using multiple coupled quantum emitters.

QI 25.3 Thu 11:30 B302

Entanglement from Wehrl Moments using Deep Learning — •Jérôme Denis, François Damanet, and John Martin — University of Liège

In recent years, artificial neural networks (ANNs) have become an increasingly popular tool for studying problems in quantum theory, and in particular entanglement theory. In this work, we analyse to what extent ANNs can provide us with an accurate estimate of the geometric measure of entanglement of pure and mixed symmetric multiqubit states on the basis of a few moments of the Husimi function (Wehrl moments) of the state. We compare the results we obtain by training ANNs with the use of convergence acceleration methods and find that these algorithms do not compete with ANNs when given the same input data. This opens up perspectives for the estimation of SU(2) invariant quantities that should be more easily accessible in experiments than full state tomography.

QI 25.4 Thu 11:45 B302

Constructing generalized SSC witnesses for bound entangled Bell-diagonal states of unequal local dimensions — •Johannes Moerland[1,2], Nikolai Wyderka[1], Hermann Kampermann[1], and Dagmar Bruss[1] — [1]Institut für Theoretische Physik III, Heinrich-Heine-Universität Düsseldorf, Universitätsstr. 1, D-40225 Düsseldorf, Germany — [2]Universität Göttingen, Friedrich-Hund-Platz 1, D-37073 Göttingen, Germany

We extend a class of bipartite mixed quantum states, so-called Bell diagonal states, to the case where the dimensions of the subsystems do not match. These states are canonically expressed in a unitary operator basis. To investigate their entanglement properties, we generalize a separability criterion originally derived for hermitian operator bases by Sarbicki, Scala and Chruściński to the case of non-hermitian bases. We then construct entanglement witnesses for arbitrary bipartite quantum states that are equivalent to said separability criterion. While for Bell diagonal states with subsystems of matching dimension our results are equivalent to the CCNR criterion, we show that our witnesses outperform CCNR by constructing appropriate bound entangled states of unequal dimensions.

QI 25.5 Thu 12:00 B302

General class of continuous variable entanglement criteria — Martin Gärttner[1,2,3], •Tobi Haas[4], and Johannes Noll[3] — [1]ITP, Heidelberg, Germany — [2]PI, Heidelberg, Germany — [3]KIP, Heidelberg, Germany — [4]QuIC, Brussels, Belgium

We present a general class of entanglement criteria for continuous variable systems. Our criteria are based on the Husimi Q-distribution and allow for optimization over the set of all concave functions rendering them extremely general and versatile. We show that several entropic criteria and second moment criteria are obtained as special cases. Our criteria reveal entanglement of families of states undetected by any commonly used criteria and provide clear advantages under typical experimental constraints such as finite detector resolution and measurement statistics.

QI 25.6 Thu 12:15 B302

Bipartite entanglement and the arrow of time — •Markus Frembs — Griffith University, Gold Coast, Australia

We provide a new perspective on the close relationship between entanglement and time. Our main focus is on bipartite entanglement, where this connection is foreshadowed both in the positive partial transpose criterion due to Peres [A. Peres, Phys. Rev. Lett., 77, 1413 (1996)] and in the classification of quantum within more general non-signalling bipartite correlations [M. Frembs and A. Döring, arXiv:2204.11471]. Extracting the relevant common features, we identify a necessary and sufficient condition for bipartite entanglement in terms of a compatibility condition with respect to time orientations in local observable algebras, which express the dynamics in the respective subsystems. We discuss the relevance of the latter in the broader context of von Neumann algebras and the thermodynamical notion of time naturally arising within the latter.

See arXiv:2207.00024 for details.

QI 25.7 Thu 12:30 B302

Average Correlation as an Indicator for Nonclassicality — •Michael Erich Nicolas Tschaffon, Johannes Seiler, and Matthias Freyberger — Institut für Quantenphysik, Universität Ulm, D-89069 Ulm, Germany

Since their introduction, Bell inequalities have been used to verify nonclassicality of bipartite qubit states. While being a popular tool to test and even quantify nonclassicality, Bell inequalities suffer from being complicated to construct experimentally and cumbersome to evaluate and analyse theoretically. We suggest a solution to this trade-off between accurate predictions and simplicity. For this purpose, we introduce another quantity as a new indicator for nonclassicality: average correlation. It has both advantages of indicating whether a state is nonclassical, while still being simple to calculate and measure. We show that based on average correlation we obtain new inequalities that can be used to test nonclassicality. Moreover, we discuss how average correlation can even be used to classify all bipartite qubit states.

QI 25.8 Thu 12:45 B302

Number-phase uncertainty relations and bipartite entanglement detection in spin ensembles — Giuseppe Vitagliano[1,2], Matteo Fadel[3,4], Iagoba Apellaniz[2,5], Matthias Kleinmann[6,2], Bernd Lücke[7], Carsten Klempt[7,8], and •Géza Tóth[2,9,10,11] — [1]Institute for Quantum Optics and Quantum Information, AT-1090 Vienna, Austria — [2]UPV/EHU, ES-48080 Bilbao, Spain — [3]ETH Zürich, CH-8093 Zürich, Switzerland — [4]University of Basel, CH-4056 Basel, Switzerland — [5]Mondragon Unibertsitatea, ES-20500 Mondragón, Spain — [6]Universität Siegen, DE-57068 Siegen, Germany — [7]Leibniz Universität Hannover, DE-30167 Hannover, Germany — [8]Deutsches Zentrum für Luft- und Raumfahrt e.V. (DLR), Institut für Satellitengeodäsie und Inertialsensorik, DLR-SI, DE-30167 Hannover, Germany — [9]DIPC, ES-20080 San Sebastián, Spain — [10]IKERBASQUE, Basque Foundation for Science, ES-48011 Bilbao, Spain — [11]Wigner RCP, HU-1525 Budapest, Hungary

We present a method to detect bipartite entanglement and EPR steering based on number-phase-like uncertainty relations in split spin ensembles. In particular, we show how to detect bipartite entanglement in an unpolarized Dicke state of many spin-1/2 particles. We demonstrate the utility of the criteria by applying them to a recent experiment given in K. Lange et al. [Science 360, 416 (2018)]. Our methods also work well if split spin-squeezed states are considered. We discuss how to handle experimental imperfections.

[1] G. Vitagliano et al., arXiv:22104.05663.