Q 37: Quantum information: Concepts and methods I

Time: Thursday 10:30–12:30 Location: Kinosaal

Q 37.1 Thu 10:30 Kinosaal

Entangled particles in a dynamically controlled trap — •Thomas Stefan Häberle and Matthias Freyberger — Institut für Quantenphysik, Universität Ulm, D-89069 Ulm

We consider two colliding particles in a harmonic trap, whose trap frequency could be varied within a narrow interval. However, the interaction of the particles, modelled via point-like collisions, will remain fixed. By applying optimal control theory we will improve the motional entanglement of the particles at some final time T in comparison to the best static trap. This motional entanglement can, for example, be measured by the violation of a suitable Bell inequality. Therefore, we propose a modified gradient method, that overcomes some numerical problems of the restricted optimization problem. It turns out that a time-dependent steepness of the trap will significantly increase motional entanglement after many collisions even for a strongly restricted trap frequency.

Q 37.2 Thu 10:45 Kinosaal

Maximally entangled states for higher local Hilbert space dimension — •Osterloh Andreas — Universität Duisburg-Essen, Duisburg, Germany.

The maximally entangled states for qubits are so called balanced states. There it means that as many 1's occur in the state as 0's. This concept is extended to arbitrary dimension of the local Hilbert space, or spin. Based on the simplest SL invariance, the determinant, a simple rule is extracted. This rule is hence transported into a set of equations, a state has to satisfy for being called "balanced". The "irreducibly balanced" states play a crucial role among these "maximally entangled" states, which are those states that are detected by some SL invariant.

Q 37.3 Thu 11:00 Kinosaal

Many-particle entanglement in a spinor condensate — •Bernd Lücke[1], Jan Peise[1], Giuseppe Vitagliano[2], Wolfgang Ertmer[1], Luis Santos[3], Géza Toth[2], and Carsten Klempt[1] — [1]Institut für Quantenoptik, Leibniz Unviersität Hannover — [2]Department of Theoretical Physics, The University of the Basque Country, Bilbao, Spain — [3]Institut für theoretische Physik, Leibniz Unviersität Hannover

Ensembles of neutral atoms with entangled spins are a valuable resource for quantum enhanced metrology, quantum simulation and quantum information. Recently spin changing collisions in a Bose-Einstein condensate were established as a new tool to create such ensembles. Here we present a characterization of a quantum state produced by this mechanism. We show that the fluctuations in the z-component of the ensemble's total spin are reduced by 12.4 dB compared to an unentangled coherent state. Meanwhile, the length of the total spin almost reaches its maximum achievable value of $N/2$. This shows that the state is close to a highly entangled Dicke state with a fluctuating total number of particles with up to 10000 ^{87}Rb atoms. We measure an optimal spin squeezing parameter of $-11.4(5)$ dB and use newly derived methods to prove that the state contains at least genuine 28-particle entanglement.

Q 37.4 Thu 11:15 Kinosaal

Detection of multipartite entanglement close to symmetric Dicke states — •Géza Tóth[1,2,3], Giuseppe Vitagliano[1], Iagoba Apellaniz[1], Iñigo L. Egusquiza[1], Bernd Lücke[4], Jan Peise[4], and Carsten Klempt[4] — [1]Theoretical Physics, University of the Basque Country UPV/EHU, E-48080 Bilbao, Spain — [2]IKERBASQUE, Basque Foundation for Science, E-48011 Bilbao, Spain — [3]Wigner Research Centre for Physics, H-1525 Budapest, Hungary — [4]Institut für Quantenoptik, Leibniz Universität Hannover, Welfengarten 1, D-30167 Hannover, Germany

We define a new spin squeezing parameter for entanglement detection that, for large particle numbers, is strictly stronger than the original spin squeezing parameter defined in [A. Sorensen *et al.*, Nature 409, 63 (2001)]. For almost fully polarized states and for large particle numbers, the new parameter equals the old one and has a large noise tolerance. Our new parameter detects unpolarized states, such as symmetric Dicke states, that are not detected by the original spin squeezing parameter. We show that the collective quantities necessary to measure the new parameter can also be used to detect multipartite entanglement in the vicinity of symmetric Dicke states, which is very relevant to recent experiments in cold atoms.

Q 37.5 Thu 11:30 Kinosaal

Entanglement properties of hypergraph states — •Frank Steinhoff, Tobias Moroder, and Otfried Gühne — Naturwissenschaftlich-Technische Fakultät, Universität Siegen, Walter-Flex-Str. 3, D-57068 Siegen, Germany

Recently the formalism of hypergraph states was introduced in the literature [1,2], motivated initially by their role in Grover's and Deutsch-Josza's algorithms. Standard graph states are, as expected, a special case within this construction, which brings the question of the main differences between graph states and the more general hypergraph states. In this work we characterize some properties of the entanglement of hypergraph states, adress their equivalence under local operations, search for suitable entanglement monotones and entanglement witnesses and study some qualitative aspects of the hypergraph framework.

[1] M. Rossi, M. Huber, D. Bruß, C. Machiavello, New J. Phys. 15, 113022 (2013).

[2] R. Qu, J. Wang, Z-S. Li, Y-R. Bao, Phys. Rev. A 87, 022311 (2013).

Q 37.6 Thu 11:45 Kinosaal

Analytic expressions for the genuine multiparticle negativity — •Martin Hofmann, Tobias Moroder, and Otfried Gühne — Theoretical Quantum Optics, University of Siegen, Siegen, Germany

Entanglement is considered a very useful resource in quantum information. It is involved in some quantum key distribution protocols, quantum metrology, quantum phase transitions and many other physical applications and phenomena. To gain new insights the detection and quantification of entangled states turned out to be very helpful.

In systems with more than two parties the entangled states itself yield an interesting substructure making it more challenging to to detect and quantify entangled states in these subsets. For bipartite mixed states there is essentially only one computable entanglement monotone. That is the bipartite negativity.

In our work we investigate a slightly modified version of the genuine multiparticle negativity, which was introduced in Ref. [1]. That is a computable mixed state monotone detecting genuine multiparticle entanglement. Although it can not detect all genuine multiparticle entangled states it turns out to work quite good in practice. We show that two equivalent definitions of this monotone yield naturally arising upper and lower bounds. These can be used to derive exact analytic expressions for the modified genuine multiparticle negativity for n-qubit GHZ diagonal and four-qubit cluster diagonal states. These formulas are necessary and sufficient to fully characterize the set of genuine multiparticle entangled states within both families.

[1] B. Jungnitsch et al., Phys. Rev. Lett. 106, 190502 (2011).

Q 37.7 Thu 12:00 Kinosaal

An algebraic aproach to topological entanglement entropy — •Pieter Naaijkens and Tobias J. Osborne — Institut für Theoretische Physik, Leibniz Universität Hannover

Topological entanglement entropy (TEE) signifies topological order in a state, in the sense that there is long range entanglement. Such states can have quasiparticle excitations that have anyonic statistics. TEE is then related to the so-called total quantum dimension of these anyons. We will relate this total quantum dimension to a data hiding task, and give an interpretation of this quantity in an algebraic language, i.e., in terms of the relation between different algebras of observables. In the thermodynamic limit this leads to the Jones-Kosaki-Longo index.

Q 37.8 Thu 12:15 Kinosaal

Negativity as a counter of entangled dimensions — •Christopher Eltschka[1] and Jens Siewert[2,3] — [1]Institut für Theoretische Physik, Universität Regensburg, Regensburg, Germany — [2]Departamento de Química Física, Universidad del País Vasco UPV/EHU, Bilbao, Spain — [3]IKERBASQUE, Basque Foundation for Science, E-48011 Bilbao, Spain

Among all entanglement measures negativity arguably is the best known and most popular tool to quantify bipartite quantum correlations. It is easily computed for arbitrary states, including mixed states, of a composite system and can therefore be applied to discuss entanglement in an ample variety of situations. We show that the negativity can be viewed as an estimator of the number of degrees of freedom in which two subsystems are entangled. As it is possible to give lower bounds for the negativity even in a device-independent setting, it is the appropriate quantity to certify quantumness of both parties in a bipartite system and to determine the minimum number of dimensions that contribute to the quantum correlations. Unlike other methods to certify the dimension of a system, it does not need an independent upper bound to the number of dimensions in order to certify quatumness.