Q 67: Quantum information: Concepts and methods V

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

Q 67.1 Fri 14:00 E 214

External vs internal spin squeezing. How to tell them apart? — Giuseppe Vitagliano[1], •Zoltan Zimboras[1], Philipp Hyllus[1], Inigo Egusquiza[1], and Geza Toth[1,2,3] — [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

Spin squeezing with collective angular momentum operators is studied for an ensemble of atoms with a local spin larger than 1/2. In these systems, unlike the case of spin-1/2 ensembles, it is possible to carry out *internal spin squeezing*: only the local spin of each atom is squeezed, while there is no correlation between the atoms. We discuss the possibility of introducing entanglement conditions that can identify whether the ensemble of atoms is in such an internal squeezed state or there is genuine inter-particle spin squeezing, which we term *external squeezing*. Also the detection of internal and external squeezing with possible collective measurements in actual experiments is addressed.

Q 67.2 Fri 14:15 E 214

Area Laws for thermal free fermions — •Michael Kastoryano[1], Jens Eisert[1], and Holger Bernigau[2] — [1]FU Berlin — [2]MPI für Mathematik, Leipzig

We introduce a framework allowing to compute the mutual information, showing an area law, as well as the complete spectra of reduced states of translationally invariant free fermionic lattice systems in Gibbs states in a rigorous and asymptoti- cally exact fashion. The framework introduced develops new methods for computing determinants of Toeplitz operators with smooth symbols, and allows for considering Toeplitz matrices the entries of which depend on the physical system size. The expres- sions derived constitute a setting for studying the interplay of ground state scaling of entanglement entropies and temperature effects, showing that only at extremely low temperatures, signatures of criticality can be seen. As an example, we discuss the sit- uations of the XX in one dimension and free fermionic models on the torus in higher dimensions in detail. We highlight in particular the dependence of the mutual informa- tion scaling like the logarithm of the inverse temperature, constituting an exponential improvement over known general bounds derived from the extremality of the free en- ergy.

Q 67.3 Fri 14:30 E 214

Witnessing genuine entanglement from local information: possible, but hard — Alexandre Lopes, •Panagiotis Papanastasiou, and David Gross — University of Freiburg

It has recently been observed [M. Walter et al, arXiv:1208.0365] that in some instances, strong statements about multi-particle entanglement can be deduced from single-site information alone. The conceptually simplest case concerns the presence of *genuine entanglement*: It has been shown that certain local density matrices are compatible only with a global state that is not bi-separable (assuming it is close to pure). Here, we analyze the *computational complexity* of this task. We show that, while there are many efficiently solvable instances, the general problem is NP-hard. This leaves us with the situation that few, easily obtainable physical measurements may be sufficient to witness many-body entanglement – but that the classical post-processing is intractable. To the best of our knowledge, this is the first natural instance of a *pure state* entanglement problem that has been proven to be hard.

Q 67.4 Fri 14:45 E 214

Quantum Transport Enhancement by Time-Reversal Symmetry Breaking — Zoltan Zimboras[1,2], •Mauro Faccin[2], Zoltan Kadar[2], James Whitfield[2,3], Ben Lanyon[4], and Jacob Biamonte[2] — [1]Theoretical Physics, University of the Basque Country UPV/EHU, E-48080 Bilbao, Spain — [2]Institute for Scientific Interchange Foundation, Via Alassio 11/c, 10126 Torino, Italy — [3]Vienna Center For Quantum Science and Technology, Boltzmanngasse 5 1090 Vienna, Austria — [4]Institut für Quantenoptik und Quanteninformation, Otto-Hittmair-Platz 21a 6020 Innsbruck, Austria

Quantum mechanics still provides new unexpected effects when considering the transport of energy and information. Models of continuous time quantum walks, which implicitly use time-reversal symmetric Hamiltonians, have been intensely used to investigate the effectiveness of transport. Here we show how breaking time-reversal symmetry in this model can enable directional control, enhancement, and suppression of quantum transport. Examples ranging from exciton transport to complex networks are presented. This opens new prospects for more efficient methods to transport energy and information.

Q 67.5 Fri 15:00 E 214

SU(d) squeezing and entanglement in systems of d-level particles — •Giuseppe Vitagliano[1], Philipp Hyllus[1], Zoltan Zimboras[1], Inigo Luis Egusquiza[1], and Geza Toth[1,2,3] — [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

We discuss the problem of finding inequalities useful to detect entanglement in systems of particles with a spin j higher than 1/2. We derive a set of inequalities based on the first two moments of collective quantities different from the angular momentum operators, like the $su(2j+1)$ generators G_k. We study the states that saturate and violate the inequalities and compute the tolerance of the conditions to white noise. We compare our criteria to other entanglement conditions, such as the PPT condition and show that our criteria can detect bound entangled states. Finally, inequalities that can detect genuine k-particle entanglement are also derived.

[1] G. Vitagliano, P. Hyllus, I.L. Egusquiza, and G. Tóth, Phys. Rev. Lett. 107, 240502 (2011).

Q 67.6 Fri 15:15 E 214

Optimized entanglement witnesses for Dicke states — •Marcel Bergmann and Otfried Gühne — Naturwissenschaftlich-Technische Fakultät, Universität Siegen, Department Physik, Walter-Flex-Straße 3, D-57068 Siegen

Quantum entanglement is an important ressource for applications in quantum information processing like quantum teleportation and cryptography. Moreover, the number of particles that can be entangled experimentally using polarized photons or ion traps has been significantly enlarged. Therefore, criteria to decide the question whether a given multiparticle state is entangled or not have to be improved.

Our approach to this problem uses the notion of PPT mixtures [1] which form an approximation to the set of biseparable states. With this method, entanglement witnesses can be obtained in a natural manner via linear semidefinite programming. In our contribution, we will present analytical results for entanglement witnesses for Dicke states. This allows to overcome the limitations of convex optimization.

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

Q 67.7 Fri 15:30 E 214

Improved contraction schemes for Projected Entangled Pair States — •Michael Lubasch, Juan Ignacio Cirac, and Mari-Carmen Bañuls — Max Planck Institute of Quantum Optics, Hans-Kopfermann-Strasse 1, 85748 Garching, Germany

Projected Entangled Pair States (PEPS) represent the natural generalization of Matrix Product States (MPS) in higher dimensions. The strength of MPS in the numerical simulation of 1D quantum many-body systems is well established, as they are the variational class of states underlying the Density Matrix Renormalization Group and the latter is nowadays considered numerically exact for systems comprising hundreds of quantum particles. In algorithms based on MPS or PEPS, the bond dimension D of the state determines the number of variational parameters and the computational cost. While bond dimensions on the order of hundreds and thousands are feasible with MPS, standard 2D PEPS algorithms are limited to values in the range 2 to 6 due to the much worse scaling of the computational cost with D. Recently, a new algorithm based on an alternative contraction has been proposed [1] that reduces this cost significantly. It resorts to the single-layer picture where the contraction is done in ket and bra separately. We investigate the advantages and disadvantages of this algorithm which can be understood in terms of the PEPS's boundary approximation [2].

[1] I. Pižorn, L. Wang, and F. Verstraete, Phys. Rev. A **83**, 052321

(2011).
[2] J. I. Cirac, D. Poilblanc, N. Schuch, and F. Verstraete, Phys. Rev. B **83**, 245134 (2011).

Q 67.8 Fri 15:45 E 214

Efficient State Analysis and Entanglement Detection — •C. Schwemmer[1,2], G. Tóth[3,4,5], D. Richart[1,2], T. Moroder[6], W. Laskowski[7], L. Knips[1,2], O. Gühne[6], and H. Weinfurter[1,2] — [1]MPI für Quantenoptik, D-85748 Garching — [2]Ludwig-Maximilians-Universität, D-80797 München — [3]University of the Basque Country, E-48080 Bilbao — [4]IKERBASQUE, E-48011 Bilbao — [5]Wigner Research Centre, H-1525 Budapest — [6]Universität Siegen, D-57068 Siegen — [7]University of Gdańsk, PL-80-952 Gdańsk

Multi-partite entangled quantum states offer great opportunities with potential applications in quantum information processing. Therefore, practical tools for entanglement detection and characterization are needed. However, conventional state tomography suffers from an exponentially increasing measurement effort with the number of qubits. In contrast, low rank or symmetric states like W, Dicke or GHZ states enable tomographic analysis at polynomial effort [1,2]. Here, we apply these schemes to experimentally analyze four and six photon symmetric Dicke states. For data processing a fitting algorithm based on convex optimization is used offering significant improvements in terms of speed and accuracy [3]. It is further studied how the principle of correlation complementarity can be applied to detected entanglement with few measurements and to speed up quantum state tomography [4].

[1] Tóth et al., Phys. Rev. Lett. **105**, 250403 (2010)
[2] Gross et al., Phys. Rev. Lett. **105**, 150401 (2010)
[3] Moroder et al., New J. Phys. **14**, 105001 (2012)
[4] Laskowski et al., Phys. Rev. Lett. **108**, 240501 (2012)