Q 41: Quantum Information: Concepts and Methods VI

Time: Thursday 11:00–13:00 Location: P 2

Group Report Q 41.1 Thu 11:00 P 2

Processing of two matter qubits using cavity QED — •Stephan Welte, Bastian Hacker, Severin Daiss, Stephan Ritter, and Gerhard Rempe — Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Str. 1, 85748 Garching, Germany

In a quantum network, optical resonators provide an ideal platform for the creation of interactions between matter qubits. This is achieved by exchange of photons between the resonator-based network nodes, and in this way enables the distribution of quantum states and the generation of remote entanglement [1]. Here we will show how single photons can also be used to generate local entanglement between matter qubits in the same network node [2]. Such entangled states are indispensable as a resource in a plethora of quantum communication protocols. We will give an overview of the necessary experimental toolbox for an implementation with neutral atoms. Several entanglement protocols showing the generation of all the Bell states for two atoms will be presented. We will also detail how we experimentally exploit the employed method for quantum computation and quantum communication applications.

[1] S. Ritter et al., *Nature* **484**, 195 (2012)

[2] A. Sørensen and K. Mølmer, *Phys. Rev. Lett.* **90**, 127903 (2003)

Q 41.2 Thu 11:30 P 2

Robust creation of large entangled quantum states in Rydberg lattice system — •Maike Ostmann[1,2], Jiri Minar[1,2], and Igor Lesanovsky[1,2] — [1]School of Physics and Astronomy, University of Nottingham, Nottingham, NG7 2RD, United Kingdom — [2]Centre for the Mathematics and Theoretical Physics of Quantum Non-equilibrium Systems, University of Nottingham, Nottingham, NG7 2RD, United Kingdom

Due to new experimental developments, the generation of quantum states in Rydberg lattice systems is of interest. Recently, there has been success in the realisation of a quantum simulator for an Ising model using Rydberg atoms [1]. This promising new platform is able to deal with one and two-dimensional arrays of arbitrary geometry. Furthermore, new procedures to prepare neutral atoms in optical lattices with unit filling fraction have been developed [2,3]. Consequently, the question arises whether it is possible to easily produce a quantum state, which can be used as a resource state in quantum simulators or quantum computation. A simple protocol, which makes use of the Rydberg blockade effect, is considered. Three laser pulses are applied to a one-dimensional chain of Rydberg atoms resulting in an entangled graph state. The effect of this protocol has been simulated, and the entanglement of the state is specified by calculating the concurrence depending on the interatomic separation. [1] H. Labuhn et al., arXiv:1509.04543 (2016) [2] D. Barredo et al., arXiv:1607.03042 (2016) [3] M. Endres et al., arXiv:1607.03044 (2016)

Q 41.3 Thu 11:45 P 2

Randomized entanglement detection — •Jasmin D. A. Meinecke[1,4,5], Lukas Knips[1,4], Jan Dziewior[1,4], Pete Shadbolt[2], Joseph Bowles[3], Nicolas Brunner[3], Jeremy O'Brien[5], and Harald Weinfurter[1,4] — [1]Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Str. 1, D-85748 Garching, Germany — [2]Department of Physics, Imperial College London, SW7 2AZ, UK — [3]Groupe de Physique Appliquée, Université de Genève, CH-1211 Genève, Switzerland — [4]Fakultät für Physik, Ludwig-Maximilians-Universität München, D-80799 München, Germany — [5]Centre for Quantum Photonics, H. H. Wills Physics Laboratory & Department of Electrical and Electronic Engineering, University of Bristol, Merchant Venturers Building, Woodland Road, Bristol, BS8 1UB, UK

Entangled particles exhibit quantum correlations over arbitrary long distances in time and space which cannot be mimicked by local realistic models. In order to detect and utilize these correlations for quantum information tasks, measurements in different bases are necessary. Schemes for experimentally characterizing quantum states have been devised, which are often experimentally demanding in terms of stability and insensitivity against noise. We show that entanglement detection is possible even under uncontrolled, unknown, local environmental noise on the quantum channel - a scenario under which established entanglement witnesses and tomography schemes fail - and demonstrate our new practical method by determining the degree of entanglement and purity of an unknown state using photonic multi-qubit states.

Q 41.4 Thu 12:00 P 2

Measurement-device-independent randomness generation with arbitrary quantum states — •Felix Bischof, Hermann Kampermann, and Dagmar Bruss — Institut für Theoretische Physik III, Heinrich-Heine-Universität Düsseldorf, Universitätsstraße 1, D-40225 Düsseldorf, Germany

Measurements of quantum systems can be used to generate classical data that is truly unpredictable for every observer. However, this true randomness needs to be discriminated from randomness due to ignorance or lack of control of the devices. At the same time, the number of assumptions and explicit modeling of the devices should be low to guarantee the safety and practicality of the scheme.

We analyze the randomness gain of a measurement-device-independent setup, consisting of a well-characterized source and completely uncharacterized detector. Our framework generalizes previous schemes[1] as it quantifies the randomness generation for any implementation: arbitrary input states, and detectors with an arbitrary number of outcomes can be analyzed. Our method is used to suggest simple and realistic implementations that yield high randomness generation rates of more than one random bit per qubit for detectors of sufficient quality.

[1] Z. Cao, H. Zhou, and X. Ma (2015)

Q 41.5 Thu 12:15 P 2

Free-Space Entangled Quantum Carpets — •Andreas Ketterer[1,2], Mariana R. Barros[3], Osvaldo J. Farías[4], Fernando de Melo[4], and Stephen P. Walborn[3] — [1]Université Paris Diderot, Paris, France — [2]Universität Siegen, Siegen, Germany — [3]Universidade Federal do Rio de Janeiro, Rio de Janeiro, Brazil — [4]Centro Brasileiro de Pesquisas Físicas, Rio de Janeiro, Brazil

The Talbot effect in quantum physics is known to produce intricate patterns in the probability distribution of a particle, known as "quantum carpets", corresponding to the revival and replication of the initial wave function. Recently, it was shown that one can encode a D-level qudit, in such a way that the Talbot effect can be used to process the D-dimensional quantum information [1]. In this talk I will introduce a scheme to produce free-propagating "entangled quantum carpets" with pairs of photons produced by spontaneous parametric down-conversion [2]. First I introduce an optical device that can be used to synthesize arbitrary superposition states of Talbot qudits. Sending spatially entangled photon pairs through a pair of these devices produces an entangled pair of qudits. As an application, I show how the Talbot effect can be used to test a D-dimensional Bell inequality.

[1] O. J. Farías et al., Phys. Rev. A **91**, 062328 (2015)

[2] M. R. Barros, A. Ketterer et al., *in prep.* (2016)

Q 41.6 Thu 12:30 P 2

Recovering quantum properties of continuous-variable states in the presence of measurement errors — •Evgeny Shchukin and Peter van Loock — Johannes-Gutenberg University of Mainz, Institute of Physics, Staudingerweg 7, 55128 Mainz, Germany

We present two results which combined enable one to reliably detect multimode, multipartite entanglement in the presence of measurement errors. The first result leads to a method to compute the best (approximated) physical covariance matrix given a measured non-physical one assuming that no additional information about the measurement is available except the standard deviations from the mean values. The other result states that a widely used entanglement condition is a consequence of negativity of partial transposition. Our approach can quickly verify entanglement of experimentally obtained multipartite states, which is demonstrated on several realistic examples. Compared to existing detection schemes, ours is very simple and efficient. In particular, it does not require any complicated optimizations.

Q 41.7 Thu 12:45 P 2

Distribution of entanglement in arbitrary finite dimensionality — •Christopher Eltschka[1] and Jens Siewert[2,3] — [1]Institut für Theoretische Physik, Universität Regensburg, D-93040 Regensburg, Germany — [2]Departamento de Química Física, Universidad

del País Vasco UPV/EHU, E-48080 Bilbao, Spain — [3]IKERBASQUE Basque Foundation for Science, E-48013 Bilbao, Spain

While the quantitative theory of bipartite entanglement is developed quite far, much less is known regarding multipartite entanglement. Moreover, many of the results on multipartite entanglement are specific to qubit systems. An important example that illustrates this point is the distribution of entanglement (as well as other quantum correlations), often termed as 'monogamy of entanglement'. Here, essentially all of the quantitative results are established only for qubits, although the concept is believed to be valid in general.

In this contribution we present exact results for an arbitrary number of parties of arbitrary finite Hilbert space dimensions. It turns out that, by generalizing the multi-qubit case, a new concurrence-like entanglement monotone can be introduced. We show that this monotone is closely related to the distribution of bipartite entanglement across the multi-party system.