Q 52: Quantum Information: Concepts and Methods IV / Photons and Nonclassical Light I

Time: Thursday 14:00–16:15 Location: E 214

Q 52.1 Th 14:00 E 214

Quantifying entanglement with covariance matrices — •Oleg Gittsovich and Otfried Gühne — Institut für Quantenoptik und Quanteninformation, Technikerstrasse 21a, A-6020, Innsbruck, Österreich

Covariance matrices are a useful tool to investigate correlations and entanglement in quantum systems. They are widely used in continuous variable systems, but recently also for finite dimensional systems powerful entanglement criteria in terms of covariance matrices have been derived. We show how these results can be used for a quantification of entanglement in bipartite systems. To that aim we introduce an entanglement parameter that quantifies the violation of the covariance matrix criterion and can be used to give a lower bounds on the concurrence. These lower bounds are easily computable and give entanglement estimates for many weakly entangled states.

Q 52.2 Th 14:15 E 214

Optimal super dense coding for correlated noise with unitary and non-unitary encoding — •zahra shadman[1], hermann Kampermann[1], chiara macchiavello[2], and dagmar bruss[1] — [1]Heinrich-Heine-Universität, Institut für Theoretische Physik III , Düsseldorf, Deutschland — [2]University of Pavia, Italy

We study an important protocol in quantum information processing, namely super dense coding in the presence of correlated noise. For this case we discuss the optimal super dense coding capacity with unitary encoding. We calculate this capacity for specific examples. We also show that in case of general encoding, the optimal capacity can be reached by preprocessing on the sender's side and unitary encoding.

Q 52.3 Th 14:30 E 214

Discrimination of graph states in experiments — •Sönke Niekamp[1], Bastian Jungnitsch[1], Oleg Gittsovich[1], Matthias Kleinmann[1], and Otfried Gühne[1,2] — [1]Institut für Quantenoptik und Quanteninformation, Österreichische Akademie der Wissenschaften, Technikerstraße 21a, 6020 Innsbruck, Österreich — [2]Institut für Theoretische Physik, Universität Innsbruck, Technikerstraße 25, 6020 Innsbruck, Österreich

Which observables should one measure in order to discriminate experimentally a state against another class of states? We will consider the case that this class is given by states that can be transformed into each other by local unitaries, or by SLOCCs (cf. [1]). We are interested in experimentally feasible measurement strategies that use a small number of measurement settings. In this talk we will argue that the relative entropy, which has previously been used to assess the statistical strength of nonlocality proofs [2], gives a measure for the certainty with which a given set of observables allows us to discriminate states. We apply this measure to graph states and the measurement of their stabilizing operators. It will be shown how the stabilizer formalism helps to compute this measure and how to find sets of observables that give maximal certainty.

[1] C. Schmid, N. Kiesel, W. Laskowski, W. Wieczorek, M. Żukowski, and H. Weinfurter, Phys. Rev. Lett. 100, 200407 (2008)

[2] W. van Dam, R. D. Gill, and P. D. Grünwald, IEEE Trans. Inf. Theory 51, 2812 (2005)

Q 52.4 Th 14:45 E 214

Geometry of Dynamical Quantum Systems — •Robert Zeier and Thomas Schulte-Herbrüggen — Technische Universität München, Department Chemie, Lichtenbergstr. 4, 85747 Garching

We relate the geometry of dynamical quantum systems to the broader context of classifying Lie algebras. We give an explicit description of all possible geometries and their inclusion relations relying on results of Dynkin [1] and complementing the work of McKay and Patera [2]. Building on previous work [3,4], we use the description of all possible geometries to present readily applicable conditions for the controllability of quantum systems. We compare our approach with the standard method of deciding controllability by computing the Lie closure [5]. We emphasize the importance of our methods for the universality of quantum computers and consider partial universality with respect to subsystems. We discuss computer implementations and present concrete examples.

[1] Borel/Siebenthal, Comment. Math. Helv. 23, 200 (1949); Dynkin, Trudy Mosov. Mat. Obsh. 1, 39 (1952), Amer. Math. Soc. Transl. (2) 6, 245 (1957); Dynkin, Mat. Sbornik (N.S.) 30(72), 349 (1952), Amer. Math. Soc. Transl. (2) 6, 111 (1957)
[2] McKay/Patera, Tables of Dimensions, Indices, and Branching Rules for Representations of Simple Lie Algebras (1981)
[3] Sander/Schulte-Herbrüggen, http://arxiv.org/abs/0904.4654
[4] Polack/Suchowski/Tannor, Phys. Rev. A 79, 053403 (2009)
[5] Jurdjevic/Sussmann, J. Diff. Eq. 12, 313 (1972)

Q 52.5 Th 15:00 E 214

Experimental entanglement of a six-photon symmetric Dicke state — •Witlef Wieczorek[1,2], Roland Krischek[1,2], Nikolai Kiesel[1,2], Patrick Michelberger[1,2], Geza Toth[3,4], and Harald Weinfurter[1,2] — [1]Max-Planck-Institut für Quantenoptik, D-85748 Garching — [2]Department für Physik, LMU München, D-80799 München — [3]IKERBASQUE and Department of Theoretical Physics, The University of the Basque Country, E-48080 Bilbao — [4]Research Institute for Solid State Physics and Optics, Hungarian Academy of Sciences, H-1525 Budapest

We report on the experimental implementation of a symmetric Dicke state with six photonic qubits [1]. The necessary photons are generated by the use of a novel SPDC photon source based on a femtosecond UV enhancement cavity. To observe the Dicke state, photons from this SPDC source, arranged for collinear type II emission, are symmetrically distributed by polarization-independent beam splitters into six spatial modes. We discuss characteristic properties of Dicke states with respect to their relevance for applications in quantum information protocols and for quantum metrology. For our experimental analysis we introduce efficient tools, which require significantly fewer measurement settings than a full reconstruction of the density matrix, in order to determine the fidelity and to prove genuine multi-partite entanglement [2].

[1] W. Wieczorek *et al.*, Phys. Rev. Lett. 103, 020504 (2009); R. Prevedel *et al.*, *ibid.*, 020503.

[2] G. Tóth *et al.*, New J. Phys. 11, 083002 (2009).

Q 52.6 Th 15:15 E 214

Multi-mode quantum mechanical propagation equations for waveguided PDC — Wolfgang Mauerer, •Andreas Christ, and Christine Silberhorn — MPI for the Science of Light, IQO-Group, Erlangen, Germany

In recent years parametric down-conversion (PDC) processes have been established as a reliable source of quantum states for both fundamental quantum optics experiments and quantum information applications.

Most concepts are well understood theoretically, but they usually are based on a single-mode description or rely on first-order perturbation theory. Current PDC experiments however employ ultrafast pump lasers with high peak powers, hence contributions from many spectral modes and higher-order effects are unavoidable and need to be accounted for by theory.

In this talk we present recent progress towards full quantum-mechanical propagation equations for waveguided PDC explicitly including spatio-spectral effects utilizing the Heisenberg picture and Bogoliubov transformations. We use these as a basis for further structural analysis with special emphasis on the multi-mode spectral structure, photon-number distributions and intensity dependent effects. Furthermore we present differences between the different theoretical approaches and highlight the impacts of higher-order effects.

Q 52.7 Th 15:30 E 214

Efficient all-optical switching using slow light within a hollow fiber — •Sebastian Hofferberth[1], Thibault Peyronal[2], Michal Bajcsy[2], Alexander Zibrov[2], Vladan Vuletic[1], and Mikhail Lukin[1] — [1]Harvard-MIT Center for Ultracold Atoms, Department of Physics, Harvard University, Cambridge, MA 02138 — [2]Harvard-MIT Center for Ultracold Atoms, Department of Physics, MIT, Cambridge, MA 02139

In analogy with an electronic transistor, an all-optical switch is a device in which one light beam can fully control another. Realization of efficient all-optical switches is a long-standing goal in optical science and engineering. If integrated with modern fiber-optical technologies, such devices may have important applications for optical communication and computation. Optical switches operating at a fundamental limit of one photon per switching event would further enable the realization of key protocols from quantum information science.

Here, we present an all-optical switch that makes use of cold atoms trapped inside the hollow core of a photonic crystal fiber and quantum optical techniques for generating large nonlinear interaction between light beams. We show that this switch is activated at tiny energies corresponding to few hundred photons per pulse. We also present recent experiments using stationary light techniques to further the nonlinear optical efficiency.

Q 52.8 Th 15:45 E 214

Long-range interaction of single atoms through nanowires with nontrivial topology of couplings — •David Dzsotjan[1,2] and Michael Fleischhauer[1] — [1]Technical University of Kaiserslautern, Germany — [2]Research Institute for Particle and Nuclear Physics, Budapest, Hungary

We investigate the long-range coupling of individual atoms placed close to metallic nanowires. Putting the emitter close to the surface of the wire, a strong Purcell effect can be observed: with very high probability, the emitter will decay into guided modes of the wire, the so-called surface plasmons [1], with a rate exceeding that of free space by a large factor. The strength of the coupling originates from the fact that surface plasmon modes have an extremely small mode volume, being confined at around the surface of the nanowire. There is an optimal, sub-wavelength emitter-wire distance where the coupling to the plasmon is maximal due to the losses originating from circulating currents. When two emitters are placed along the wire (both strongly coupled to a single surface plasmon mode), we observe a strong, wire-mediated long-range interaction between the emitters. As a result of this, super- and subradiance can occur over distances large compared to the resonant wavelength. Here, the states with enhanced or suppressed decay rate are the well-known symmetric or anti-symmetric Dicke states. Taking more atoms and coupling them to a wire network with a nontrivial coupling topology leads to interesting entangled states being the subradiant states of the system.

[1] D.E. Chang et al, Phys. Rev. Lett. 97, 053002 (2006); Phys. Rev. B 76, 035420 (2007)

Q 52.9 Th 16:00 E 214

Directly detecting negative Wigner functions — Andrea Mari[1], •Konrad Kieling[1], and Jens Eisert[1,2] — [1]Institut für Physik und Astronomie, Universität Potsdam, 14476 Potsdam-Golm — [2]Institute for Advanced Study Berlin, 14193 Berlin

One of the most accepted signatures of non-classicality of a quantum state is the Wigner function – the phase space distribution becoming a probability distribution in the classical limit – being negative. To witness such a negative Wigner function is a valid test of having prepared a quantum state – in a mode of the light field, or even in an optomechanical system.

Yet, to reconstruct an entire Wigner function is a very difficult task, and requires a large series of highly accurate measurements. This is due to the fact that the usual way of achieving full tomographic knowledge and then reconstructing the state is highly ill-conditioned and hence prone to errors. It seems important and desirable, therefore, to find ways to directly measure signatures of Wigner function negativity, in a robust fashion, that make use of as little data as possible, which yet still give quantitative bounds.

We will introduce such certifiable bounds by bringing together phase space methods such as Bochner's theorem and optimization tools such as semi-definite programming. Also, the multi-mode version of this scheme can be used to witness entanglement. By showing applications to sample data we demonstrate the reliable functioning of the method and that it is ready to use as a tool for quantum state characterisation.