Q 64: Quanteneffekte: Verschränkung

Zeit: Freitag 14:00–16:30 Raum: VMP 6 HS-D

Q 64.1 Fr 14:00 VMP 6 HS-D

Violation of local realism with freedom of choice — •Thomas Scheidl[1,2], Rupert Ursin[1,2], Johannes Kofler[1,2], Sven Ramelow[1,2], Xiaosong Ma[1,2], Thomas Herbst[1,2], Lothar Ratschbacher[1,2], Alessandro Fedrizzi[1,2], Nathan Langford[1,2], Thomas Jennewein[1,2], and Anton Zeilinger[1,2] — [1]Faculty for Physics, University of Vienna, Boltzmanngasse 5, 1090 Vienna, Austria — [2]Institute for Quantum Optics and Quantum Information, Austrian Academy of Sciences, Boltzmanngasse 3, 1090 Vienna, Austria

The predictions of quantum mechanics can be in striking contradiction with local realism if entanglement exists between distant systems. Bell's theorem shows that local realistic theories place a strong restriction on observable correlations between different systems in experiments, giving rise to Bell's inequality. This allows an experimental test of whether nature itself agrees with local realism or quantum mechanics. To derive his inequality, Bell made three assumptions: realism, locality, and freedom of choice. In experimental Bell test, there may be "loopholes" which allow observed violations to still be explained by local realistic theories. Many Bell tests so far have closed individual loopholes, specifically the locality loophole and the fair-sampling loophole. However, the loophole related to Bell's freedom-of-choice assumption was not yet addressed experimentally. Here we report an experiment using entangled photons, which for the first time closes this loophole and simultaneously closes the locality loophole. It is also the first to close two of the three crucial loopholes at the same time.

Q 64.2 Fr 14:15 VMP 6 HS-D

Entangled Quantum Systems in Number Theory — •Rüdiger Mack and Wolfgang P. Schleich — Institute for Quantum Physics, Ulm University

There is an evident connection between quantum mechanics and number theory. Simply think of Shor's algorithm or quantum billards. In important function in number theory is the ζ-function of Riemann and a fundamental concept of quantum theory are entangled systems. We bring these two elements together and depict analytic continuation in mathematics in terms of a physical system.

We present a method to evaluate the ζ-function by preparing an appropriate quantum system. We emphasize the point where entanglement comes to play a role.

Q 64.3 Fr 14:30 VMP 6 HS-D

2D Spatial Entanglement Characterization of Biphotons — •Dietmar Korn, Dirk Puhlmann, Sebastian Wander, Robert Elsner, and Martin Ostermeyer — Institute for Physics and Astronomy, University of Potsdam, Potsdam, Germany

Several schemes in quantum imaging rely on multi-photon absorption. Therefore a detailed knowledge of the temporal and spatial correlations of the photons used is desired.

We investigate the correlations of space-momentum entangled biphotons. A pair of photons is generated by type II parametric down conversion and subsequently a biphoton is created utilizing a Hong-Ou-Mandel interference. To obtain a complete mapping of the biphoton's space and momentum cross sections, the near and far field of the crystal is analysed by a Hanbury-Brown-Twiss like setup with two single mode fiber probes, one in each path behind a beam splitter.

The fibre probes, having a mode-field diameter of $5\mu m$, can be moved independently over an area of $20\mu m$ x $20\mu m$ onto which the near / far field of the crystal plane has been mapped. By evaluating the coincidence photon count rate with respect to the probe positions [1] a product of variances in space and momentum can be derived which shows a strong violation of the classical correlation bound [2].

[1] Howell, J.C. et al., *Phys. Rev. Lett.* **92**, 210403(2004).

[2] Mancini, S. et al., *Phys. Rev. Lett.* **88**, 120401(2002).

Q 64.4 Fr 14:45 VMP 6 HS-D

Dissociation-induced entanglement in the motion of material particles — •Clemens Gneiting and Klaus Hornberger — Arnold Sommerfeld Center for Theoretical Physics, Ludwig-Maximilians-Universität München

The controlled dissociation of Feshbach molecules permits one to generate pairs of counterpropagating atoms that are entangled in their motional degrees of freedom. Sequences of dissociation pulses may result in delocalized single-particle states that can be manipulated by addressing individual spatial components. We describe a scheme based on dissociating trapped ultracold Feshbach molecules into an atom guide and discuss possible tests of non-classicality that would be made possible by choosing appropriate dissociation pulses. In particular, the generation of 'dissociation-time' entangled atom pairs, processed by subsequent Mach-Zehnder interferometric devices, permits to violate a Bell inequality based only on the motional entanglement of the particles [1].

[1] C. Gneiting and K. Hornberger, Phys. Rev. Lett. (2008), in press

Q 64.5 Fr 15:00 VMP 6 HS-D

Structures in entanglement dynamics — •Markus Tiersch, Fernando de Melo, and Andreas Buchleitner — Physikalisches Institut der Albert-Ludwigs-Universität, Hermann-Herder-Str. 3, D-79104 Freiburg, Germany

Understanding the dynamics of entanglement that is exhibited by a quantum system constitutes a major step in the venture to harvest this quantum effect in potential applications, and to elaborate the role that entanglement plays in real world settings. Interesting dynamics include collective coherent driving and general decoherence processes.

Without resorting to the phenomenological treatment of specific examples, we present *general* features of the structure underlying the dynamics of entanglement. Starting from low dimensional systems where algebraic properties of some entanglement monotones allow for an "entanglement equation of motion" [1,2] we continue, using topological and measure theoretic approaches [3], to typical behaviour exhibited in the thermodynamic limit.

[1] T. Konrad, F. de Melo, M. Tiersch, C. Kasztelan, A. Aragão, A. Buchleitner, Nature Phys. **4**, 99 (2008).

[2] M. Tiersch, F. de Melo, A. Buchleitner, Phys. Rev. Lett. **101**, 170502 (2008).

[3] M. Tiersch, F. de Melo, A. Buchleitner, arXiv:0810.2506.

Q 64.6 Fr 15:15 VMP 6 HS-D

Testing the spin-statistics theorem with a pair of entangled particles — •Christian Roos[1] and Hartmut Häffner[1,2] — [1]Institut für Quantenoptik und Quanteninformation, Otto-Hittmair-Platz 1, 6020 Innsbruck, Österreich — [2]Dept. of Physics, University of California, Berkeley, CA 94720, USA

We discuss how the fundamental quantum statistical property of two identical particles can be directly accessed. For this we propose to entangle the two particles by using their internal degrees of freedom and then to exchange their positions conditioned on their respective internal state. Interfering the internal states locally, allows to distinguish fermionic from bosonic statistics, even if the particles' wave function overlap vanishes at all times. Possible experimental realizations using trapped ions or neutral atoms are outlined.

Q 64.7 Fr 15:30 VMP 6 HS-D

Coherent single surface-plasmon transport in a nanowire coupled to double quantum dots — •Guang-Yin Chen[1,2], Yueh-Nan Chen[3], Niel Lambert[4], Florian Mintert[2], Der-San Chuu[5], and Andreas Buchleitner[2] — [1]Institute of Physics, National Chiao Tung University, Hsinchu 300, Taiwan — [2]Albert-Ludwigs-Universität Freiburg, Physikalisches Institut, Hermann-Herder-Strasse 3, D-79104 Freiburg, Germany — [3]Department of Physics and National Center for Theoretical Sciences, National Cheng-Kung University, Tainan 701, Taiwan — [4]Digital Materials Lab, Single Quantum Dynamics Research Group, FRS, Riken, Wako, Saitama 351-0198, Japan — [5]Department of Electrophysics, National Chiao Tung University, Hsinchu 300, Taiwan

We theoretically study coherent single surface-plasmon transport in a nanowire strongly coupled to two quantum dots. Using a real-space Hamiltonian we find analytical expressions for the transmission and reflection coefficients and dot-dot entanglement. Our results show that remotely entangled states can be created if the separation between the two dots is equal to multiple half-wavelength of the plasmon. Furthermore, by applying classical laser pulses to the quantum dots, the entangled states can be stored in metastable states which are decoupled from the surface plasmons. We also investigate dissipative effects due to "non-connecting"surface-plasmon modes.

[1] J.T. Shen and S. Fan, Phys. Rev. Lett. 95, 213001 (2005).
[2] D. E. Chang, A. S. Sørensen, E. A. Demler, and M. D. Lukin, *Nature Physics* **3**, 807 (2007).

Q 64.8 Fr 15:45 VMP 6 HS-D

Steady state entanglement in the mechanical vibrations of two dielectric membranes — •Michael Hartmann[1,2,3] and Martin Plenio[2,3] — [1]Technische Universität München, Physik Department, 85748 Garching, Germany — [2]Institute for Mathematical Sciences, Imperial College London, United Kingdom — [3]QOLS Blackett Laboratory, Imperial College London, United Kingdom

We consider two dielectric membranes suspended inside a Fabry-Perot-cavity, which are cooled to a steady state via a drive by suitable classical lasers. We show that the vibrations of the membranes can be entangled in this steady state. They thus form two mechanical, macroscopic degrees of freedom that share steady state entanglement.

Q 64.9 Fr 16:00 VMP 6 HS-D

Generation of Long-lived Entanglement on Demand in Remote Qubits — •Uwe Schilling[1], Christoph Thiel[1], Thierry Bastin[2], Enrique Solano[3], and Joachim von Zanthier[1] — [1]Institut für Optik, Information und Photonik, Friedrich-Alexander-Universität Erlangen-Nürnberg, Erlangen, Germany — [2]Institut de Physique Nucléaire, Atomique et de Spectroscopie, Université de Liège, Liège, Belgium — [3]Departamento de Química Física, Universidad del País Vasco – Euskal Herriko Unibertsitatea, Bilbao, Spain

We propose a scheme for the generation of entanglement between localized atoms with either a two-level or a Λ internal level structure. By measuring in the photons incoherently scattered off the atoms in the far field, we find that the atoms may be entangled *remotely* and *to an arbitrary degree*. For both level structures, the amount of entanglement between the particles is tunable by two easily accessible and independent experimental parameters. In case of the Λ level structure, it is found that the degree of entanglement generated can be quantified simply by the relative orientation of two polarization filters in equivalence to the well-known Malus' Law.

Q 64.10 Fr 16:15 VMP 6 HS-D

Creation and control of atomic entanglement by means of optical cavities — •Denis Gonta[1] and Stephan Fritzsche[2,3] — [1]Max–Planck–Institut für Kernphysik, Postfach 103980, D–69029 Heidelberg — [2]Physikalisches Institut der Universität Heidelberg, Philosophenweg 12, D-69120 Heidelberg — [3]Frankfurt Institute for Advanced Studies, Ruth-Moufang-Str. 1, D-60438 Frankfurt am Main

Cavity QED provides an excellent tool to control the interaction between two distant neutral atoms, for example, when the atoms pass through the cavity and are coupled simultaneously to the same cavity mode. This opens a route towards the implementation of entanglement and quantum gates via cavity-mediated atom-atom interactions.

In this contribution, a scheme is proposed to generate a entangled state between two (Λ-type) four-level atoms, which are interacting effectively by means of an off-resonant optical cavity and a laser beam. We show how the degree of entanglement for two atoms passing subsequently through the cavity depends on their velocity and the (initial) distance between the atoms. In addition, we suggest schemes to implement various two-qubit gates within the framework of the proposed atom-cavity-laser setup. For all these schemes, we display and discuss the atomic velocities and inter-atomic distances for which these gates are realized.