Q 2: Quantum Effects: Entanglement and Decoherence I

Time: Monday 11:30–13:00 Location: B/gHS

Q 2.1 Mon 11:30 B/gHS

Is macroscopic entanglement typical? — •Malte C. Tichy[1], Chae-Yeun Park[2], Minsu Kang[2], Hyunseok Jeong[2], and Klaus Mølmer[1] — [1]Deparment of Physics and Astronomy, University of Aarhus, Denmark — [2]Center for Macroscopic Quantum Control, Seoul National University, Korea

Would a world without decoherence host cohorts of Schrödinger cats? Our analytical and numerical results clearly negate this question: Although most pure random quantum states in non-trivial ensembles are highly entangled, they do not feature macroscopic fluctuations in any additive local observable and therefore do not qualify as macroscopically entangled. We establish these results by formulating bounds on measures of macroscopicity in terms of geometric entanglement, which largely determine the statistics of geometric and macroscopic entanglement in random spin-chains under different ensembles of pure quantum states. Since high geometric entanglement is an obstacle to macroscopicity, generic pure states naturally feature little Schrödinger-cat-like behavior. Permutation-symmetric states, on the other hand, carry significant macroscopicity, consistent with their low geometric entanglement.

Q 2.2 Mon 11:45 B/gHS

Macroscopicity of quantum experiments — •Stefan Nimmrichter and Klaus Hornberger — Universität Duisburg-Essen, Fakultät für Physik, 47048 Duisburg

We present a measure for the macroscopicity reached in quantum superposition experiments [1]. It is based on the principle of hypothesis tests: One quantum experiment is more macroscopic than another if it realizes a more significant test of the validity of quantum mechanics against macroscopic realism [2]. Since the main observable consequence of the latter is a hypothetical breakdown of the superposition principle on macroscopic scales, quantum superposition experiments with massive systems of many particles are the ideal candidates for such hypothesis tests. We can quantify and compare the degree of macroscopicity reached in these experiments by specifying the mathematical form of a broad generic class of hypothetical modifications of the Schrödinger equation leading to classicality in the macroworld. Objective collapse models [3], in particular, are a renowned example of macrorealistic modifications.

[1] SN & KH, PRL 110, 160403 (2013)
[2] A.J. Leggett, J. Phys.: Condens. Matter 14, R415 (2002)
[3] A. Bassi et al, RMP 85, 471 (2013)

Q 2.3 Mon 12:00 B/gHS

Quantum-entangled light from localized emitters — •Peter Grünwald and Werner Vogel — Institut für Physik, Universität Rostock, D-18055 Rostock, Germany

Quantum entanglement as a nonclassical phenomenon is a key feature in both quantum optics and quantum information [1]. The relation between nonclassicality in general and quantum entanglement in particular is a major topic of research and many questions remain unanswered until now.

We consider a localized radiation source, for which we study the relation between nonclassical light and quantum entanglement of the radiation emitted in different directions [2]. If the state of light is nonclassical, the state of the light fields emitted in two directions is also entangled, cf. [3,4]. We also conclude that nonclassicality occuring in higher-order moments implies genuine multipartite entanglement of the fields emitted in multiple directions, cf. [5]. Furthermore, the method directly provides witnesses to verify the quantum entanglement. Our approach may also be extended to describe space-time dependent quantum correlations [6].

Referenzen

[1] R. Horodecki *et. al.*, Rev. Mod. Phys. **81**, 865 (2009).
[2] P. Grünwald and W. Vogel, Phys. Rev. A **90**, 022334 (2014).
[3] E. V. Shchukin and W. Vogel, Phys. Rev. A **72**, 043808 (2005).
[4] E. Shchukin and W. Vogel, Phys. Rev. Lett. **95**, 230502 (2005).
[5] E. Shchukin and W. Vogel, Phys. Rev. A **74**, 030302(R) (2006).
[6] W. Vogel, Phys. Rev. Lett. **100**, 013605 (2008).

Q 2.4 Mon 12:15 B/gHS

Entanglement in systems of decaying particles — •Marius Paraschiv, Otfried Gühne, and Thomas Mannel — Universität Siegen, Deutschland

The study of entanglement within systems of decaying particles started in the 1960s, when Lee and Yang (among others) showed the EPR-like properties of the neutral kaon system, where the strangeness number played the role of spin up or spin down, from the traditional spin 1/2 case. Since then, neutral kaons have been investigated by many authors. Our aim is to create a general formalism for a decaying system. Staying true to the above-mentioned kaons, the initial 3-level model retains the oscillating nature of the probabilities for the two excited levels, while a third one acts as a ground state. In order to achieve a greater degree of universality, the model is formulated in an effective operator formalism, as derived in [1]. This model is then tested against the CHSH inequality, in order to verify a possible violation, but also the Sliwa-Collins-Gisin inequality is considered, a three-setting inequality not equivalent to the CHSH. The study of entanglement within this formalism is also motivated by the application of various types of Bell inequalities to atomic systems, where only one level can be detected.

[1] A. Di Domenico et al. : Foundations of Physics 42 (6), 778 (2012), arXiv:1101.4517

Q 2.5 Mon 12:30 B/gHS

Quantum state read-out and entanglement generation with optical photons in a hybrid system — •Sumanta Das[1], Sanli Faez[2], and Anders S. Sørensen[1] — [1]Niels Bohr Institute, Copenhagen University — [2]Leiden Institute of Physics, University of Leiden

We propose an efficient scheme for quantum information processing with optical photons in an engineered hybrid quantum system. Our novel hybrid comprise of a cooper pair box (CPB) qubit engineered near the surface of slot waveguide containing a molecule embedded in a polymer matrix inside it. The molecule is coupled to the CPB via D.C. stark effect that arise from the molecules large permanent dipole moment [1]. The molecule is supposed to have good coupling to the single guided modes in the slot waveguide [2,3]. We investigate how to achieve the strong coupling regime in such hybrid systems which can then be harnessed to study various quantum effects. In particular we propose schemes to achieve efficient qubit state read-out and transfer with optical photons. Furthermore, we propose schemes to create high fidelity entanglement between two remote hybrid systems. The scalability of this hybrid structure makes it promising for future integrated quantum communication circuitry.

[1] Y. L. A. Rezus, S. G. Walt, R. Lettow, A. Renn, G. Zumofen, S. Geotzinger, and V. Sandoghdar, Single- photon spectroscopy of a single molecule. Phys. Rev. Lett. (108), 093601, 2012. [2] M. Orrit, T. Ha, and V. Sandoghdar, Single-molecule optical spectroscopy. Chem. Sov. Rev. (43), 973, 2014.

Q 2.6 Mon 12:45 B/gHS

Squeezing in spin clusters and its optical detection — •Johannes Greiner, Philipp Neumann, and Jörg Wrachtrup — 3. Physikalisches Institut, Universität Stuttgart

Spin squeezing is of great interest for applications in quantum metrology and as a possible resource in quantum information. We examine the possibility to obtain squeezing in solid state spin clusters, in particular with the use of nitrogen-vacancy defects in diamond. Recent results have shown that the sensitivity of diamond based magnetometers can approach the order of spin projection noise. We discuss how spin squeezing can be used to go beyond this standard quantum limit.