Q 17: Quantum effects: Interference and correlations

Time: Monday 16:30–18:30 Location: F 342

Group Report Q 17.1 Mon 16:30 F 342

Two-photon interference and complementarity with bright twin beams — Dirk Puhlmann, Axel Heuer, •Carsten Henkel, and Ralf Menzel — Institute of Physics and Astronomy, Universität Potsdam

We discuss experiments performed with bright twin beams produced by spontaneous parametric down-conversion (SPDC) from pump beams in different spatial modes. Two-photon interferences are observed both in polarization and spatially, inserting a Mach-Zehnder interferometer in the signal beam. Our setups are designed to favor conditions where the single-photon signal shows no contrast because *Welcher Weg* information is available from the idler photon [1, 2]. In the case of a pump mode of odd symmetry (TEM_{01}), we have observed double-slit interference in a mixed coincidence signal (signal far-field, idler near-field), although the strong position correlation in near-near coincidences suggests that the idler carries *Welcher Weg* information [3]. The interpretation of these results touches upon complementarity, nonlocality in delayed-choice experiments [4], and our understanding of two-photon quantum mechanics [5].

[1] T. J. Herzog & al, Phys. Rev. Lett. **75** (1995) 3034
[2] B.-G. Englert, Phys. Rev. Lett. **77** (1996) 2154
[3] R. Menzel, D. Puhlmann, A. Heuer, and W. P. Schleich, Proc. Natl. Acad. Sci. USA **109** (2012) 9314
[4] A. Peruzzo & al, Science **338** (2012) 634; F. Kaiser & al, Science **338** (2012) 63
[5] M. H. Rubin, & al, Phys. Rev. A **50** (1994) 5122

Q 17.2 Mon 17:00 F 342

Probing Quantum Coherence in Quantum Arrays — •Javier Almeida[1], Pieter C. de Groot[2], Susana F. Huelga[1], Alexandra Liguori[1], and Martin B. Plenio[1] — [1]Ulm Universität, Ulm, Baden-Württemberg — [2]Max Planck Institut fur Quantenoptik, Garching (München), Bayern.

We discuss how the observation of population localization effects in periodically driven systems can be used to quantify the presence of quantum coherence in interacting qubit arrays. Essential for our proposal is the fact that these localization effects persist beyond tight-binding Hamiltonian models. This result is of special practical relevance in those situations where direct system probing using tomographic schemes becomes infeasible beyond a very small number of qubits. As a proof of principle, we study analytically a Hamiltonian system consisting of a chain of superconducting flux qubits under the effect of a periodic driving. We provide extensive numerical support of our results in the simple case of a two-qubits chain. For this system we also study the robustness of the scheme against different types of noise and disorder. We show that localization effects underpinned by quantum coherent interactions should be observable within realistic parameter regimes in chains with a larger number of qubits.

Q 17.3 Mon 17:15 F 342

Bosonic behavior of entangled fermions — •Malte C. Tichy[1], Peter Alexander Bouvrie[2], and Klaus Mølmer[1] — [1]Lundbeck Foundation Theoretical Center for Quantum System Research, Department of Physics and Astronomy, University of Aarhus, DK-8000 Aarhus C, Denmark — [2]Departamento de Física Atómica, Molecular y Nuclear and Instituto Carlos I de Física Teórica y Computacional, Universidad de Granada, E-18071 Granada, Spain

Two bound, entangled fermions form a composite boson, which can be treated as an elementary boson as long as the Pauli principle remains irrelevant. The bosonic character of the composite is intimately linked to the entanglement of the fermions: Large entanglement implies good bosonic properties [1]. The deviation from perfect bosonic behavior manifests itself in the statistical properties of the composites and in their collective interference. As a consequence, the counting statistics exhibited by composites allow one to infer the form of the two-fermion wave-function [2]. Bosonic behavior can thus be used as a probe for the underlying structure of composite particles without directly accessing their constituents.

[1] M.C. Tichy, P.A. Bouvrie, K. Mølmer, Phys. Rev. A 86, 042317 (2012).
[2] M.C. Tichy, P.A. Bouvrie, K. Mølmer, arxiv:1209.3610, Phys. Rev. Lett., in press.

Q 17.4 Mon 17:30 F 342

Two-photon spectra — •Elena del Valle[1], Alejandro Gonzalez-Tudela[2], Fabrice P. Laussy[2], Carlos Tejedor[2], and Michael J. Hartmann[1] — [1]Technische Universität München, Germany — [2]Universidad Autónoma de Madrid, Spain

We apply our recently developed theory of frequency-filtered and time-resolved N-photon correlations [1] to study the two-photon spectra of a variety of systems of increasing complexity: single mode emitters and the various combinations that arise from their coupling. We consider both the linear and nonlinear regimes under incoherent excitation [2]. We find that even the simplest systems display a rich dynamics of emission, not accessible by simple single photon spectroscopy. In the strong coupling regime, novel two-photon emission processes involving virtual states are revealed which can be exploited for two-photon state generation [3].

[1] Theory of frequency-filtered and time-resolved N-photon correlations, E. del Valle, A. Gonzalez-Tudela, F. P. Laussy, C. Tejedor and M. J. Hartmann. Phys. Rev. Lett. 109, 183601 (2012)
[2] Two-photon spectra of quantum emitters, A. Gonzalez-Tudela, F. P. Laussy, C. Tejedor, M. J. Hartmann, E. del Valle. arXiv:1211.5592 (2012)
[3] Distilling one, two and entangled pairs of photons from a quantum dot with cavity QED effects and spectral filtering, E. del Valle. arXiv:1210.5272 (2012)

Q 17.5 Mon 17:45 F 342

Many-particle quantum walks in disordered media — •Felix R. Anger[1,2], Sibylle Braungardt[2], and Andreas Buchleitner[2] — [1]Fakultät für Physik, Ludwig-Maximilians-Universität München — [2]Physikalisches Institut, Albert-Ludwigs-Universität Freiburg

The problem of many-particle transport through disordered media lies at the heart of a multitude of physical processes. We study quantum walks on a biased beam splitter array as a simple model for the time evolution of many-particle states in a disordered potential. Using a general expression for the particle number correlation functions, we characterize the transport properties of such systems by investigating the dependence of localization phenomena on the number of injected particles as well as on their entanglement.

Q 17.6 Mon 18:00 F 342

Einzelphotonen-Interferenz durch induzierte Kohärenz bei parametrischer Fluoreszenz — •Sebastian Raabe, Axel Heuer und Ralf Menzel — Universität Potsdam, Institut für Physik und Astronomie, Karl-Liebknecht-Str. 24/25, 14476 Potsdam

Die bei parametrischer Fluoreszenz erzeugten Photonen eines Photonenpaares besitzen eine zueinander feste Phasenbeziehung, die durch synchrones Pumpen und Strahlüberlagerung auf ein zweites Photonenpaar aufgeprägt werden kann. In einem experimentellen Aufbau wurden so Photonenpaare aus zwei unterschiedlichen Quellen durch induzierte Kohärenz zur Interferenz gebracht [1,2].
Der Vortrag wird darauf eingehen, wie die induzierte Kohärenz durch den stimulierten oder den spontanen Prozess der parametrischen Floureszenz realisiert wurde. Es wird dargestellt welchen Einfluss die Strahlungsleistung des Pump- und Signallichts sowie die spektrale Breite des Signallichts auf die Sichtbarkeit der Einzelphotonen-Interferenz hat.

[1] L.J. Wang, X.Y. Zou and L. Mandel, Phys. Rev. A 44 4614 (1991)
[2] L.J. Wang, X.Y. Zou and L. Mandel, J. Opt. Soc. Am.B, Vol.8 No.5 (1991)

Q 17.7 Mon 18:15 F 342

Collective strong coupling in multimode cavity QED — •Arne Wickenbrock[1], Michael Hemmerling[2], Gordon R.M. Robb[2], Clive Emery[3], and Ferruccio Renzoni[1] — [1]University College London, London, UK — [2]University of Strathclyde, Glasgow, UK — [3]Technische Universitaet Berlin, Berlin, Germany

We study an atom-cavity system in which the cavity has several degenerate transverse modes. Mode-resolved cavity transmission spectroscopy reveals well-resolved atom-cavity resonances for several cavity modes, a signature of collective strong coupling for the different modes. Furthermore, the experiment shows that the cavity modes are coupled via the atomic ensemble contained in the cavity. The experimental observations are supported by numerical analysis. The work paves the way to the use of interacting degenerate modes in cavity-based quantum information processing.