Q 66: Quantum Effects IV

Time: Friday 10:30–12:15 Location: Q-H13

Q 66.1 Fri 10:30 Q-H13

Generalized expression for full characterization of spectral and spatial properties of the two-photon state in Laguerre-Gaussian basis — •Baghdasar Baghdasaryan[1,2,3], Carlos Sevilla[2], Fabian Steinlechner[3,4], and Stephan Fritzsche[1,2,4] — [1]Theoretisch-Physikalisches Institut, Friedrich-Schiller-University Jena, 07743 Jena, Germany — [2]Helmholtz-Institut Jena, 07743 Jena, Germany — [3]Fraunhofer Institute for Applied Optics and Precision Engineering IOF, 07745 Jena, Germany — [4]Abbe Center of Photonics, Friedrich-Schiller-University Jena, 07745 Jena, Germany

We present a semi-analytical expression for the two-photon state that describes quantitatively both spatial and spectral properties of down-converted photons. The expression has been derived independently of the phase-matching condition. Moreover, the pump field is a pulsed Laguerre-Gaussian (LG) beam that can be easily extended to an arbitrary laser field. The expression can be used to model and predict most SPDC experiments. As an important application, we consider the engineering of high-dimensional entangled states in spatial degree of freedom. Hereby, we focus on the decoupling of spatial and spectral degrees of freedom in the broadband regime, which is crucial for the efficient generation of entangled photons.

Q 66.2 Fri 10:45 Q-H13

Many-body coherence and entanglement from randomized correlation measurements — •Eric Brunner[1,2], Andreas Buchleitner[1,2], and Gabriel Dufour[1,2] — [1]Physikalisches Institut, Albert-Ludwigs-Universität Freiburg, Hermann-Herder-Str. 3, 79104 Freiburg, Deutschland — [2]EUCOR Centre for Quantum Science and Quantum Computing, Albert-Ludwigs-Universität Freiburg, Hermann-Herder-Str. 3, 79104 Freiburg, Deutschland

We show that k-point correlation measurements on output of a non-interacting, multimode random unitary allow to quantify the k-particle coherence of $N \geq k$ identical (bosonic or fermionic) particles. We establish a strictly monotonic relationship between k-particle coherence, the interference contrast in the experimentally accessible counting statistics, and the degree of the particles' mutual distinguishability, as controlled by their internal degrees of freedom, given separable many-particle input states. Non-separability on input can be unveiled by comparison of correlation measurements of different orders.

Q 66.3 Fri 11:00 Q-H13

Investigation of incoherent-seeding effects on performance of nonlinear interferometers — •Björn Haase[1,2], Joshua Hennig[1,2], Mirco Kutas[1,2], Georg von Freymann[1,2], and Daniel Molter[1] — [1]Fraunhofer Institute for Industrial Mathematics, Kaiserslautern, Germany — [2]Department of Physics and Research Center OPTIMAS, Technische Universität Kaiserslautern, Germany

In the last decade, measurement techniques with undetected photons have undergone remarkable improvements and their potential has been demonstrated for various spectral ranges like the infrared or terahertz frequency range. This effect is based on the interference of biphotons which are generated in nonlinear crystals. In those interferometers solely the interference of the signal photons generated in one of the crystals is detected while the correlated idler radiation interacts with a sample. If both the signal and idler are aligned the sample's information can be transferred from the idler to the signal photons which are easier to detect. Yet, if the idler photon energy is very small thermal idler radiation present at room temperature has to be considered. To simulate this kind of radiation we added an incoherent seed to a nonlinear Mach-Zehnder interferometer setup used in the original work [Lemos *et al.*, Nature **512**, 409, (2014)] to evaluate its influence on the performance of nonlinear interferometers. Here, 532-nm pump photons decay into signal and idler photons at 810 nm and 1550 nm due to DFG with the incoherent seed or SPDC with vacuum fluctuations. I will present the findings, that might be useful to enhance the applicability in spectral regions suffering from insufficient sensor sensitivity.

Q 66.4 Fri 11:15 Q-H13

Dynamics of partially distinguishable particles — •Gabriel Dufour, Eric Brunner, Christoph Dittel, and Andreas Buchleitner — Physikalisches Institut, Albert-Ludwigs-Universität Freiburg

A complete description of bosonic and fermionic many-body systems should include any degree of freedom which could, in principle, allow to distinguish the particles. Indeed, even if they do not participate in the dynamics, the existence of such "labels" leads to a degradation of many-particle interference in the dynamical degrees of freedom. We show that partial distinguishability can be described in terms of entanglement between dynamical and label degrees of freedom, conditioned by the overall symmetry of the many-particle state. This entanglement suppresses interference contributions to expectation values of many-body observables, which are governed by the coherences of the reduced state of the dynamical degrees of freedom.

Q 66.5 Fri 11:30 Q-H13

Non-Markovian Stochastic Schrödinger Equation: Matrix Product State Approach to the Hierarchy of Pure States — Xing Gao[1], Jiajun Ren[2], Zhigang Shuai[2], and •Alexander Eisfeld[3] — [1]Sun Yat-sen University, Shenzhen, Guangdong, China — [2]Tsinghua University, Beijing, China — [3]MPI-PKS, Dresden

We derive a stochastic hierarchy of matrix product states (HOMPS) for non-Markovian dynamics in open quantum system at finite temperature, which is numerically exact and efficient. HOMPS is obtained from the stochastic hierarchy of pure states (HOPS) by expressing HOPS in terms of formal creation and annihilation operators. The resulting stochastic first order differential equation is then formulated in terms of matrix product states and matrix product operators. In this way the exponential complexity of HOPS can be reduced to scale polynomial with the number of particles. The validity and efficiency of HOMPS is demonstrated for the spin-boson model and long chains where each site is coupled to a structured, strongly non-Markovian environment.

[1] arXiv:2109.06393 [quant-ph]

Q 66.6 Fri 11:45 Q-H13

Decoherence of Nanorotors due to Heat Radiation — •Jonas Schäfer, Benjamin A. Stickler, and Klaus Hornberger — Faculty of Physics, University of Duisburg-Essen, Duisburg

Recent breakthroughs in levitated optomechanics with aspherical nanoparticles open the door to observing and exploiting rotational quantum interference for fundamental tests of quantum physics and for sensing applications [1]. This talk presents a theory of spatio-orientational decoherence of arbitrarily shaped dielectrics due to thermal emission of radiation. It will be shown that the orientational coherences decay gradually even for isotropic particles due to the vector character of phononic dipole transitions. We quantify the decoherence and discuss its impact for upcoming lab and space-based quantum superposition tests.

[1] Stickler et al., Nat. Rev. Phys. 3, 589-597 (2021)

Q 66.7 Fri 12:00 Q-H13

Certification of High-Dimensional Entanglement in Ultracold Atom Systems — •Niklas Euler[1,2] and Martin Gärttner[1,2,3] — [1]Physikalisches Institut, Universität Heidelberg, Heidelberg, Germany — [2]Kirchhoff-Institut für Physik, Universität Heidelberg, Heidelberg, Germany — [3]Institut für Theoretische Physik, Universität Heidelberg, Heidelberg, Germany

Quantum entanglement has been identified as a crucial concept underlying many intriguing phenomena in condensed matter systems. Recently, instead of considering mere quantifiers of entanglement like entanglement entropy, the study of entanglement structure in terms of the entanglement spectrum has shifted into focus, leading to new insights into topological phases and many-body localization, among others. What remains a challenge is the experimental detection of such fine-grained properties of quantum systems. Here we present a method to bound the width of the entanglement spectrum or entanglement dimension of cold atoms in lattice geometries, requiring only measurements in two experimentally accessible bases and utilizing ballistic time-of-flight (ToF) expansion. Building on previous proposals for entanglement certification for photon pairs, we first consider entanglement between two atoms of different atomic species and later generalize to higher numbers of atoms per species and multispecies configurations showing multipartite high-dimensional entanglement. Through numerical simulations of a Fermi-Hubbard system we demonstrate that our method is robust against typical experimental noise effects and that the required measurement statistics is manageable.