Q 78: Quantum Optics and Control III

Time: Friday 14:30–16:15 Location: P 3

Q 78.1 Fri 14:30 P 3

Deciding finiteness of bosonic dynamics — •Tim Heib — Institute for Quantum Computing Analytics (PGI-12), Forschungszentrum Jülich, 52425 Jülich, Germany — Theoretical Physics, Universität des Saarlandes, 66123 Saarbrücken, Germany

Determining the exact dynamics of a given system is paramount in most areas of physics, especially in quantum mechanics. A well-known method for systematically solving these dynamics by factorizing the time-evolution operator into a finite product of exponentials is the Wei-Norman method.

Recently, a new approach has been proposed to investigate the classes of Hamiltonians for which this method is applicable. This involves analyzing the dimensionality of Hamiltonian Lie algebras by appropriately characterizing their generating terms. In our work, we generalize previous results by significantly extending their applicability to a broader class of physically relevant bosonic Hamiltonians. We reduce the complexity of verifying finiteness conditions from quadratic to linear, and we also introduce a visual algorithm to implement the corresponding procedure. Furthermore, we identify a universal Lie algebraic structure encompassing all finite-dimensional algebras within this framework. Our contributions represent a substantial step toward a comprehensive classification of Hamiltonian Lie algebras, with potential impact for practical applications in quantum technologies.

Q 78.2 Fri 14:45 P 3

Optimal Quantum States for Frequency Estimation Limited by Spontaneous Emission — •Marius Burgath[1,2] and Klemens Hammerer[2,1] — [1]Institut für Theoretische Physik, Leibniz Universität Hannover, Germany — [2]Institut für Theoretische Physik, Universität Innsbruck, Austria

We investigate ultimate bounds for frequency estimation with an ensemble of qubits subject to local spontaneous decay. For that purpose, a numerical maximization of the quantum Fisher information (QFI) over the initial state of the ensemble is carried out. For different numbers N of qubits, the QFI is maximized by very different state classes. In the regime of small N, unbalanced GHZ states with a correlated measurement and a nonlinear estimator perform close to optimal. Above a critical number of qubits, the QFI can be maximized by spin Gottesman-Kitaev-Preskill (Spin-GKP) states, which are the compact phase space analogues of the GKP states known from quantum error correction with a harmonic oscillator. The Spin-GKP states show a comb structure in phase space, and the performance of different phase space lattices is investigated. Spin-GKP-like states can also be created with a simple gate sequence. Two one-axis twisting gates and a rotation can be used to create Spin-GKP-like structures around the equator of the Bloch sphere to reach QFI values close to the ultimate bounds.

Q 78.3 Fri 15:00 P 3

Density matrx estimation of multi-mode quantum states from incomplete homodyne data — •Isabell Mischke[1], Carlos Lopetegui[2], Bastien Oriot[2], Mattia Walschaers[2], Valentina Parigi[2], and Tim J. Bartley[1,3] — [1]Department of Physics, Paderborn University, Warburger Str. 100, 33098 Paderborn, Germany — [2]Laboratoire Kastler Brossel, Sorbonne Université, CNRS, ENS-PSL Research University, Collège de France, 4 place Jussieu, F-75252, Paris, France — [3]Institue for Photonic Quantum Systems (PhoQS), Paderborn UNiversity, Warburger Str. 100, 33098 Paderborn, Germany

Homodyne tomography is an experimental procedure to characterize for instance non-classical states as it allows us to determine the state*s statistical operator. The maximum likelihood estimation (MLE) is one possibility to recreate the density matrix from the experimental homodyne quadrature data by finding the most-likely matrix that could have produced the data. The reconstruction itself is a computationally demanding task with exponential scaling for an ascending number of modes. More degrees of freedom become increasingly relevant when looking at highly entangled systems such as cluster states.

We investigate whether it is possible to completely identify the density matrix of a multi-mode state when only a subset of modes is experimentally accessible. With a semidefinite programming approach, we are working towards the approximation of the density matrix by reducing the necessary computational time compared to the analysis of the data of the whole multi-mode state. In the future this method might enable the reconstruction of states with more than four modes.

Q 78.4 Fri 15:15 P 3

Revisiting the fully quantum approach to twisted photons' propagation in atmospheric turbulence — •Tim Ehret, Vyacheslav Shatokhin, and Andreas Buchleitner — Physikalisches Institut, Universität Freiburg, Hermann-Herder Straße 3, 79104 Freiburg

Propagation of photonic spatial modes carrying orbital angular momentum (OAM) through a turbulent atmosphere is an active research area that is important from the fundamental point of view, as well as for applications. A standard approach to account for atmospheric effects on spatial modes is based on the stochastic parabolic equation and the numerical multiple phase screens method derived therefrom. Notwithstanding the success of these approaches, a fully quantum treatment of the propagation of photons through turbulence taking full advantage of the open quantum system toolbox will be highly desirable. However, until now this problem has remained essentially unsolved. In the present contribution, we derive a quantum master equation for the ensemble-averaged density matrix of twisted photons that are phase-distorted by turbulence, show its equivalence to the master equation postulated by F. S. Roux [1], and present some preliminary numerical results. We also compare our results to state of the art of the research field.

[1] Filippus S. Roux, The Lindblad equation for the decay of entanglement due to atmospheric scintillation, Journal of Physics A: Mathematical and Theoretical 47.19, (2014), DOI: 10.1088/1751-8113/47/19/195302

Q 78.5 Fri 15:30 P 3

Spectral signatures of dissipative quantum chaos induced by structured internal degrees of freedom — •Morgan Berkane, Gabriel Dufour, and Andreas Buchleitner — Physikalisches Institut, Albert-Ludwigs-Universität Freiburg, Hermann-Herder-Straße 3, 79104, Freiburg, Germany

Chaos plays a central role in the coherence properties of many-particle quantum systems. In particular, decoherence arises when the internal degrees of freedom of the particles are not exactly identical and become (partially) distinguishable. In this work, we study the emergence of dissipative quantum chaos in a two-level system that is non-chaotic in isolation but coupled to a set of structured internal modes. We examine how chaotic internal modes degrade Hong-Ou-Mandel interference and thus generate particle distinguishability. Our results demonstrate that spectral chaos in inaccessible internal degrees of freedom can leave measurable traces in open quantum dynamics and quantum interference experiments.

Q 78.6 Fri 15:45 P 3

Quantized helicity in optical media — Neel Mackinnon[1], •Jörg Götte[1,2], Stephen Barnett[1], and Niclas Westerberg[1] — [1]University of Glasgow, University Avenue, Glasgow G12 8QQ, United Kingdom — [2]Max-Planck-Institut für Physik komplexer Systeme, Nöthnitzer Str. 38, 01187 Dresden, Germany

We present a novel approach to defining optical helicity in dispersive media that resolves the fundamental incompatibility between duality transformations and linear constitutive relations. By treating electromagnetic and matter degrees of freedom equally, we derive a helicity density that explicitly includes contributions from polarization and magnetization fields. Our formalism, based on duality transformation of vector potentials and matter fields, naturally expresses helicity in terms of polariton excitations. In dual-symmetric media, each circularly polarised polariton carries helicity equal to total energy density divided by frequency, generalising the free-space result. For arbitrary media, single-polariton states exhibit wave-vector-dependent helicity, reflecting different electric and magnetic responses. Remarkably, when helicity is not conserved, superpositions of polariton branches exhibit temporal oscillations analogous to neutrino oscillations. States initially prepared in helicity eigenstates evolve with time-dependent helicity, oscillating at frequency differences between polariton branches. Unlike previous approaches, our definition naturally extends to inhomogeneous, lossy, chiral, and nonreciprocal media, providing a unified framework for understanding helicity transfer in light-matter interactions and chiroptical effects.

Q 78.7 Fri 16:00 P 3

Distinguishability-induced many-body decoherence — •Christoph Dittel[1,2,3,4] and Andreas Buchleitner[1,2] — [1]Physikalisches Institut, Albert-Ludwigs-Universität, Hermann-Herder-Straße 3, 79104 Freiburg, Germany — [2]EUCOR Centre for Quantum Science and Quantum Computing, Albert-Ludwigs-Universität Freiburg, Hermann-Herder-Straße 3, 79104 Freiburg, Germany — [3]Freiburg Institute for Advanced Studies, Albert-Ludwigs-Universität Freiburg, Albertstraße 19, 79104 Freiburg, Germany — [4]Department of Physics, Lund University, Box 118, 221 00 Lund, Sweden

We show that many-body interference phenomena are exponentially suppressed in the particle number, if the identical quantum objects brought to interference acquire a finite level of distinguishability through statistical mixing of some internal, unobserved degrees of freedom. We discuss consequences for cold atom and photonic circuitry experiments.