Q 17: Quantum Information I

Time: Tuesday 11:00–13:00 Location: HS 1199

Q 17.1 Tue 11:00 HS 1199

Deciding Observability in Quantum Dynamics Made Easy — •Thomas Schulte-Herbrüggen and Markus Wiener — Technical University of Munich (TUM)

In quantum engineering a fundamental question arises: given a controlled quantum dynamical system, for which observables can measurements give full information for system identification?

In finite-dimensional closed systems, a unified (Lie) frame of quantum systems theory settles this observability problem—as will be illustrated in paradigmatic n-qubit systems. Implications and generalisations will be outlined as well.

Q 17.2 Tue 11:15 HS 1199

Towards exact factorization of quantum dynamics via Lie algebras — •David Edward Bruschi[1], André Xuereb[2], and Robert Zeier[3] — [1]Institute for Quantum Computing Analytics (PGI-12), Forschungszentrum Jülich, Jülich, Germany — [2]Department of Physics, University of Malta, Malta — [3]Quantum Control (PGI-8), Forschungszentrum Jülich, Jülich, Germany

Determining exactly the dynamics of a physical system is the paramount goal of any branch of physics. Quantum dynamics are characterized by the non-commutativity of operators, which implies that the dynamics usually cannot be tackled analytically and requirecad-hoc solutions or numerical approaches. A priori knowledge on the ability to obtain exact results would be of great advantage for many tasks of modern interest, such as quantum computing, quantum simulation and quantum annealing.

In this work we lay the foundations for an approach to determine the dimensionality of a Hamiltonian Lie algebra by appropriately characterizing its generating terms. This requires us to develop a new tool to construct sequences of operators that determine the final dimension of the algebra itself. Our work is exact and fully general, therefore providing statements on the ultimate ability to exactly control the dynamics or simulate specific classes of physical systems. This work has important implications not only for theoretical physics, but it also aids our understanding of the structure of the Hilbert space, as well as Lie algebras.

Q 17.3 Tue 11:30 HS 1199

Analytical quantum dynamics of coupled harmonic oscillators — •David Edward Bruschi — Institute for Quantum Computing Analytics (PGI-12), Forschungszentrum Jülich, Jülich, Germany

Harmonic oscillators are paramount systems in quantum physics. They are used to model a variety of physical systems, among which the modes of the electromagnetic field are a preeminent example. Dynamics of coupled quantum harmonic oscillators have been studied extensively, however, simple exact analytical solutions to problems of key interest have so far been lacking.

We employ symplectic geometry and the covariance matrix formalism in the context of quantum dynamics of coupled harmonic oscillators to provide the analytical solution to a few problems of interest: the validity of the rotating wave approximation for bosonic systems; exact solutions to (multimode and multi-oscillator) quantum optomechanical systems; dynamics of two coupled harmonic oscillators with single and two-mode squeezing. We conclude by commenting on current research and future direction.

Q 17.4 Tue 11:45 HS 1199

Indistinguishability of identical bosons from a quantum information theory perspective — Matthias Englbrecht[1,2], Tristan Kraft[1,2], Christoph Dittel[3,4,5], Andreas Buchleitner[3,4], •Géza Giedke[6,7], and Barbara Kraus[1,2] — [1]Institute for Theoretical Physics, University of Innsbruck, Innsbruck, Austria — [2]Department of Physics, QAA, TU Munich, Garching, Germany — [3]Physikalisches Institut, Albert-Ludwigs-Universität Freiburg, Freiburg, Germany — [4]EUCOR Centre for Quantum Science and Quantum Computing, Albert-Ludwigs-Universität Freiburg, Freiburg, Germany — [5]Freiburg Institute for Advanced Studies, Albert-Ludwigs-Universität Freiburg, Freiburg, Germany — [6]Donostia International Physics Center, San Sebastián, Spain — [7]IKERBASQUE, Basque Foundation for Science, Bilbao, Spain

We present a general theory of indistinguishability of identical bosons in experiments consisting of passive linear optics followed by particle number detection. Our approach uses tools from quantum information theory and the results do neither rely on additional assumptions on the input state of the interferometer, such as fixed mode occupation number, nor on the degrees of freedom that potentially make the particles distinguishable. We identify the expectation value of the projector onto the N-particle symmetric subspace as an operationally meaningful measure of indistinguishability, and derive tight and efficiently measureable lower bounds. We present a definition of perfect distinguishability and characterize the corresponding set of states.

Q 17.5 Tue 12:00 HS 1199

Fourier analysis of many-body transition amplitudes and states — •Gabriel Dufour and Andreas Buchleitner — Physikalisches Institut der Albert-Ludwigs-Universität Freiburg

The Fourier transform over a finite group is a generalisation of the ordinary discrete Fourier transform which allows the analysis of a function's behaviour under non-abelian transformations of its domain. We apply the Fourier transform over the symmetric group S_N to the set of multiparticle transition amplitudes arising from the permutations of N identical particles. For indistinguishable particles, these amplitudes add up coherently, giving rise to many-particle interference. The Fourier transform provides an analysis of the counting statistics at the output of multiparticle and multimode interferometers in terms of contributions from irreducible symmetry types. We apply this formalism to the interference of partially distinguishable bosons or fermions, whose states can likewise be submitted to a Fourier analysis, and to the determination of suppressed transitions for states of a given symmetry type.

Q 17.6 Tue 12:15 HS 1199

Correlations in two-particle quantum tunneling — •Jonathan Brugger, Christoph Dittel, and Andreas Buchleitner — Physikalisches Institut, Albert-Ludwigs-Universität Freiburg, Hermann-Herder-Straße 3, 79104 Freiburg, Germany

Quantum tunneling is key for our understanding of diverse processes in nature, such as nuclear and chemical reactions. While the tunneling of a single particle is nearly perfectly understood, we still lack a comprehensive understanding of the tunneling processes of two or more interacting particles: Under which conditions do they tunnel individually or in a correlated way? What is the role and influence of the particles' interaction? And is there an underlying spectral structure?

Here we answer these questions for the tunneling dynamics of two interacting bosons via exact numerical diagonalization, for hard-core and soft-core Coulomb, as well as contact interaction of variable strength. We find that correlated two-particle tunneling is the primary process, while uncorrelated single-particle tunneling is due to resonances between the two-particle system's eigenfunctions. We determine the necessary prerequisites for the latter and provide an intuitive picture of the underlying spectral structure. As a corollary, we establish a diagnostic protocol to infer the particles' interaction mechanism from interaction-induced dynamical signatures, via an experimentally readily accessible observable.

Q 17.7 Tue 12:30 HS 1199

Generalization of the Peres test: Multi-slit and multi-particle extension — •Ece Ipek Saruhan[1,2], Marc-Oliver Pleinert[2], and Joachim von Zanthier[2] — [1]Institute for Quantum Optics and Quantum Information (IQOQI) Vienna, Boltzmanngasse 3, A-1090 Vienna, Austria — [2]Quantum Optics and Quantum Information Group, Friedrich-Alexander-Universität Erlangen-Nürnberg, Staudtstr. 1, 91058 Erlangen, Germany

The axioms of quantum mechanics provide limited information regarding the structure of the Hilbert space, such as the underlying number system, which may be real, complex, or hyper-complex. Asher Peres proposed a method to test hyper-complex quantum mechanics with a single particle and three scatterers [1]. In this talk, we introduce a convenient way to derive the test and extend it to a higher number of particles and scatterers (slits). We show that the sensitivity to detect - still hypothetical - hyper-complex phases changes with the number of slits and particles. In particular, we find that if one wants to test d vs. k dimensional theories where $d < k$, one must use $d + 1 \leq s \leq k$

slits. [1] A. Peres, Phys. Rev. Lett. 42, 683 (1979)

Q 17.8 Tue 12:45 HS 1199

Demonstration of entanglement-enabled work extraction — •Alexander Stahl[1], Michael Kewming[2], John Goold[2], Daniel Pijn[1], Ulrich Poschinger[1], and Ferdinand Schmidt-Kaler[1] — [1]Institut für Physik, Universität Mainz, Staudingerweg 7, 55128 Mainz, Germany — [2]Department of Physics, Trinity College Dublin, Dublin 2, Ireland

Trapped ion quantum computers provide an ideal platform for experimental studies in the field of quantum thermodynamics. We experimentally realize a work extraction protocol, converting entanglement into classical correlation and then into work. In this protocol, a 'demon' has access to an entangled ressource state shared with an 'agent'. The agent has only local access, such that this ressource appears to be thermal. By a sequence of manipulations, the demon can betray the agent and use information gained about the agents state to extract work. We show how this corroborates the work extraction protocol proposed in [1] and that the maximum work extraction is indeed bound by the concurrence as $\frac{\delta W}{E} \gtrsim \frac{C^2}{2}$. To enable the implementation of the protocol, the measurement outcome of qubits has to be used for a classical decision logic, such that a coherent feedforward for the following operations can be realized. Specifically, in the shuttling based trapped ion quantum computer this requires the capability to decide on a μs-timescale about future ion transports and laser pulses to execute.

[1] G. Francica, J. Goold, F. Plastina, and M. Paternostro, npj Quantum Information 3 (2017)