SYQS 3: Characterization and control of complex quantum systems III

Time: Friday 16:30–18:30 Location: Audimax

SYQS 3.1 Fri 16:30 Audimax

Exciton-polariton lasing in disordered ensembles of correlated Mie resonators — •Regine Frank[1] and Andreas Lubatsch[2] — [1]Institute for Theoretical Physics, Eberhard-Karls University Tübingen, Germany Center for Light-Matter-Interaction, Sensors and Analytics (LISA+) and Center for Complex Quantum Phenomena (CQ) — [2]Electrical Engineering, Precision Engineering, Information Technology, Georg-Simon-Ohm University of Applied Sciences, Kesslerplatz 12, 90489 Nürnberg, Germany

The spectral density of electronic states of ZnO is investigated for experimentally relevant pump power values of random lasers. Nonequilibrium Keldysh theory and numerics for the Hubbard model predicts unusal broadening of the electronic bands. We discuss whether this leads to exciton-polariton coupling within the single ZnO cylinders in the Mie resonance condition. The cylinders are considered random in space but coherently correlated by photonic transport and multiple scattering. Long range interferences are found to be crucial for the development of a polariton condensate and lasing of large-area quantum efficiency.

R. Frank, A. Lubatsch, Phys. Rev. A 84, 013814 (2011) R. Frank, Phys. Rev. B 85, 195463 (2012)

SYQS 3.2 Fri 16:45 Audimax

Tomography of squeezed and oversqueezed states of mesoscopic atomic ensembles — •Baptiste Allard, Roman Schmied, Caspar F. Ockeloen, and Philipp Treutlein — Department of Physics, University of Basel, Klingelbergstrasse 82, 4056 Basel, Switzerland

The experimental characterization of the quantum state of a mesoscopic ensemble of particles is a major challenge in quantum physics, especially when multi-particle entanglement is present.

We experimentally demonstrate tomographic state reconstruction of non-classical many-body (pseudo-)spin states. The system consists of a two-component ^{87}Rb Bose-Einstein condensate of a few hundred atoms created on an atom-chip [1]. A state-selective potential gives rise to a S_z^2 interaction term in the Hamiltonian in the collective spin representation. Using this one-axis twisting dynamics [2], we prepare non-classical spin states such as spin-squeezed and spin-oversqueezed states.

Using well-controlled Rabi rotations and projective measurements, we perform a Stern-Gerlach-type analysis to characterize the many-body quantum states. From the results of measurements along many quantization axes, we determine the most likely positive-semidefinite density matrix; this represents an improvement over our previously published backprojection technique [3].

[1] M. F. Riedel, *et al.*, Nature **464**, 1170 (2010). [2] M. Kitagawa and M. Ueda, Phys. Rev. A **47**, 5138-5143 (1993). [3] R. Schmied and P. Treutlein, New J. Phys. **13**, 065019 (2011).

SYQS 3.3 Fri 17:00 Audimax

On the versatility of quantum master equations: an effective description of disorder dynamics — •Chahan M. Kropf, Clemens Gneiting, and Andreas Buchleitner — Institute of Physics, Albert-Ludwigs University of Freiburg, Hermann-Herder-Str.3, D-79104 Freiburg, Germany

In order to describe the dynamics of quantum systems subject to disorder, one typically computes the ensemble average either with a perturbative approach or by direct numerical simulation. Another possibility consists in an effective description of the ensemble-averaged dynamics.

Here we propose to derive general, local-in-time, quantum master equations for the ensemble-averaged dynamics of finite, isolated, disordered quantum systems. To do so, we first invert the exact dynamics for single realizations, and then perform the ensemble averaging explicitly. Under rather general conditions do we find Non-Markovian dynamics and master equations with time-dependent decay rates and Hermitian Lindblad operators.

Invited Talk SYQS 3.4 Fri 17:15 Audimax

Multi-photon dynamics in complex integrated structures — •Fabio Sciarrino — Dipartimento di Fisica, Sapienza Università di Roma, Italy

Integrated photonic circuits have a strong potential to perform quantum information processing. Indeed, the ability to manipulate quantum states of light by integrated devices may open new perspectives both for fundamental tests of quantum mechanics and for novel technological applications. The evolution of bosons undergoing arbitrary linear unitary transformations quickly becomes hard to predict using classical computers as we increase the number of particles and modes. Photons propagating in a multiport interferometer naturally solve this so-called boson sampling problem, thereby motivating the development of technologies that enable precise control of multiphoton interference in large interferometers. Here, we use novel three-dimensional manufacturing techniques to achieve simultaneous control of all the parameters describing an arbitrary interferometer. We implement a small instance of the boson sampling problem by studying three-photon interference in a nine-mode integrated interferometer, confirming the quantum-mechanical predictions. Scaled-up versions of this set-up are a promising way to demonstrate the computational advantage of quantum systems over classical computers. The possibility of implementing arbitrary linear-optical interferometers may also find applications in high-precision measurements and quantum communication.

Invited Talk SYQS 3.5 Fri 17:45 Audimax

Complexity and many-boson coherence — •Malte Tichy — Department of Physics and Astronomy, Aarhus University, DK-8000 Aarhus, Denmark

Many-boson systems feature a subtle interplay of complexity and coherence. Many-boson coherence is a source of complexity, which makes Boson-Sampling – the simulation of many-boson interference – a paradigm that may demonstrate the superiority of quantum devices. However, current protocols that aim at certifying the functionality of Boson-Sampling setups are shown to be bypassed by an efficient model with randomly prepared independent particles. An alternative test based on a solvable instance of the problem is shown to permit more stringent certification for arbitrarily many particles [1]. The protocol paves the road to rule out alternative models for many-particle behavior that extricate themselves from true complexity. Bosonic composites made of two constituents, however, deviate from ideal elementary bosonic behavior when their constituents are not sufficiently entangled. The complexity of the constituent wavefunction thus becomes a requirement for the ideal collective bosonic behavior of composites and the absence of complexity leads to observable deviations [2].

[1] Malte C. Tichy, Klaus Mayer, Andreas Buchleitner, Klaus Mølmer, arXiv:1312.3080 (2013). [2] Malte C. Tichy, P. Alexander Bouvrie, Klaus Mølmer, Phys. Rev. A 86, 042317 (2012); Phys. Rev. A 88, 061602(R) (2013).

Questions & answers (18:15 - 18:30)