A 52: Characterization and control of complex quantum systems SYQS 1 (with Q, MO, MS, MP, AGjDPG)

Time: Friday 10:30–12:30 Location: Audimax

Invited Talk A 52.1 Fri 10:30 Audimax
Tutorial Complex Systems: From Classical to Quantum, from Single to Many Particle Problems — •Klaus Richter — Institut für Theoretische Physik, Universität Regensburg, 93040 Regensburg, Germany

There does not exist a common notion of what defines a complex (quantum) system; depending on context and community perception of complex behavior varies a lot. I will first review aspects and characteristics of complexity in classical systems, where it has been originally considered, pointing out analogies between complex phenomena in simple low-dimensional settings and emergent complexity from interactions in the many-body case. Thereby I will put forward the notion that complex behaviour is linked to discontinuities. In the second part of the lecture I will discuss implications for complex quantum systems.

Questions & answers (11:15 - 11:30)

Invited Talk A 52.2 Fri 11:30 Audimax
Multiphoton random walks: Experimental Boson Sampling on a photonic chip — •Ian Walmsley[1], Justin Spring[1], Ben Metcalf[1], Peter Humphreys[1], Steve Kolthammer[1], Xianmin Jin[1], Animesh Datta[1], James Gates[2], and Peter Smith[2] — [1]University of Oxford, Department of Physics, Clarendon Laboratory, Parks Rd. Oxford, OX2 3PU, UK — [2]Optoelectronics Research Center, University of Southampton, SO17 1BJ, UK

Photonics provides a feasible platform for implementing many quantum information protocols, with the opportunity to realise quantum enhancements to technologies from sensing to computation. For instance, ideal universal quantum computers may be exponentially more efficiently than classical machines for certain classes of problems. Nonetheless, the formidable challenges in building such a device motivate the search for and demonstration of alternative problems that still promise a quantum speedup. Quantum boson sampling (QBS) provides such an example. We have constructed a photonic quantum boson sampling machine (QBSM) to sample the output distribution resulting from the nonclassical interference of photons in an integrated photonic circuit, a problem thought to be exponentially hard to solve classically. Unlike universal quantum computation, boson sampling merely requires indistinguishable bosons, linear state evolution, and detectors, imperfections of which may result in systematic errors. Our studies open the way to larger devices that could offer the first definitive quantum enhanced computation.

A 52.3 Fri 12:00 Audimax
Antiresonance in a Strongly-Coupled Atom-Cavity System — •Christoph Hamsen, Christian Sames, Haytham Chibani, Paul A. Altin, Tatjana Wilk, and Gerhard Rempe — Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Str. 1, D-85748 Garching

The strongly-coupled atom-cavity system has proven useful for the observation of fundamental quantum effects. Recently, it has found application as a building block for more complex structures in elementary quantum circuits for quantum information processing. Moreover, large networks of strongly-coupled systems have been proposed for simulation of quantum phase transitions. However, due to the strong coupling these compound systems cannot be treated perturbatively, but require a holistic analysis of all constituents making characterization a challenging task.

Here, we provide a route to address this challenge. It is based on an experiment where, by heterodyne detection of the light transmitted through a cavity containing a single atom, we see a hitherto unobserved negative phase shift which is associated with an antiresonance. The linewidth and frequency of this antiresonance are solely determined by the atom. The corresponding phase shift can be optically controlled via the AC stark shift and reaches values of up to 140° - the largest ever reported for a single emitter. We explain how this opens up new routes towards characterization of complex quantum circuits.

A 52.4 Fri 12:15 Audimax
Tuning the Quantum Phase Transition of Bosons in Optical Lattices via Periodic Modulation of s-Wave Scattering Length — Tao Wang[1,2], •Xue-Feng Zhang[1], Francisco Ednilson Alves dos Santos[3], Sebastian Eggert[1], and Axel Pelster[1] — [1]Physics Department and Research Center OPTIMAS, Technische Universität Kaiserslautern, Germany — [2]Department of Physics, Harbin Institute of Technology, China — [3]Instituto de Física de São Carlos, Universidade São Paulo, Brazil

We investigate how the superfluid-Mott insulator quantum phase transition for bosons in a 2D square and a 3D cubic optical lattice changes due to a periodic modulation of the s-wave scattering length. At first we map the underlying periodically driven Bose-Hubbard model approximately to an effective time-independent Hamiltonian with a conditional hopping [1]. Combining different analytical approaches with quantum Monte Carlo simulations then reveals that the location of the quantum phase boundary turns out to depend quite sensitively on the driving amplitude. A more quantitative analysis shows even that the effect of driving can be described within the usual Bose-Hubbard model provided that the hopping is rescaled appropriately with the driving amplitude. This finding indicates that the Bose-Hubbard model with a periodically driven s-wave scattering length and the usual Bose-Hubbard model belong to the same universality class from the point of view of critical phenomena.

[1] A. Rapp, X. Deng, and L. Santos, Phys. Rev. Lett. **109**, 203005 (2012).