Q 44: Quantum Information (Concepts and Methods) III

Time: Thursday 10:30–12:30 Location: S HS 001 Chemie

Q 44.1 Thu 10:30 S HS 001 Chemie

States that can be reached with hybrid algorithms — •Joachim Welz, Filip Wudarski, and Andreas Buchleitner — Physikalisches Institut, Albert-Ludwigs-Universität Freiburg, Germany

Recent developments in quantum computer's architecture have allowed us to run proof-of-principle hybrid quantum-classical algorithms. One of the most prominent examples of the latter is the Variational Quantum Eigensolver (VQE) that searches Hilbert space for the ground state of arbitrary Hamiltonians. Here, we discuss the structure of quantum circuits running the VQE in order to identify the space of reachable states. We analytically investigate 2-qubit Hamiltonians and formulate conditions for obtaining the ground state. Finally, we present limitations and restrictions for higher-dimensional (n-qubit) problems.

Q 44.2 Thu 10:45 S HS 001 Chemie

Quantum walk driven by entangled coins — •Shahram Panahiyan and Stephan Fritzsche — Helmholtz Institute Jena, Jena, Germany

We talk about one-dimensional quantum walk driven by entangled coins. We will demonstrate that the entanglement, introduced by the coins, enables one to steer the walker's state from a classical to standard quantum-walk behavior, and to novel behavior not found for one-dimensional walks otherwise. We also show that states with a symmetric density distribution and a maximum or minimum of the entropy are found only for maximally entangled initial states (Bell states). On the other hand, the type of probability density distribution and its variance are only determined by entangled coins. In addition, we explain how the entanglement of initial state determines the most probable place to find the walker.

Q 44.3 Thu 11:00 S HS 001 Chemie

Eigenvalue Measurement of Topologically Protected Edge states in Split-Step Quantum Walks — •Thomas Nitsche[1], Tobias Geib[2], Christoph Stahl[2], Lennart Lorz[1], Christopher Cedzich[2,3], Sonja Barkhofen[1], Reinhard F. Werner[2], and Christine Silberhorn[1] — [1]Applied Physics, IQO, University of Paderborn, Warburger Str. 100, 33098 Paderborn, Germany — [2]Institut für Theoretische Physik, Leibniz Universität Hannover, Appelstr. 2, 30167 Hannover, Germany — [3]Institut für Theoretische Physik, Universität zu Köln, Zülpicher Str. 77, 50937 Köln, Germany

We study topological phenomena of quantum walks by implementing a novel protocol that extends the range of accessible properties to the eigenvalues of the walk operator. To this end, we experimentally realise for the first time a split-step quantum walk with decoupling, which allows for investigating the effect of a bulk-boundary while realising only a single bulk configuration. We approximate the symmetry protected edge states with high similarities and read out the phase relative to a reference for all modes. In this way we observe eigenvalues which are distinguished by the presence or absence of sign flips between steps. Furthermore, the results show that investigating a bulk-boundary with a single bulk is experimentally feasible when decoupling the walk beforehand.

Q 44.4 Thu 11:15 S HS 001 Chemie

Bound entangled states fit for robust experimental verification — •Gael Sentís[1,2], Johannes N. Greiner[3], Jiangwei Shang[1,4], Jens Siewert[2,5], and Matthias Kleinmann[1,2] — [1]Universität Siegen, Siegen, Germany — [2]Universidad del País Vasco UPV/EHU, Bilbao, Spain — [3]University of Stuttgart and Institute for Quantum Science and Technology, Stuttgart, Germany — [4]Beijing Institute of Technology, Beijing, China — [5]IKERBASQUE, Bilbao, Spain

Preparing and certifying bound entangled states in the laboratory is an intrinsically hard task, due to both the fact that they typically form narrow regions in state space, and that a certificate requires a tomographic reconstruction of the density matrix. Indeed, the previous experiments that have reported the preparation of a bound entangled state relied on such tomographic reconstruction techniques. However, the reliability of these results crucially depends on the extra assumption of an unbiased reconstruction. We propose an alternative method for certifying the bound entangled character of a quantum state that leads to a rigorous claim within a desired statistical significance, while bypassing a full reconstruction of the state. The method is comprised by a search for bound entangled states that are robust for experimental verification, and a hypothesis test tailored for the detection of bound entanglement that is naturally equipped with a measure of statistical significance. We apply our method to families of states of 3x3 and 4x4 systems, and find that the experimental certification of bound entangled states is well within reach.

Q 44.5 Thu 11:30 S HS 001 Chemie

Experimental implementation of a device-independent dimension test using genuine temporal correlations — •Hendrik Siebeneich, Cornelia Spee, Timm Florian Gloger, Peter Kaufmann, Michael Johanning, Matthias Kleinmann, Otfried Gühne, and Christoph Wunderlich — Department Physik, Universität Siegen, 57068 Siegen, Germany

Temporal correlations that appear in sequential measurements of a quantum system depend on the system's dimension. Exploiting this property, a device-independent measurement scheme has been devised that witnesses the dimension of the quantum system through the violation of temporal inequalities [1]. Using the hyperfine manifold of a single $^{171}Yb^{+}$ ion stored in a micro-structured 3D linear Paul trap [2], we observe temporal correlations between sequential measurements of hyperfine states and the violation of the above-mentioned inequalities. This serves to certify a lower bound for the dimension of the qauntum system used in these experiments [3]. Extending measurement sequences to length three, we further show, that the genuine temporal correlation scheme goes beyond the prepare-and-measure schemes.

[1]J. Hoffmann, C. Spee, O. Gühne and C. Budroni, New J. Phys. 20, 102001 (2018).
[2]P. Kaufmann, T. F. Gloger, D. Kaufmann, M. Johanning and Ch. Wunderlich, Physical Review Letters 120, 010501 (2018)
[3]C. Spee, H. Siebeneich, T. Gloger, P. Kaufmann, M. Johanning, C. Wunderlich, M. Kleinmann and O. Gühne, arXiv:1811.12259v1 [quant-ph].

Q 44.6 Thu 11:45 S HS 001 Chemie

Blind calibration quantum state tomography — •Jadwiga Wilkens, Ingo Roth, Dominik Hangleiter, and Jens Eisert — Freie Universitaet, Berlin, Deutschland

For the last 20 years, the research on quantum information processing is experiencing a rapid growth and holds great promises for revolutionary new technology. In the development of these quantum technologies efficient and flexibel methods for extracting information about a quantum state from measurements are required. One important task is to fully determine a quantum state from the measured data with only mild structure assumptions on the state. This is the problem of quantum state tomography. Using a signal processing paradigm called compressed sensing, quantum tomography schemes for low-rank states were developed that are resource-optimal. But to date compressed sensing schemes for quantum state tomography lack robustness against imperfection of the measurement devices. For this reason, experimental setups performing these schemes need to have measurement devices that are calibrated to a high precision. In this work we develop the framework of blind calibration tomography which allows for incomplete knowledge of the measurement device during the tomography of a quantum state. It simultaneously determines both the device calibration and the quantum state with minimal resources and efficient classical post-processing. Building on recent techniques from the field of compressed sensing, we derive algorithmic strategies for blind calibration tomography and provide analytical performance guarantees. We further demonstrate their performance in numerical simulations.

Q 44.7 Thu 12:00 S HS 001 Chemie

Sample complexity of device-independently certified "quantum supremacy — •Dominik Hangleiter[1], Martin Kliesch[2], Jens Eisert[1], and Christian Gogolin[3] — [1]Freie Universität Berlin, 14195 Berlin — [2]Heinrich Heine Universität Düsseldorf, 40225 Düsseldorf — [3]Universität Köln, 50937 Köln

Results on the hardness of approximate sampling are seen as important stepping stones towards a convincing demonstration of the superior computational power of quantum devices. The most prominent suggestions for such experiments include boson sampling, IQP circuit sampling, and universal random circuit sampling. A key challenge for any such demonstration is to certify the correct implementation. For all these examples, and in fact for all sufficiently flat distributions, we show that any non-interactive certification from classical samples and a description of the target distribution requires exponentially many uses of the device. It is an ironic twist of our results that the same property that is a central ingredient for the approximate hardness results, prohibits sample-efficient certification: namely, that the sampling distributions, as random variables depending on the random unitaries defining the problem instances, have small second moments.

Q 44.8 Thu 12:15 S HS 001 Chemie

Distinguishing between statistical and systematic errors in quantum process tomography — •Sabine Wölk[1,2], Theeraphot Sriarunothai[2], Gouri Giri[2], and Christof Wunderlich[2] — [1]Institute for Theoretical Physics, University of Innsbruck, Innsbruck, Austria — [2]Naturwissenschaftlich-Technische Fakultät, Department Physik, Universität Siegen, Siegen, Germany

It is generally assumed that every process in quantum physics can be described mathematically by a completely positive map. However, experimentally reconstructed processes are not necessarily completely positive due to statistical or systematic errors. In this talk, we introduce a test for discriminating statistical from systematic errors which is necessary to interpret experimentally reconstructed, non-completely positive maps. We discuss the significance of the test with the help of several examples given by experiments and simulations. In particular, we discuss an experimental example of initial correlations between the system to be measured and its environment that leads to an experimentally reconstructed map with negative eigenvalues. These experiments are carried out using atomic $^{171}Yb^{+}$ ions confined in a linear Paul trap, addressed and coherently manipulated by radio frequency radiation.