Q 8: Quantum Information: Concepts and Methods II

Time: Monday 14:30–16:30 Location: e214

Q 8.1 Mon 14:30 e214

Quantum Complexity Classes with Disturbed Witnesses — •Friederike Anna Dziemba and Tobias Osborne — Insitut für Theoretische Physik, Leibniz Universität Hannover, Germany

Quantum complexity theory categorizes computational problems into complexity classes characterized by a specific type of quantum protocol. The most famous classes are formed by the problems that can be solved efficiently by a quantum computer (class BQP) and the problems that can be verified efficiently by a quantum computer provided with a so-called witness which can either be a quantum or a classical state (classes QMA or QCMA).

We consider these three classes as variants of a complexity class defined by an efficient quantum protocol and a witness that is sent through a parametrized quantum channel. Depending on the noise the channel introduces into the witness we reobtain either the class QMA, QCMA or BQP. Thresholds for the channel parameter guaranteeing one of these cases allow for new characterizations of the standard complexity classes.

Q 8.2 Mon 14:45 e214

Practical applications of compressed sensing in quantum state tomography — •Carlos Riofrio, Adrian Steffens, and Jens Eisert — Dahlem center for complex quantum systems, Freie Universität Berlin, 14195 Berlin, Germany.

As quantum systems get closer to technological applications, the problem of identifying, certifying, and characterizing them becomes more daunting. In fact, a complete characterization of a quantum system requires determining a number of parameters that grow exponentially with the system size. New paradigms that allow for efficient signal processing must be developed and tested to overcome this roadblock. In this talk, we present an overview of the most recent developments in quantum state tomography via compressed sensing. We show a complete analysis based on experimental data from two different systems: First, a photonic circuit that prepares highly entangled photons corresponding to 4-qubit states, which we use as a testbed to showcase our tomographic procedure in a variety of scenarios; Second, a 7-qubit system of trapped ions which encodes a single logical qubit via a color code, in which highly incomplete data is observed. We show how compressed sensing and model selection ideas can be combined, which is necessary in practice when little information is available.

Q 8.3 Mon 15:00 e214

Heisenberg-Weyl basis observables and related applications — •Ali Asadian[1], Pauli Erker[2], Otfried Guehne[1], Marcus Huber[2], and Claudio Kloeckl[2] — [1]Naturwissenschaftlich-Technische Fakultaet, Walter-Flex-Straße 3, Siegen, Germany — [2]Universitat Autonoma de Barcelona, 08193 Bellaterra, Barcelona, Spain

The Bloch vector provides a very useful geometrical representation of quantum states for characterizing their properties. We establish a new basis of observables constructed by a suitable combination of the non-Hermitian generalization of the Pauli matrices, the Heisenberg-Weyl operators. This allows us to identify a (Hermitian) Bloch representation for an arbitrary density operator of finite, as well as infinite dimensional systems in terms of complete set of Heisenberg-Weyl observables. Compared to the canonical basis of Gell-Mann operators, the Heisenberg-Weyl based observables exhibit number of advantageous properties which we highlight in the context of entanglement detection.

Q 8.4 Mon 15:15 e214

Testing an axiom of quantum theory: Which measurements are admissible? — •Matthias Kleinmann[1] and Adán Cabello[2] — [1]University of the Basque Country, Bilbao, Spain — [2]Universidad de Sevilla, Sevilla, Spain

Quantum theory is not particularly complicated when it comes to the question of admissible measurements: A measurement is admissible as long as it does not contradict the rules of probability. We confront this assumption with an alternative, minimalistic construction, where quantum measurements with any number of outcomes are generated from quantum measurements with only two outcomes. The predictions of this alternative are vastly identically to quantum theory, except for specialized high-precision Bell-like scenarios. In fact, experimental data of such experiments already provide evidence that correlations in nature are not emerging from measurements with only two or three outcomes. In addition, it is also possible to confront quantum theory with another challenge. A large class of generalized models makes predictions that are in conflict with quantum theory and allows for experiments on quantum systems that would rule out such “post-quantum” models.

Q 8.5 Mon 15:30 e214

How long does it take to obtain a physical density matrix? — •Lukas Knips[1,2], Christian Schwemmer[1,2], Nico Klein[1,2], Jonas Reuter[3], Géza Tóth[4,5,6], and Harald Weinfurter[1,2] — [1]Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Strasse 1, D-85748 Garching — [2]Department für Physik, Ludwig-Maximilians-Universität, D-80797 München — [3]Bethe Center for Theoretical Physics, Universität Bonn, D-53115 Bonn — [4]Department of Theoretical Physics, University of the Basque Country UPV/EHU, P.O. Box 644, E-48080 Bilbao, Spanien — [5]IKERBASQUE, Basque Foundation for Science, E-48013 Bilbao, Spanien — [6]Wigner Research Centre for Physics, Hungarian Academy of Sciences, P.O. Box 49, H-1525 Budapest, Ungarn

The statistical nature of measurements easily causes unphysical estimates in quantum state tomography. We show that multinomial or Poissonian noise results in eigenvalue distributions converging to the Wigner semicircle distribution for already a modest number of qubits. In this talk, I will show that this fact can be used to specify the number of measurements necessary to avoid unphysical solutions as well as a new approach to convert unphysical estimates into physical ones.

Q 8.6 Mon 15:45 e214

Quantum-enabled measurement of the electric field using Rydberg atoms — •Eva-Katharina Dietsche, Adrien Facon, Dorian Grosso, Serge Haroche, Jean-Michel Raimond, Michel Brune, and Sebastien Gleyzes — Laboratoire Kastler Brossel, College de France, ENS-PSL, UPMC-Sorbonne Universite, CNRS, 11 Place Marcelin Berthelot 75005 Paris, France

In the classical world there is no fundamental limit to the precision of a measurement. In quantum mechanics, however, the precision of a measurement is ultimately limited by quantum fluctuations. For instance, the direction of a large angular momentum J prepared in a coherent spin state cannot be determined with a precision better than 1/sqrt(J), the standard quantum limit (SQL) for this system. A measurement uncertainty below the SQL can only be attained by the use of quantum-enabled metrology techniques. It is then possible to reach the ultimate limit, the Heisenberg limit, which scales as 1/J.

Here, we present a quantum-enhanced measurement of the electric field using mesoscopic Schrödinger-cat-like superpositions of Rydberg states. The atom behaves like a large angular momentum J whose precession frequency depends on the electric field. Instead of performing a standard Ramsey experiment using a coherent spin state, we prepare the atom in a cat-like state and measure the quantum phase accumulated by the spin during its Ramsey evolution. With this single-atom-electrometer we succeed in measuring field variations in the order of 1mV/cm in 100ns, beating the SQL. The extreme sensitivity of this measurement could pave the way to many practical applications.

Q 8.7 Mon 16:00 e214

Beyond Conventional Photon Counting — •Johannes Kröger[1], Thomas Ahrens[1], Jan Sperling[2], Boris Hage[3], Werner Vogel[2], and Heinrich Stolz[1] — [1]Semiconductor Optics Group, University of Rostock, Rostock, Germany — [2]Theoretical Quantum Optics Group, University of Rostock, Rostock, Germany — [3]Experimental Quantum Optics Group, University of Rostock, Rostock, Germany

Quantum information sciences are heavily depending on photon number resolving measurements. Advancing demands on detector performances go beyond the abilities of state-of-the-art devices. The established high sensitivity detectors operate in a binary detection mode, creating only a click for any number of absorbed photons.

Systems of click detectors, such as APD-arrays, superconducting nanowires or time multiplexed setups, proved convenient and reliable in many recent experiments. We demonstrate, with experimental evidence, that neither is the statistical information acquired with these devices insufficient for discriminating quantum states, nor is the nonlinear detection mode a disadvantage towards true photon counters.

We developed a model for detector characteristics, enabling us to extract vital information about the light field with intensities ranging from few photons to photon numbers higher than the number of detector elements (or time bins). Exposing our 10×10 APD-array to fs-Ti:Sapphire laser pulses, we measured a parameter for indication of quantum light (similar to the Mandel Q parameter) and higher quantum correlations.

Q 8.8 Mon 16:15 e214

Device-Independent Bounding of Detector Efficiencies —
•Jochen Szangolies, Hermann Kampermann, and Dagmar Bruss — Institut für Theoretische Physik III, Heinrich-Heine Universität Düsseldorf

In many quantum information applications, a minimum detection efficiency must be exceeded to ensure success. Protocols depending on the violation of a Bell inequality, for instance, may be subject to the so-called detection loophole: imperfect detectors may yield spurious violations, which consequently cannot be used to ensure, say, quantum cryptographic security. Hence, we investigate the possibility of giving lower bounds on detector efficiency even if an adversary has full control over both the source and the detectors. To this end, we present a technique, based on characterizing the polytope of local correlations, to systematically derive Bell inequalities free from the detection loophole whose violation certifies that the detectors used exceed a certain minimal efficiency.