Q 3: Quantum Information (Concepts and Methods) I

Time: Monday 11:00–13:00 Location: e001

Group Report Q 3.1 Mon 11:00 e001

Breaking Symmetries in Quantum Control Engineering: Principles and Applications — •Thomas Schulte-Herbrüggen[1], Ville Bergholm[1], Witlef Wieczorek[2], Michael Keyl[3], Frederik vom Ende[1], and Amit Devra[1] — [1]Dept. Chem., TU-Munich (TUM), Munich, Germany — [2]Dept. Microtechnology and Nanoscience, Chalmers University of Technology, Sweden — [3]Dahlem Centre for Complex Quantum Systems, FU Berlin, Germany

In emerging quantum technologies, quantum optimal control is often key to unlock the full potential of experimental set-ups.

For quantum engineering, our Lie frame of quantum systems theory provides full symmetry assessment of controllability, accessibility and reachability. In view of quantum sensing, here we focus the same tools on observability and tomographiability.

We see which symmetries to break to get a better handle both on the preparation and the detection of states. Principles are put into practice by optimal control.

Our recent proposal for an optomechanical oscillator extended by a two-level atom is a perfect illustration: without breaking the system symmetries of the optomechanical oscillator, one can only interconvert *within* classes of states of the same Wigner negativity. Coupling to the atom breaks the symmetry and thus allows to go *between* them, e.g., from Gaussian states to non-classical ones.

Worked examples thus elucidate guiding principles for quantum technologies 2.0.

Q 3.2 Mon 11:30 e001

Optimal Control: Scaling of the Control with System Size — •Matthias Mueller — Institute of Quantum Control, Peter Grünberg Institut, Forschungszentrum Jülich

Driving a quantum system with control pulses designed by Optimal Control Theory can considerably speed up desired operations like state transfer or gates and enhance the fidelity of the operations [1]. As the system size scales up, however, more resources (e.g. bandwidth, number of control parameters) are needed to control the system and the complexity of the control task grows [2]. In my contribution I will present the DCRAB algorithm [3] as an optimal control tool that allows to engineer such complex control pulses also under the action of constraints [3]. A proper choice of the control objective can decrease the effective number of parameters needed to achieve the control task [4,5]. A similar effect can be achieved by dynamically tailoring the system into subsystems relevant to the control task, e.g. by Quantum Zeno Interactions.

[1] C. Brif, R. Chakrabarti, and H. Rabitz, N. J. Phys. 12, 075008 (2010) [2] S. Lloyd, S. Montangero, PRL 113, 010502 (2014) [3] N. Rach, MMM, T. Calarco, S. Montangero, PRA 92, 052343 (2015) (ES) [4] MMM, T. Pichler, S. Montangero, T. Calarco, Appl. Phys. B, 122:104 (2016) [5] MMM, D.M. Reich, M. Murphy, H. Yuan, J. Vala, K.B. Whaley, T. Calarco, C.P. Koch, Phys. Rev. A 84, 042315 (2011)

Q 3.3 Mon 11:45 e001

Sampling scheme for neuromorphic simulation of entangled quantum systems — •Stefanie Czischek, Martin Gärttner, and Thomas Gasenzer — Kirchhoff-Institut für Physik, INF 227, 69120 Heidelberg, Germany

It has been shown recently that a large class of quantum many-body states can be represented efficiently by artificial neural networks. Furthermore, neural network architectures can be implemented in a controlled manner by means of analog hardware setups. This opens the prospect that neuromorphic computers can be used to efficiently emulate quantum many-body systems. We propose a phase-reweighted sampling scheme to draw spin states from the network-encoded distribution on neuromorphic hardware, such as the BrainScaleS system. Combining this scheme with a deep-neural-network ansatz representing quantum spin-1/2 states allows for measurements in various orthogonal spin bases. We apply the scheme to small systems with non-classical features to show that quantum entanglement can be simulated using the classical stochastic networks.

Q 3.4 Mon 12:00 e001

Statistical characterization of multipartite entanglement with moments of random correlations — •Tobias Nauck, Heinz-Peter Breuer, and Andreas Ketterer — Albert-Ludwigs-Universität Freiburg, Freiburg, Germany

Characterizing the entanglement of an unknown multipartite quantum state usually requires a number of appropriately chosen local measurements that are aligned with respect to a previously shared common reference frame. While such methods work well for small multipartite systems, they often become impractical with increasing number of involved constituents due to the exponentially growing Hilbert space dimension. In this talk we employ a statistical approach for the detection and characterization of multipartite entanglement based on moments of correlation functions obtained from a finite number of randomized measurements. In particular, we study the scaling of the required number of measurements needed to detect entanglement in the light of statistical inaccuracies and as a function of the number of involved parties.

Q 3.5 Mon 12:15 e001

Detecting entanglement of unknown continuous variable states with random measurements — Tatiana Mihaescu[1,2], Hermann Kampermann[1], •Giulio Gianfelici[1], Aurelian Isar[2,3], and Dagmar Bruss[1] — [1]Heinrich-Heine-Universität Düsseldorf, Institut für Theoretische Physik III, D-40225 Düsseldorf, Germany — [2]Department of Theoretical Physics, National Institute of Physics and Nuclear Engineering, RO-077125 Bucharest-Magurele, Romania — [3]Faculty of Physics, University of Bucharest, RO-077125 Bucharest-Magurele, Romania

We explore the possibility of entanglement detection in continuous-variable systems by entanglement witnesses based on covariance matrices, constructible from random homodyne measurements. We propose new linear constraints characterizing the entanglement witnesses based on second moments, and use them in a semidefinite programme providing the optimal entanglement test for given random measurements. We test the method on the class of squeezed vacuum states and study the efficiency of entanglement detection in general unknown covariance matrices.

Q 3.6 Mon 12:30 e001

Proving uncertainty relations with semi-definite programming — •Timo Simnacher, Xiao-Dong Yu, and Otfried Gühne — Naturwissenschaftlich-Technische Fakultät, Universität Siegen, Walter-Flex-Straße 3, 57068 Siegen

Heisenberg's uncertainty principle conveys a major distinction between quantum and classical physics. Since its formulation, uncertainty relations have become one of the exceptional trademarks of quantum mechanics. Beside being of fundamental importance, current experiments are indeed able to approach these universal limitations. Although extensive research has been conducted in particular in the field of quantum information theory, there is still no general understanding of uncertainty relations, especially when it comes to more than two measurement settings.

One serious obstacle hindering further advances in the theory of uncertainty relations is the non-linearity common to both, variance- and entropy-based formulations. We present a general method to linearize such relations utilizing multiple copies of the same quantum state. Using semi-definite programming techniques, we provide effective relaxations to obtain non-trivial bounds for relevant state-independent uncertainty relations. Furthermore, we formulate uncertainty relations in terms of moment matrices to achieve results independent of the explicit measurement settings. Semi-definite programs have the advantage of providing a certificate, proving the obtained bounds up to numerical precision.

Q 3.7 Mon 12:45 e001

Quantum fluctuation relations for generalized quantum measurements — •Konstantin Beyer[1], Kimmo Luoma[1], Roope Uola[2], and Walter Strunz[1] — [1]TU Dresden, Institut für Theoretische Physik — [2]University of Geneva, Group of Applied Physics

Quantum fluctuation theorems are mostly discussed in the framework of two-point measurement scenarios. The validity of the results often relies explicitly on projective measurements and tacitly on the use of Lüders instruments. From a quantum information point of view, these are severe restrictions and it is desirable to clarify to what extent they are necessary for the formulation of quantum fluctuation relations. Therefore, we broaden the view and investigate generalized quantum fluctuation theorems based on POVMs and different kinds of instruments, showing that the relations for standard two-point energy measurements can be seen as special cases of a more general class of POVM fluctuation theorems.