Q 1: Quantum Information: Concepts and Methods I

Time: Monday 14:30–16:30 Location: P 2

Group Report Q 1.1 Mon 14:30 P 2

Control of quantum state transfer in one dimensional structures — •David Petrosyan — Institute of Electronic Structure & Laser, Foundation for Research and Technology - Hellas, Heraklion, Crete, Greece

After an outline of the activities of our theoretical Quantum Optics and Technology group, which involve studies of cold atoms, coherent quantum effects in atomic ensembles, interacting Rydberg gases, physical implementations of quantum computation and communication, and quantum cryptography, I will present some of our results on control and manipulation of quantum state transfer in several physical settings, including atomic and photonic lattices.

Faithful transfer of quantum states in spin chains is indispensable for scalable realization of quantum computation in many systems where qubit-qubit interactions have finite range. I will discuss state transfer protocols in spin chains with static and dynamic inter-spin couplings, and their robustness with respect to diagonal and off-diagonal disorder. I will then present a scheme for a quantum spin transistor in a Heisenberg spin chain, which realizes conditional state transfer. A proof-of-concept realization of the device can be done with just a few cold, trapped atoms, but the idea is generally applicable to various other implementations of spin chains. Finally, I will describe manipulation and transfer of non-classical motional states of atoms in a lattice using Rydberg dressing with off-resonant lasers.

Group Report Q 1.2 Mon 15:00 P 2

Toward the Limits of Controlling Closed and Open Quantum Systems — •Thomas Schulte-Herbrüggen[1], Ville Bergholm[1,2], Frank K. Wilhelm[3], and Gunther Dirr[4] — [1]Technical University of Munich (TUM) — [2]University of Helsinki — [3]University of Saarbrücken — [4]University of Würzburg

Optimal control is proving more and more indispensable for steering quantum devices with high fidelity. Recent examples in NV centres include single-shot readout quantum sensing enhanced via a quantum memory [1].

Here we report on latest extensions of the optimal-control platform DYNAMO [2]. They include switchable noise as additional control beyond coherent ones and its implications for reachability under open-loop versus closed-loop control designs.

We propose experimental implementation of fast noise switching in a superconducting device, i.e. a two-qutrit GMon with fast tunable coupling to an open transmission line serving as a low-temperature bath. The setting is closest to the one available in the Martinis group.

References:

[1] S. Zaiser et al., Nature Commun. 7, 12279 (2016).

[2] S. Machnes et al., Phys. Rev. A 84, 022305 (2011).

[3] V. Bergholm, F.K. Wilhelm, and T. Schulte-Herbrüggen, arXiv:1605.06473

Q 1.3 Mon 15:30 P 2

Quantum control of few level systems — Marcus Theisen[1] and •Sandro Wimberger[1,2,3] — [1]ITP, Heidelberg University, 69120 Heidelberg, Germany — [2]DiFeST, Università degli Studi di Parma, 43124 Parma, Italy — [3]INFN, Sezione di Milano Bicocca, Gruppo Collegato di Parma, Italy

We present and discuss possible ways to exert quantum control on few level systems. The focus is on finding protocols that drive the system's dynamics exactly. These protocols describe the temporal developement of control parameters, e.g., external fields in spin resonance experiments. In particular, we are interested in superadiabatic protocols (1) which allow for adiabatic population transfer between quantum states. This type of transitionless quantum driving is illustrated for the Landau-Zener model. Similar control protocols are tested for more complex 2 and 3 level systems numerically. They are found to result in the desired behaviour. Future prospects include possible ways to stir the 4 level quantum system as a basic model for two interacting Qbits. All protocols could turn out to be useful in quantum computation.

(1) M. V. Berry, Transitionless quantum driving, J. Phys. A, 42 (365303), 2009

Q 1.4 Mon 15:45 P 2

Randomized Benchmarking with symmetries — •Emilio Onorati[1], Albert H. Werner[2], and Jens Eisert[1] — [1]Dahlem Center for Complex Quantum Systems, Freie Universität Berlin, Germany — [2]Department of Mathematical Sciences, University of Copenhagen, Denmark

A central step toward the realization of quantum information processing devices is the estimation of the accuracy in the implementation of unitary gates. While a complete characterization of any quantum operation may be obtained through quantum process tomography, this approach suffers from two major shortcomings: SPAM errors sensitivity and exponentially growing necessary resources. Randomized benchmarking has become a standard technique to overcome these limitations. The method involves the measurement of density operators after application of a random sequence of gates, chosen from the Clifford or other small groups, which drastically reduces the number of needed parameters. While randomized benchmarking has proven to be successful in numerous experiments, the initial assumptions of the protocol are demanding: up to small perturbations, the average error is assumed to be both gate- and time-independent with respect to all gates. We propose a novel approach to overcome these issues: by exploiting the symmetries of the gates to be benchmarked, we are able to estimate the error of each operator individually. To this aim, knowledge regarding the representation theory of the symmetry group is necessary; nevertheless, we investigate how well-known and small groups allow for the characterization of a large number of multi-qubit gates.

Q 1.5 Mon 16:00 P 2

Limits of Quantum Control: bounds on minimum time and control field amplitudes — •Christian Arenz, Benjamin Russell, and Herschel Rabitz — Frick Laboratory, Princeton University, Princeton NJ, 08544 US

We derive a lower bound for the time that is needed in order to implement a target unitary transformation through classical time-dependent fields. The bound depends on the target gate, the strength of the internal Hamiltonian and the highest control field amplitude. Furthermore, based on the established bound we characterize the reachable set of unitary operations as a function of the evolution time and the control field amplitude, here explicitly analyzed for a single qubit. Moreover, for a fully controllable system we show that the derived bound yields a lower bound for the time at which all unitary gates become reachable. We use numerical gate optimization in order to study the tightness of the obtained bounds. It is shown that in the single qubit case our analytical findings describe remarkably well the limit of reducing the highest control field amplitude and the evolution time as much as possible, while still being able to implement some unitary target operation. Finally we discuss the challenges in obtaining more accurate bounds for higher dimensional systems.

Q 1.6 Mon 16:15 P 2

Recovering the ideal results of a perturbed analog quantum simulator — •Iris Schwenk[1], Jan-Michael Reiner[1], Sebastian Zanker[1], Lin Tian[2], Juha Leppäkangas[1], and Michael Marthaler[1] — [1]Institute of Theoretical Solid State Physics, Karlsruhe Institute of Technology (KIT), 76131 Karlsruhe, Germany — [2]School of Natural Sciences, University of California, Merced, California 95343, USA

Well controlled quantum systems can potentially be used as quantum simulators. However inevitably a quantum simulator is perturbed by coupling to additional degrees of freedom. This constitutes a major roadblock to useful quantum simulations, since so far there are only a limited amount of possibilities to understand the effects of these perturbation on the result of the quantum simulation. We present a method which in limited circumstances, allows for the reconstruction of the ideal result from measurements on a perturbed quantum simulator. We study the case where we are interested in extracting a correlator $\langle \hat{O}^i(t)\hat{O}^j(0)\rangle$ from the simulated system in equilibrium, where $\hat{O}^i$ are the operators which couple the system to its environment. The ideal correlator can be reconstructed if any n-time correlator of operators $\hat{O}^i$ of the ideal system can be written as products of two-time correlators. We give an approach to verify the validity of this assumption experimentally using additional measurements on the perturbed quantum simulator.