FM 22: Quantum Control

Time: Monday 16:30–18:15 Location: 3042

Invited Talk FM 22.1 Mon 16:30 3042

Control Engineering Taken to the Limits of Quantum Systems Theory — •Thomas Schulte-Herbrüggen[1], Ville Bergholm[1], Witlef Wieczorek[2], and Michael Keyl[3] — [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

Quantum optimal control is often key to exploiting the full potential of experimental set-ups pertinent to quantum emerging technologies.

We sketch a Lie frame for quantum systems theory, where symmetries and conservation laws are in quantum Noether-type 1:1 correspondence. Thus one gets a full assessment of controllability, obervability, and accessibility in quantum engineering. We now see which symmetries to break for more control and we show how to apply optimal control to exploit quantum dynamics within the enlarged accessible territory.

Our recent proposal for an optomechanical oscillator extended by a two-level atom perfectly illustrates these principles: without breaking the system symmetries of the optomechanical oscillator, one can only interconvert *within* 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.

The example thus elucidates guiding principles for quantum technologies 2.0.

FM 22.2 Mon 17:00 3042

Optimal Control of Superconducting Qubits — •Max Werninghaus[1], Daniel J. Egger[1], Marc Ganzhorn[1], Federico Roy[2], Shai Machnes[2], Frank Wilhelm-Mauch[2], and Stefan Filipp[1] — [1]IBM Research Zurich — [2]Saarland University

Fast and accurate two-qubit gates are a key requirement to perform complex algorithms on current quantum computers. Ideally, the duration of the gate should be much shorter than the coherence time of the system. However, shorter gates can result in unwanted leakage out of the computational subspace. Optimal control theory aims to design fast control pulses suppressing such side effects of the driving field. However, even with an accurately calibrated system model, control pulses require a tune-up to accommodate for parameter-drifts and -inaccuracies. Here we present our work on techniques to speed up calibration routines of control pulses defined by up to 20 parameters. We improve the interplay of control instruments and multidimensional optimization algorithms to reduce hardware constraints to realize efficient tune-up feedback-loops.

FM 22.3 Mon 17:15 3042

Coherent control of two-photon absorption via entangled photons — •Edoardo Carnio[1], Frank Schlawin[2], and Andreas Buchleitner[1] — [1]Physikalisches Institut, Albert-Ludwigs-Universität Freiburg, Germany — [2]Clarendon Laboratory, University of Oxford, United Kingdom

Coherent control exploits the coherence of classical light to drive an initial quantum state to a desired final state. In two-photon absorption (TPA), in particular, two photons are used to excite a molecule from the ground to an excited state. Under certain conditions, frequency-entangled photons drive the transition more efficiently than in the classical case [1]. We quantify the correlations in the state with the entropy of entanglement, which we compare to the enhancement of the transition. We perform this analysis in the two cases of finite and infinite interaction time.

[1] Schlawin, F. & Buchleitner, A. *Theory of coherent control with quantum light.* New J. Phys. 19, 013009 (2017).

FM 22.4 Mon 17:30 3042

Collective dephasing of tripartite Werner states — •Clément Canard, Edoardo Carnio, and Andreas Buchleitner — Physikalisches Institut, Albert-Ludwigs-Universität Freiburg, Germany

An improved understanding of the entanglement dynamics of multipartite quantum states coupled to a noisy environment is an indispensable prerequisite for scalable quantum information processing. As a specific example, we consider the fate of highly symmetric, three-partite Werner states [1,2] under structural perturbations of their rotational symmetry, and subsequently investigate the robustness of their entanglement properties under collective dephasing, as a ubiquitous source of decoherence e.g. in ion trap experiments.

[1] Werner, R.F. *Quantum states with Einstein-Podolsky-Rosen correlations admitting a hidden-variable model.* Phys. Rev. A 40, 4277 (1989).
[2] Eggeling, T. & Werner, R. F. *Separability properties of tripartite states with $U\otimes U\otimes U$ symmetry.* Phys. Rev. A 63, 042111 (2001).

FM 22.5 Mon 17:45 3042

Quantum-state-controlled reactive atom-atom collisions — Tobias Sixt, Jiwen Guan, Markus Debatin, Frank Stienkemeier, and •Katrin Dulitz — Institute of Physics, University of Freiburg, 79104 Freiburg i. Br., Germany

In our experiments, we study quantum-state-controlled reactive collisions between lithium atoms and metastable helium atoms to explore the influence of electron-spin polarization on the reaction rate and to observe quantum resonance effects at low collision energies. Eventually, these experiments are aimed at controlling the outcome of chemical reaction rates, e.g., using coherent control techniques. In our approach, we use an experimental apparatus which consists of a discharge source for the production of metastable helium atomic beams and a magneto-optical trap (MOT) for ultracold lithium atoms [1]. In this contribution, I will show results illustrating that the reaction rate dramatically depends on the initial electronic state of both metastable helium and lithium, respectively. To distinguish between the relative contribution of the $He(2^1S_0)$ and $He(2^3S_1)$ states to the reaction rate, we make use of an original optical quenching scheme [2] which makes it possible to fully deplete the population of $He(2^1S_0)$ in the supersonic beam via optical excitation to the 4^1P_1 state.

[1] Jonas Grzesiak, Takamasa Momose, Frank Stienkemeier, Marcel Mudrich and Katrin Dulitz, *J. Chem. Phys.* **150**(3), 034201, 2019. [2] Jiwen Guan, Vivien Behrendt, Pinrui Shen, Simon Hofsäss, Thilina Muthu-Arachchige, Jonas Grzesiak, Frank Stienkemeier, and Katrin Dulitz, *Phys. Rev. Appl.*, **11**(5), 054073, 2019.

FM 22.6 Mon 18:00 3042

Generalized Filter Functions for Sequences of Quantum Gates — •Julian Teske, Pascal Cerfontaine, Tobias Hangleiter, and Hendrik Bluhm — JARA-FIT Institute for Quantum Information, Forschungszentrum Jülich GmbH and RWTH Aachen University, 52074 Aachen, Germany

When sequences of quantum gates are executed in the presence of non-Markovian noise, the process description of the entire operation is not given by the composition of the individual quantum processes. In my talk I will first present an extension of the filter function formalism to allow the efficient calculation of quantum processes in the presence of correlated noise, e.g. the 1/f-like noise found in many solid-state qubit systems. I will then use this formalism to obtain correction terms for sequences of quantum gates which depend on the individual gates' process descriptions and the structure of the algorithm. For all of these purposes we present an efficient and easy-to-use software implementation.