PhD-Symposium - Optimal Control Theory in the Leading Domains of Quantum Technology (SYPS)

organised by Working Group young DPG (AKjDPG)
supported by all divisions of the section AMOP

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A term frequently used in recent years is the "second quantum revolution". It describes the promise of accelerating the development of Quantum Computation, Encryption, Sensing, and generally making quantum physics an intrinsic part of technology. These so-called Quantum Technologies hold the promise to improve state-of-the-art classical technologies beyond their current, classically limited capabilities. They intrinsically harness quantum effects which are simply not present in the classical world. In general, these Quantum Technologies can be divided into four different pillars, namely Quantum Simulation, Quantum Communication, Quantum Computing and Quantum Metrology. Although all these fields strive to solve different technological challenges and differ in experimental and theoretical complexity, they have one crucial necessity in common: they require control over the respective quantum systems in use. Control over these quantum systems is thereby mediated by a set of external, experimentally accessible control fields and parameters. How these control fields should be chosen for optimal performance, i.e., such that the respective task in question is solved optimally, is tackled by Quantum Optimal Control Theory (OCT). However, since the fundamental idea of OCT is very general, its application ranges far beyond Quantum Technologies, as it can, for instance, also be used to control all kinds of atomic or molecular systems. Nevertheless, the field of Quantum Technologies serves as an excellent example to highlight the vast amount of possibilities emerging from OCT. In our symposium we bring together leading experts in experiment and theory from all four pillars of Quantum Technology to give a general introduction to the field of OCT and a broad overview of what has and can be done

Overview of Invited Talks and Sessions

(Lecture room U Audimax)

Invited Talks

SYPS 1.1	Mon	14:00–14:30	U Audimax	**Optimal control of many-body quantum systems** — •Simone Montangero
SYPS 1.2	Mon	14:30–15:00	U Audimax	**Light matter quantum interface based on single colour centres in diamond** — •Fedor Jelezko
SYPS 1.3	Mon	15:00–15:30	U Audimax	**Principles of Quantum Systems Theory and Control Engineering** — •Thomas Schulte-Herbrüggen
SYPS 1.4	Mon	15:30–16:00	U Audimax	**Quantum metrology with Rydberg atoms** — •Sebastien Gleyzes, Arthur Larrouy, Remi Richaud, Sabrina Patsch, Jean-Michel Raimond, Michel Brune, Christiane Koch

Sessions

SYPS 1.1–1.4	Mon	14:00–16:00	U Audimax	**PhD - Symposium: Optimal Control Theory in the Leading Domains of Quantum Technology**

SYPS 1: PhD - Symposium: Optimal Control Theory in the Leading Domains of Quantum Technology

Time: Monday 14:00–16:00 Location: U Audimax

Invited Talk SYPS 1.1 Mon 14:00 U Audimax

Optimal control of many-body quantum systems — •Simone Montangero — Physics and Astronomy department "G. Galilei", Padova University, Italy.

Quantum optimal control allows finding the optimal strategy to drive a quantum system in a target state. We review an efficient algorithm to optimally control many-body quantum dynamics and present an information theoretical analysis of quantum optimal control processes and its implications.

We optimally control many-body systems to achieve an optimal quantum annealing process that goes beyond the adiabatic strategy. Finally, we review some theoretical and experimental applications of optimal annealing to different quantum simulation setups, ranging from the control of Rydberg atoms in optical lattices to the optimal crossing of the Superfluid to Mott insulator quantum phase transition.

Invited Talk SYPS 1.2 Mon 14:30 U Audimax

Light matter quantum interface based on single colour centres in diamond — •Fedor Jelezko — Institute of Quantum Optics, Ulm University, Ulm, Germany

Efficient interfaces between photons and atoms are crucial for quantum networks and enable nonlinear optical devices operating at the single-photon level. In this talk I will highlight properties of single color centers at low temperatures and show that single SiV and GeV color centers in diamond are promising candidates for creating such interfaces. I will also show experiments towards realization of fully integrated, scalable nanophotonic quantum devices.

Invited Talk SYPS 1.3 Mon 15:00 U Audimax

Principles of Quantum Systems Theory and Control Engineering — •Thomas Schulte-Herbrüggen — Technical University of Munich (TUM), Germany

We exemplify system-theoretical principles and tools by analysing systems following an extended Lindblad master equation. The extensions incorporate coherent and incoherent controls and make the dynamics take the form of a (bilinear) control system thus setting the frame for the tutorial.

In this picture, a Quantum Noether-type Theorem naturally arises and relates symmetries to fixed points. It allows for symmetry assessment of *controllability* in closed systems and, analogously, *accessibility* in open Markovian systems—both in a unified frame.

By recent examples we illustrate how breaking system symmetries with the help of numerical optimal control then paves the way to exploiting the full quantum potential of experimental set-ups pertinent in quantum engineering and emerging technologies.

Invited Talk SYPS 1.4 Mon 15:30 U Audimax

Quantum metrology with Rydberg atoms — •Sebastien Gleyzes[1], Arthur Larrouy[1], Remi Richaud[1], Sabrina Patsch[2], Jean-Michel Raimond[1], Michel Brune[1], and Christiane Koch[2] — [1]Laboratoire Kastler Brossel, College de France, CNRS, ENS-Universite PSL, Sorbonne Universite, 75231 Paris, France — [2]Theoretical Physics, University of Kassel, Heinrich-Plett-Straße 40, 34132 Kassel, Germany

Rydberg atoms are extremely sensitive to their electromagnetic field environment, which make them a very promising tools for metrology. Rydberg atoms can be described by the model of the hydrogen atom. By applying a small static electric field, it is possible to partially lift the degeneracy between same n levels. The new sublevel forms a regular structure. It is possible to manipulate the state of the atom using a rf field with a well-defined polarization to prepare states with large electric or magnetic dipole. In our experiment, we generate Schrödinger cat states of the Rydberg atom of rubidium by preparing quantum superposition of two trajectories with very different classical property. The relative phase of the superposition is very sensitive to the variations of the probe environment, which allows us to measure electric or magnetic field with a very good sensitivity. However, the preparation fidelity is limited by the actual energy structure of rubidium, which is much more anharmonic than that of hydrogen. I will show how implementing RF pulse shape that have been optimized by the University of Kassel using Optimal Control Theory allowed us to drastically improve the efficiency of our pulses.