# QUANTUM STATE ANALYSIS AND ESTIMATION (SYSA)

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## ÜBERSICHT DER HAUPTVORTRÄGE UND FACHSITZUNGEN
(Hörsaal HVI)

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# Fachsitzungen

– Hauptvorträge –

## SYSA 1 Quantum state analysis and estimation I

Zeit: Dienstag 10:30–12:30 Raum: HVI

### Hauptvortrag SYSA 1.1 Di 10:30 HVI

**Detection and characterization of multipartite entanglement in atomic systems** — •Dieter Jaksch and Rebecca Palmer — University of Oxford, Parks road, OX1 3PU Oxford, United Kingdom

We investigate the detection and characterization of multi partite entangled states in systems on neutral atoms. Such states have been realized in seminal recent experiments using optical lattices but their detailed characterization has not been achieved yet. Our scheme is based on measuring violations of entropic inequalities using simple quantum networks involving only two copies of the state under consideration. We first give a detailed discussion of the ideal scheme where no errors are present and full spatial resolution in the measurements is available. Then we discuss the situation where no spatial resolution is available and find that even in this case entanglement can be detected and characterized in various kinds of states including cluster states and macroscopic superposition states. We also study the effects of detection errors and imperfect dynamics on the detection network. For our scheme to be practical these errors have to be on the order of one over the number of investigated lattice sites. Finally, we consider the case of limited spatial resolution and conclude that significant improvement in entanglement detection and characterization compared to having no spatial resolution is only possible if single lattice sites can be resolved.

### Hauptvortrag SYSA 1.2 Di 11:00 HVI

**Improved entanglement witnesses** — •Otfried Gühne[1], Wolfgang Dür[1,2], Norbert Lütkenhaus[3], and Geza Toth[4] — [1]Institut für Quantenoptik und Quanteninformation, Österreichische Akademie der Wissenschaften, A-6020 Innsbruck — [2]Institut für Theoretische Physik, Universität Innsbruck, A-6020 Innsbruck — [3]Quantum Information Theory Group, Institut für Theoretische Physik I, und Max-Planck Research Group, Institute of Optics, Information and Photonics, Universität Erlangen-Nürnberg, D-91058 Erlangen — [4]Max-Planck-Institut für Quantenoptik, D-85748 Garching

Due to the rapid development of experimental techniques multiparticle entangled states of several ions or photons are now available. To confirm the success of an experiment, the analysis of the state has to verify that genuine multipartite entanglement was indeed produced. Entanglement witnesses are one of the most powerful tools for this task. These are linear inequalities for mean values of certain observables, where violation indicates entanglement.

In this talk we present several ideas to improve witnesses for special experimental situations. This can be done in several directions: First, one can reduce the required measurements, minimizing the experimentalists effort. Then, one can use new types of witnesses, which are more robust against noise. Also, one may apply local operations on the state, which do not change the entanglement properties. Finally, one may use nonlinear entanglement witnesses. We will also explain recent experiments, where some of these ideas have been used.

### Hauptvortrag SYSA 1.3 Di 11:30 HVI

**Zustands-Tomographie in einem Ionen-Quantenprozessor** — •Ferdinand Schmidt-Kaler[1], Hartmut Häffner[2,3], Christian Roos[2,3], Timo Körber[2], Wolfgang Hänsel[2], Mark Riebe[2], Jan Benhelm[2], Umarkant Rapol[2], Rainer Blatt[2,3] und Christoph Becher[4] — [1]Abteilung für Quanten-Informationsverarbeitung, Universität Ulm, Deutschland — [2]Institut für Experimentalphysik, Universität Innsbruck, Österreich — [3]Institut für Quantenoptik und Quanteninformation, Österreichische Akademie der Wissenschaften, Innsbruck, Österreich — [4]Technische Physik, Universität des Saarlandes, Deutschland

Skalierbare Quantenprozessoren auf der Basis von Kristallen gefangener Ionen haben es ermöglicht Vielteilchen-Verschränkung zu realisieren. Zur Analyse dieser Quantenzustände und ebenso zur Beschreibung quantenlogischer Operationen werden tomographische Methoden genutzt. Ich diskutiere diese Methoden anhand der Experimente zur Prozesstomographie der Teleportation [1] und der Tomographie langlebiger Bellzustände von zwei Ionen [2].

[1] H. Häffner, F. Schmidt-Kaler, C.F. Roos, T., Körber, M. Chwalla, M. Riebe, J. Benhelm, U. D. Rapol, C. Becher, R. Blatt, Appl. Phys. B 81 (2005) 151.

[2] M. Riebe, H. Häffner, C. F. Roos, W. Hänsel, J. Benhelm, G. P. T. Lancaster, T. W. Körber, C. Becher, F. Schmidt-Kaler, D. F. V. James, R. Blatt, Nature 429 (2004) 734

### Hauptvortrag SYSA 1.4 Di 12:00 HVI

**Analysing entangled states** — •Harald Weinfurter[1,2], Nikolai Kiesel[1,2], Wieslaw Laskowski[3], Wenjamin Rosenfeld[1], Christian Schmid[1,2], Geza Toth[2], Markus Weber[1], Marek Zukowski[3], and Jürgen Volz[1] — [1]Ludwig-Maximilians Universität München — [2]Max-Planck-Institut für Quantenoptik — [3]Universität Danzig

Entanglement often is labeled as the key resource or currency of quantum information. But particularly for the "currency" picture it is quite important to know the real value of your money and also where you can use it at all.

We consider several experiments on atom-photon and on multi-photon entangled states to demonstrate the various possibilities for the experimental analysis of entangled states. Key requirement for such an analysis are of course short measurement time and low uncertainty. Even if general schemes exist, it is of great advantage to tailor the measurements and measurement methods to the particular state and physical system under investigation.

## SYSA 2 Quantum state analysis and estimation II

Zeit: Dienstag 14:00–16:00 Raum: HVI

### Hauptvortrag SYSA 2.1 Di 14:00 HVI

**Optimal quantum measurements: From minimum error to maximum confidence** — •Stephen Barnett — Department of Physics, University of Strathclyde, Glasgow G4 0NG, UK

The superposition principle carries with it the existence of quantum states that are similar in the sense that no measurement strategy can distinguish between them with certainty. Under such circumstances it is both interesting and of practical importance to ask what is the best that can be done.

In my talk I will concentrate of quantum communications problems in which prior information about the set of possible states and their associated probabilities is known. Within this I will discuss state detection with minimum error and unambiguous, or error-free state discrimination, which works by including the possibility of an inconclusive result. I will also describe a new strategy, the maximum confidence measurement, which is optimised so that we can be as confident of our state identification as is possible within the rules of quantum theory. I will show how such measurements can be performed by reference to experiments performed using optical polarisation.

If we have two quantum systems then the range of possible observations and conclusions is greatly enhanced by the possibility of using entangled states. As an example, we seek to determine whether or not the two systems have been prepared in the same state, without the need to identify the state itself. I will conclude with some examples of such "state comparison" measurements.

## Hauptvortrag SYSA 2.2 Di 14:30 HVI

**Discriminating mixed quantum states: General relations and applications** — •Ulrike Herzog — Institut für Physik, Humboldt-Universität Berlin, Newtonstr. 15, 12489 Berlin

State discrimination with minimum error, on the one hand, and optimum unambiguous state discrimination, on the other hand, are two different optimized measurement strategies for distinguishing between given quantum states that occur with given prior probabilities. In the latter case the discrimination is error-free provided that the measurement succeeds, but inconclusive results, where the measurement fails, are admitted as well, and their probability is minimized.

We provide general inequalities for the minimum failure probability in a measurement for optimum unambiguous discrimination of two mixed states, as well as exact solutions in certain special cases. Moreover, we discuss two applications for optimized mixed-state discrimination. The first is quantum state comparison, where we want to decide whether two quantum systems are in the same or different pure states, both of which are unknown and have arbitrary prior probabilities to occur. The second application is quantum state identification, where we assume that two reference qubits are prepared in two different but unknown pure states and that the state of a third qubit is guaranteed to coincide, with given prior probability of occurrence, with either one of these two states. We determine the two different optimized measurement strategies for identifying the state of the third qubit, studying also the modified problem that the state of one of the reference qubits is known.

## Hauptvortrag SYSA 2.3 Di 15:00 HVI

**Superbroadcasting of mixed states** — •Chiara Macchiavello — Dipartimento di Fisica "A. Volta", Via Bassi 6, 27100 Pavia (Italy)

"Broadcasting", namely distributing information over many users, suffers in-principle limitations when the information is quantum. For pure states ideal broadcasting coincides with the so-called "quantum cloning", which is forbidden by the no-cloning theorem for pure states drawn from a nonorthogonal set. For mixed states the no-broadcasting theorem says that perfect broadcasting from an input state drawn from a set of two noncommuting density operators to two output states cannot be achieved. We prove that this theorem cannot be generalized to more than a single input copy. Moreover, we present the phenomenon of superbroadcasting, where it is possible to purify the input states while broadcasting. We also discuss the relations between optimal superbroadcasting and other tasks of interest in quantum information.

## Hauptvortrag SYSA 2.4 Di 15:30 HVI

**A consumer guide to quantum state preparators** — •Reinhard Werner — Inst. Math.Phys, TU Braunschweig

One of the basic requirements for a quantum computer is that we can initialize it in a specific, usually pure quantum state. However, any physical state source will produce deviations form the desired state, and we need to employ methods of error correction to improve the quality of the initialization, especially at the beginning of a very long computation.

In this talk we ask: What promise do we need about the quality of the source so that we can guarantee any desired quality of initial states after error correction? In order to isolate this problem from the problem of improving on noisy gates, we assume that unitary operations can be performed exactly, but that the ancillas used for irreversible operations, including measurements, are also obtained from the noisy source under investigation.

A typical sufficient promise about the source would be exact independence of the successive states. However, this is hardly realistic in experimental situations. It would seem that some approximate version of independence would suffice, but we show that *no promise made with finite accuracy will ever do.* Possible alternatives for the premise of a threshold theorem (such as stationarity and entropy criteria) are discussed.