ExQM Workshop 2016 - June 19th – 22nd

Hotel Chiemgauhof

Julius Exter Promenade 21

83236 Übersee

Tel.: +49 (0) 8642-8987-0

Programme - Sunday

Time: 16:30

Speaker: Norbert Schuch

Title: Assessing topological spin liquids with projected entanged pair states

Abstract:

Topological spin liquids are elusive phases of matter which do not break symmetry despite strong magnetic interactions, but nevertheless order topologically. In my talk, I will demonstrate how Projected Entangled Pair States (PEPS), which form a framework for the entanglement-based modelling of complex entangled quantum systems, can be used to study candidates for topological spin liquids and to investigate the nature of their topological order, their spin liquid behavior, and their entanglement properties.

Time: 17:30

Speaker: Volkher Scholz

Title: Entanglement in Quantum Field theories: an operational approach

Abstract:

Quantum Field Theories are interacting quantum systems described by an infinite number of degrees of freedom, necessarily living on an infinite-dimensional Hilbert space. Hence most usual quantities used to study the strength of correlations between subsystems, naively computed, just lead to infinities. They can be renormalised, but most of the times the operational meaning is lost within this process. Other problems emerge due to gauge symmetry constraints. Here we report on recent work to address these issues by strictly following the question: what are physically allowed operations? Examples discussed include conformal field theories, lattice gauge theories and implications concerning the approximation of quantum field theories by tensor network states are sketched.

based on arXiv: 1509.07414, 1511.04369, 1601.00470

based on joint work with R. Koenig, K. Van Acoylen, N. Bultinck, J. Haegeman, M. Marien, F. Verstraete

ExQM Exploring Quantum Matter

Programme – Sunday

Time: 18:15

Speaker: Christian Schwemmer

Title: Nanoscale artificial Brownian Motors

Abstract:

Brownian motors have been studied extensively over the last years and are considered to play a crucial role for the directed transport of particles inside biological cells [1]. Encouraged by these findings, we developed an artificial Brownian motor based on a nanofluidic slit comprising a spatially asymmetric potential landscape. The system can be driven out of thermal equilibrium by applying a zero-mean oscillating external force which, as a result, leads to particle transport. The trajectories of the particles inside the slit are measured by means of interferometric scattering detection allowing for a spatial resolution of <10 nm and a temporal resolution of < 2 ms [2]. In recent experiments, we observed drift velocities of up to 100 microns per second for spherical gold nano particles with 60 nm diameter. In these experiments, it has also been detected that the performance of directed particle transport strongly depends on the particle size and the gap distance of the slit. Based on this, we plan to develop a highly selective particle sorting machine for nano particles allowing the separation of any kind of sufficiently charged particles like, e.g., carbon nanotubes or DNA.

[1] Hänggi et al., Rev. Mod. Phys, **81**, 387 (2009)
[2] Fringes et al., J. Appl. Phys. **119**, 024303 (2016)

Programme – Monday

Time: 9:15

Speaker: Christian Gogolin

Title: Random states for robust quantum metrology

Abstract:

States with Quantum mechanical correlations allow to estimate certain quantities more efficiently than would be possible in a classical world. While examples of such states are known, little systematic knowledge about the metrological usefulness of states exists. We study how useful random states are for quantum metrology, i.e., surpass the classical limits imposed on precision in the canonical phase estimation scenario. First, we prove that random pure states drawn from the Hilbert space of distinguishable particles typically do not lead to super-classical scaling of precision. Conversely, we show that random states from the symmetric subspace typically achieve the optimal Heisenberg scaling. Remarkably, the Heisenberg scaling is observed for states of arbitrarily low purity and preserved under finite particle losses. Moreover, we prove that for such states a standard photon- counting interferometric measurement suffices to typically achieve the Heisenberg scaling of precision for all possible values of the phase at the same time. Finally, we demonstrate that metrologically useful states can be prepared with short random optical circuits generated from three types of beam-splitters and a non-linear (Kerr-like) transformation.

Time: 10:00

Speaker: Robert König

Title: Quantum analogues of geometric inequalities in information theory

Abstract:

We establish a quantum version of the classical isoperimetric inequality relating the Fisher information and the entropy power of a quantum state. The key tool is a Fisher information inequality for a state which results from a certain convolution operation. We show that this inequality also gives rise to several related inequalities whose counterparts are well-known in the classical setting: it implies the isoperimetric inequality, and establishes concavity of the entropy power along trajectories of the quantum heat diffusion semigroup. As an application, we derive a Log-Sobolev inequality for the quantum Ornstein-Uhlenbeck semigroup, and argue that it implies fast convergence towards the fixed point for a large class of initial states. To establish the latter result we show that Gaussian states minimize the entropy rate of the attenuation semigroup under a given input energy constraint.

Programme – Monday

Time: 11:15

Speaker: Ian McCulloch

Title: Topological order and space group symmetry fractionalization

Abstract:

Matrix Product States (MPS) are a very useful class of variational wavefunctions for 1D and quasi-1D systems, which has a natural extension to translationally invariant systems. In particular, infinitely long cylinders are an ideal geometry for detecting topologically ordered states, and the recent connection between symmetry fractionalization and topological order is readily detectable using MPS techniques. I will explain how this works, using the spin-1/2 Heisenberg model on the triangular lattice as an example, which has structure of $Z_2 \times Z_2$ topological order. The momentum-resolved entanglement spectrum reveals the structure of the low-lying excitations, which has some unusual features, suggesting Dirac nodes indicating gapless excitations in the thermodynamic limit.

Time: 14:00

Speaker: Jutho Haegeman

Title: Matrix product operator algebras and tensor categories

Abstract:

We will discuss the properties of translation invariant matrix product operators (MPOs) that are projectors, and show they give rise to an algebraic structure. Under mild conditions, this algebra is characterised by the data of a fusion category. If these projector MPOs define the the virtual subspace support of a projected entangled pair states (PEPS), that state has topologically distinct excitation sectors (anyons). We can then define a “level 2” C*-algebra out of the MPOs whose central idempotents correspond to the different anyon sectors of the PEPS.

Programme – Monday

Time: 14:45

Discussion group 1

Topic: Tensor Networks

Time: 16:30

Discussion group 1 – continued

Topic: Tensor Networks

Time: 17:30

Discussion group 2

Topic: Many-Body Simulations & Experiments

Time: 9:15

Speaker: Andre Uschmajew

Title: Some results and problems regarding singular values of tensor matricizations

Abstract:

The crucial measure for approximability of tensors in tree tensor networks are the singular values of the matricizations determined by the edges in the network. The interconnection of singular values between different matricizations is hence an important subject which has not been studied in detail so far. Given a set of desired singular values for some matricizations, it is for instance not clear whether a corresponding tensor exists at all. We can prove that the trivial compatibility condition on the Euclidean norm of the singular value vectors is not sufficient for existence of a tensor. On the other hand, we show by numerical `evidence' that the singular values of a generic tensor can be perturbed independently among principal (Tucker) matricizations, that is, the set of feasible singular value configurations is open (for tensors of order at least three). Finally, we give an explicit example that the singular values do not determine the tensor up to orthogonal equivalence, at least not when looking at Tucker matricizations only. It would be interesting to know whether this phenomenon disappears when fixing the singular values for more matricizations.

The talk is based on recent joint work with W. Hackbusch.

Time: 10:00

Speaker: James Raftery

Title: Many-body quantum optics in coupled cavity QED arrays

Abstract:

Superconducting circuits and circuit quantum electrodynamics provide an excellent toolbox for non-equilibrium quantum simulation. In circuit QED, the strong interaction of light with a single qubit can lead to strong qubit-mediated photon-photon interactions. Recent theoretical proposals have predicted phase transitions in arrays of these cavities, demonstrating that complex matter-like phenomena can emerge with such interacting photons. Due to inevitable photon dissipation and the ease of adding photons through driving, these systems are fundamentally open and a useful tool for studying non-equilibrium physics. I will discuss recent experimental and theoretical progress towards realization of these non-equilibrium quantum simulators, including a localization-delocalization crossover in a pair of coupled cavities, and measurements of large cavity arrays and multi-mode cavities. I will show a variety of available measurement tools in these systems, including transport and scanned local quantum probes.

Time: 11:15

Speaker: Jörg Schmiedmayer

Title: On ‘solving’ a quantum many body problem by experiment

Abstract:

The knowledge of all correlation functions of a system is equivalent to solving the corresponding quantum many-body problem [1]. If one can identify the relevant degrees of freedom, the knowledge of a finite set of correlation functions is in many cases sufficient to determine a sufficiently accurate solution of the corresponding field theory. Complete factorization is equivalent to identifying the relevant degrees of freedom where the Hamiltonian becomes diagonal. I will give examples how one can apply this powerful theoretical concept in experiment.

We study the quantum Sine-Gordon model, which can be realized by a pair of tunnel-coupled one-dimensional atomic super-fluids. A detailed analysis of the interference between the two super-fluids allows us to study if, and under which conditions the phase correlation functions factorize [2]. This enables us to characterize the essential features of the model solely from our experimental measurements: detecting the relevant quasi-particles, their interactions and the different topologically distinct vacuum-states the quasi-particles live in. The experiment thus provides comprehensive insight into the components needed to solve a non-trivial quantum field theory.

Our examples establish a general method to analyse quantum systems through experiments. It thus represents a crucial ingredient towards the implementation and verification of quantum simulators.

Work performed in collaboration with E.Demler (Harvard), Th. Gasenzer und J. Berges (Heidelberg). Supported by the Wittgenstein Prize, the Austrian Science Foundation (FWF): SFB FoQuS: F40-P10 and the EU: ERC-AdG *QuantumRelax*

[1] J. Schwinger Proc. Natl. Acad. Sci. **37**, 452 – 459 (1951).

[2] T. Schweigler et al., arXiv:1505.03126

Time: 14:00

Speaker: Armin Rubner

Programme – Tuesday

Time: 14:45

Discussion group 3

Topic: New uses of e-media

Time: 16:30

Discussion group 3 – continued

Topic: New uses of e-media

Time: 17:30

Discussion group 4

Topic: Experimental challenges

Programme – Wednesday

Time: 9:15

Speaker: Tobias Schätz

Title: Einstein's night mare: two-dimensional arrays of rf-surface electrode traps for experimental quantum simulations based on trapped ions

Abstract:

Direct experimental access to some of the most intriguing and puzzling quantum phenomena is difficult due to their fragility to noise. Their efficient simulation on conventional computers is impossible, since quantum behaviour is not efficiently translatable in classical language. However, one could gain deeper insight into complex quantum dynamics via experimentally simulating the quantum behaviour of interest in another quantum system, where not all but the relevant parameters and interactions can be controlled and robust effects detected sufficiently well. One example is simulating quantum-spin systems with trapped ions.
After proof of principle experiments based on few ions/spins only, we aim to explore the limitations and prospects and the options for scaling to larger and two dimensional systems, e.g. by spanning a triangular lattice by individual ion traps above 2D-electrodes of micrometer scale.

Time: 10:00

Speaker: Markus Aspelmeyer

Title: Challenges for the future: A personal perspective on quantum foundations and quantum technologies

Abstract:

I want to share my personal view on some of the fascinating opportunities - and challenges - of modern quantum science. With respect to foundations I am thrilled by the possibility of building a new class of experiments at the interface between quantum physics and gravity, in which the source mass character of the quantum system starts to play a role. Experimentally addressing the question "how does a quantum system gravitate?" is intriguing and seems feasible in principle, and I will address some of the challenges involved. With respect to technologies I am constantly impressed by the level of inventive genius of our students and PostDocs in the many quantum labs around the world. Transforming these ideas into actual (quantum) technologies represents an important yet difficult challenge that can be addressed in many different ways. I will give a specific example from the field of optomechanics, where a mix of lab-based development and entrepreneurship resulted (quite unexpectedly) in a completely new optical coating technology for the next generation of laser-based precision measurement and machining.

Time: 11:15

Final panel: Perspectives & Challenges

Sunday (June 19)

	** Getting to Hotel Chiemgauhof in Übersee / Lake Chiemsee **
	Meridian M 79013 part to Salzburg
9:55	M Main Station,11 Train to Übersee
10:04	M East, 8: Train to Übersee
11:02	Arrival at Übersee Trainstation
11:15	Check-In at Hotel
11:50	**Boat Departure to Laueninsel**
12:15	Lunch at "Klosterwirt" Laueninsel
14:00	Guided Tour: Island and Monastery
15:25	**Boat Dep. from Laueninsel**
15:50	Boat Arrival near Hotel
16:00	Opening / S. Glaser
16:30	N. Schuch
17:15	Coffee (short)
17:30	V. Scholz
18:15	C. Schwemmer
19:30	Dinner

Monday (June 20)

9:15	C. Gogolin
10:00	R. König
10:45	Coffee
11:15	I. McCulloch
12:00	*group photo*
12:30	Lunch Buffet
14:00	J. Haegeman
14:45	*Discussion Groups*
	1. Tensor Networks
16:00	Coffee
16:30	*Discussion Groups, ctd.*
	1. Tensor Networks
17:30	*2. Many-Body Simulations & Experiments*
19:00	Dinner

Tuesday (June 21)

9:15	A. Uschmajew
10:00	J. Raftery
10:45	Coffee
11:15	J. Schmiedmayer
12:00	- discussion -
12:30	Lunch Buffet
14:00	A. Rubner
14:45	*Discussion Group*
	3. New Uses of E-Media
16:00	Coffee
16:30	*Discussion Groups, ctd.*
	3. New Uses of E-Media
17:30	*2. Experimental Challenges*
19:00	Aperitivo / Reception
19:30	**Conference Dinner**

Wednesday (June 22)

9:15	T. Schätz
10:00	M. Aspelmeyer (?)
10:45	Coffee
11:15	*Final Panel: Perspectives & Challenges*
12:30	Lunch in Rest. (seated)
14:00	Coffee / End of Conference
14:30	***Option for Sailing***
	(on semi-private basis)
	Wassersportschule Chiemgau
	Mario + Julia Wallentin
	Greimelstrasse 34
	83236 Übersee
	Tel.: 08642-595581
	Mob.: 0160-97776081
	Direct Trains back to Munich
13:58	departures from Übersee
14.58	
15:58	
16:58	
17.58	
18:58	

useful phone numbers:

Hotel Chiemgauhof
Julius Exter Promenade 21
83236 Übersee
Tel.: 08642-8987-0

Taxi Wolfi Übersee
Tel.: 0160-8479462

Hotel Sonnenhof (add. rooms)
Seethal 43, **83236 Übersee**
Tel.: 08642-6815