Book of Abstracts

Current trends in open and nonequilibrium quantum optical systems

Organizers:

Carlos Navarrete-Benlloch
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Max Planck Institute
for the Science of Light
Erlangen, Germany

Workshop

July 16th - 18th, 2018

Workshop:

Current trends in open and nonequilibrium quantum optical systems

Max Planck Institute for the Science of Light

Staudtstrasse 2, 91058 Erlangen
Germany

Scope of the workshop

From early on, quantum optics distinguished itself from other quantum disciplines for dealing with systems out of equilibrium (e.g., driven by lasers) that exchange energy and information with their environments. Hence, it has always been at the forefront in the field of open and nonequilibrium quantum systems. The significant theoretical and experimental achievements of the last decades, together with the promise of revolutionary quantum technologies (which will be implemented in quantum optical settings ultimately described as open and nonequilibrium systems), have put this field in the spotlight. By now, it has turned into a broad collection of different disciplines ranging from the most abstract to the most practical, and gathering physicists, mathematicians, engineers, computer scientists, etc.

This workshop aims at bringing the community together, and intends to gather a representation of all these broad range of disciplines that synergistically make up modern quantum optics. The list of topics includes, but is not restricted to:

- Advances in theoretical and mathematical tools for open and/or nonequilibrium systems, including phase-space techniques, effective theories, Gaussian approximations and controlled non-Gaussian extensions, Keldysh formalism, tensor-network states, etc.
- Advances in experimental platforms, including nonlinear optical cavities, integrated photonics, superconducting circuits, atomic systems, mechanical devices, quantum dots, defects in solid-state, 2D materials, exciton polaritons, etc.
- Applications for quantum technologies, including quantum computation and simulation, quantum metrology, and quantum communication.
- Many-body systems out of equilibrium and/or in the presence of dissipation.
- Dissipative and/or dynamical phase transitions.
- Topological phenomena and their extensions to open and/or nonequilibrium systems.
- Low-dimensional, structured, and/or chiral environments.
- Quantum thermodynamics.
- Non-Markovian dynamics, feedback, and/or continuous monitoring of open systems.

Keynote speakers

Iacopo Carusotto (INO-CNR BEC Center, Trento, Italy)
Giovanna Morigi (Saarland University, Germany)
Christine Silberhorn (Padeborn University, Germany)
Andreas Wallraff (ETH Zurich, Switzerland)

Invited Speakers

Monika Aidelsburger (LMU Munich, Germany)
Jan Carl Budich (TU Dresden, Germany)
Johannes Fink (IST, Vienna, Austria)
Alejandro González-Tudela (MPI of Quantum Optics, Garching, Germany)
Simon Gröblacher (TU Delft, The Netherlands)
Markus Heyl (MPI for the Physics of Complex Systems, Dresden, Germany)
Zaki Leghtas (Mines ParisTech, Paris, France)
Johannes Majer (TU Vienna, Austria)
Anja Metelmann (Free University of Berlin, Germany)
Christine Muschik (University of Waterloo, Canada)
Beatriz Olmos (University of Nottingham, UK)
Hannes Pichler (Harvard University, MA USA)
Tao Shi (Institute of Theoretical Physics, Beijing, China)
Karolina Słowik (Nicolaus Copernicus University, Torun, Poland)

Contributed Speakers

Matteo Brunelli (University of Cambridge, UK)
Inés de Vega (LMU Munich, Germany)
Augustine Kshetrimayum (Free University of Berlin, Germany)
Jonas Larson (Stockholm University, Sweden)
Amit Rai (NIT Rourkela, India)
Markus Schmitt (MPI for the Physics of Complex Systems, Dresden, Germany)
Nathan Shammah (RIKEN, Saitama, Japan)
Swati Singh (Williams College, MA, USA)
Kanupriya Sinha (MPI for the Physics of Complex Systems, Dresden, Germany)

Schedule Overview

Monday 16.7		Tuesday 17.7		Wednesday 18.7	
9:30 - 9:45	Registration				
9:45 - 10:00	Welcome				
10:00 - 10:35	Wallraff	10:00 - 10:35	Carusotto	10:00 - 10:35	Morigi
10:35 - 11:00	Metelmann	10:35 - 11:00	Majer	10:35 - 11:00	Fink
11:00 - 11:15	Shammah	11:00 - 11:15	De Vega	11:00 - 11:30	Coffee break
11:15 - 11:45	Coffee break	11:15 - 11:45	Coffee break	11:30 - 11:55	Słowik
11:45 - 12:10	González-Tudela	11:45 - 12:20	Silberhorn	11:55 - 12:10	Sinha
12:10 - 12:35	Budich	12:20 - 12:45	Olmos	12:30 - 14:00	Lunch MPL
12:35 - 12:50	Schmitt	12:45 - 13:00	Kshetrimayum	14:00 - 14:25	Heyl
13:00 - 14:30	Lunch MPL	13:00 - 14:30	Lunch MPL	14:25 - 14:40	Brunelli
14:30 - 14:55	Leghtas	14:30 - 14:55	Pichler	14:40 - 15:05	Gröblacher
14:55 - 15:10	Larson	14:55 - 15:10	Rai		
15:10 - 15:40	Coffee break	15:10 - 15:40	Coffee break		
15:40 - 16:05	Aidelsburger	15:40 - 16:05	Muschik		
16:05 - 16:20	Singh	16:05 - 16:30	Shi		
16:20 - 18:30	Discussion time and poster session	16:30 - 18:30	Poster session and lab tours		
18:30 - 19:30	Dinner MPL	18:30 - 19:30	Workshop Dinner		
19:30 - 21:00	Poster Session	19:30 - 21:00			

Titles overview

Monday		
10:00 - 10:35	**Andreas Wallraff**	Deterministic Quantum State Transfer and Generation of Remote Entanglement using Microwave Photons
10:35 - 11:00	**Anja Metelmann**	Nonreciprocal Interactions and Devices via Reservoir Engineering
11:00 - 11:15	**Nathan Shammah**	Efficient numerical simulation of driven-dissipative dynamics in qubit ensembles
11:45 - 12:10	**Alejandro González-Tudela**	Quantum optics in structured photonic environments
12:10 - 12:35	**Jan Carl Budich**	Quench dynamics in ultracold topological quantum matter
12:35 - 12:50	**Markus Schmitt**	Quantum dynamics from classical networks
14:30 - 14:55	**Zakki Leghtas**	Quantum computing with Schrödinger cat states
14:55 - 15:10	**Jonas Larson**	Symmetry breaking and driven-dissipative phase transitions
15:40 - 16:05	**Monika Aidelsburger**	Floquet engineering with interacting ultracold atoms
16:05 - 16:20	**Swati Singh**	Detecting continuous gravitational waves with superfluid helium

Tuesday		
10:00 - 10:35	**Iacopo Carusotto**	Non-equilibrium physics with quantum fluids of light
10:35 - 11:00	**Johannes Majer**	Coupling Diamond Color Centers to Superconducting Cavities
11:00 - 11:15	**Inés de Vega**	TBA
11:45 - 12:20	**Christine Silberhorn**	TBA
12:20 - 12:45	**Beatriz Olmos**	Subradiant propagation in a dense atomic lattice gas
12:45 - 13:00	**Augustine Kshetrimayum**	A simple tensor network algorithm for two-dimensional steady states
14:30 - 14:55	**Hannes Pichler**	TBA
14:55 - 15:10	**Amit Rai**	Quantum walks in Glauber Fock photonic lattices
15:40 - 16:05	**Christine Muschik**	How to simulate models from high energy physics in atomic physics experiments
16:05 - 16:30	**Tao Shi**	Variational Study of Fermionic and Bosonic Systems with Non-Gaussian States: Theory and Applications

Wednesday		
10:00 - 10:35	**Giovanna Morigi**	Collective dynamics of atomic ensembles confined within high-finesse optical cavities
10:35 - 11:00	**Johannes Fink**	Stationary Entangled Radiation from Micromechanical Motion
11:30 - 11:55	**Karolina Słowik**	Quantum optical realization of arbitrary linear transformations
11:55 - 12:10	**Kanupriya Sinha**	Collective effects in Casimir-Polder forces
14:00 - 14:25	**Markus Heyl**	Dynamical quantum phase transitions
14:25 - 14:40	**Matteo Brunelli**	Linear-and-quadratic reservoir engineering of non-Gaussian states in cavity optomechanics
14:40 - 15:05	**Simon Gröblacher**	Quantum information processing with optomechanical systems

Poster list

Bijay Kumar Agarwalla	Experimental emulation of quantum non-Markovian dynamics and coherence protection in the presence of information back-flow
Miguel Bastarrachea	Spectral and dynamical features of the Dicke model
Ondrej Cernotik	Interference effects in hybrid cavity optomechanics
Burak Gurlek	Manipulation of Quenching in Nanoantenna–Emitter Systems Enabled by External Detuned Cavities: A Path to Enhance Strong-Coupling
Lingzhen Guo	Ultracold Atoms in Stroboscopic One-dimensional Lattices: Topology and Many-body Physics in Phase Space Crystals
Felicitas Hellbach	Quantum correlation between two oscillators generated by non-local electron transport
Damian Hofmann	Laser Control of Topological Polaritons
Ousama Houhou	Continuous variables quantum computation with mechanical systems
Raphael Kaubrügger	Variational Approach to quantum Metrology
Viacheslav Kuzmin	Variational dissipative cooling
Valentin Link	Stochastic Feshbach Projection for Open Quantum Systems
David Manson	Measurement-Based Quantum Control of Mechanical Motion
Diego Martín-Cano	Quadrature-squeezed light generation from single emitters mediated by optical nanostructures
Akash nag Oruganti	Linearized theory of quantum fluctuations around limit cycles in actively-phase-locked optical parametric oscillators
Giuseppe Patera	Quantum Temporal Imaging with squeezed light
Luo Qi	Multiphoton non-classical light from clusters of single-photon emitters
Michael Reitz & Francesca Mineo	Energy transfer and correlations in cavity-embedded donor-acceptor configurations
Orazio Scarlatella	Emergent Finite Frequency Criticality of Driven-Dissipative Correlated Lattice Bosons
Karolina Sedziak	Experimental demonstration of remote temporal wavepacket narrowing
Muzzamal Shaukat	Spontaneous generation of entanglement in quantum dark soliton qubits
Christian Sommer	Ramsey interferometry of Rydberg ensembles inside microwave cavities
Petru Tighineanu	Phonon Decoherence of Quantum Dots in Nanophotonics
Filippo Vicentini	Critical slowing down in Driven-Dissipative Optical Lattices
Petr Zapletal	Synthetic Electric Field and Directional Light Transport in Optomechanics

Information for the activities

Meals

On Monday a buffet dinner will be served (free of charge) from 18:30 during the poster session.

On Tuesday, everyone is welcome to join for dinner at the Kitzmann BräuSchänke (Südliche Stadtmauerstraße 25, 91054 Erlangen) at 18:30. Please, **sign up** at the registration desk **before Monday lunchtime**. Owed to budget regulations, the workshop cannot cover this dinner. You can find a copy of the menu at the registration desk or in your workshop bag.

Lunch will be served daily at MPL's canteen "Casino" (below the ground floor). Participants unrelated to the Max Planck Society can find vouchers in their workshop bags. However, owed to budget regulations, meals cannot be covered for Max Planck Society personnel.

Poster sessions

The posters can be put up any time during Monday and will be displayed for the whole duration of the workshop. Dedicated sessions have been scheduled on Monday and Tuesday after the talks.

Lab tours

On Tuesday afternoon, starting at 16:30, we have scheduled visits to a representation of the MPL's labs from Leuchs, Russell, and Sandoghdar divisions. If you are interested, please, **sign up** at the registration desk **before Tuesday lunchtime**. The tour will take about one hour in total.

Abstracts

Monday, July 16th [MON]

10:00 - 10:35 [MON]	**Andreas Wallraff** ETH Zurich, Switzerland

Deterministic Quantum State Transfer and Generation of Remote Entanglement using Microwave Photons

Sharing information coherently between nodes of a quantum network is at the foundation of distributed quantum information processing. In this scheme, the computation is divided into subroutines and performed on several smaller quantum registers connected by classical and quantum channels. A direct quantum channel, which connects nodes deterministically rather than probabilistically, is advantageous for fault-tolerant quantum computation because it reduces the threshold requirements and can achieve larger entanglement rates. Here, we implement deterministic state transfer and entanglement protocols between two superconducting qubits [1] fabricated on separate chips [2] and connected by about one meter of coaxial cable with well characterized loss [3]. Superconducting circuits constitute a universal node capable of sending, receiving, storing, and processing quantum information. Our implementation is based on an all-microwave cavity-assisted Raman process which entangles or transfers the qubit state of a transmon-type artificial atom with a time-symmetric itinerant single photon [4]. We transfer qubit states at a rate of 50 kHz using the emitted photons which are absorbed at the receiving node with a probability of 98% achieving a transfer process fidelity of 80%. We also prepare on demand remote entanglement with a fidelity as high as 79%. Our results are in excellent agreement with numerical simulations based on a master equation description of the system. Deterministic state transfer protocols have the potential to be used as a backbone of surface code quantum error correction across different nodes of a cryogenic network to realize large scale fault-tolerant quantum computation. It is also interesting to consider augmenting the methods presented in this work by quantum-non-demolition detection of single photons [5].

This research was performed by a collaboration of P. Kurpiers, P. Magnard, T. Walter, B. Royer, M. Pechal, J. Heinsoo, Y. Salathe, A. Akin, S. Storz, J.-C. Besse, S. Gasparinetti, A. Blais, and A. Wallraff.

[1] P. Kurpiers et al., Nature 558, 264-267 (2018)
[2] T. Walter et al., Phys. Rev. Applied 7, 054020 (2017)
[3] P. Kurpiers et al., EPJ Quantum Technology 4, 8 (2017)
[4] M. Pechal et al., Phys. Rev. X 4, 041010 (2014)
[5] J.-C. Besse et al., Phys. Rev. X 8, 021003 (2018)

10:35 - 11:00 [MON] **Anja Metelmann**
Free University of Berlin, Germany

Nonreciprocal Interactions and Devices via Reservoir Engineering

An interaction process between two quantum systems is in general reciprocal. This means that forward and backward process are inherently present and both systems are influenced by the interaction. One may ask the question if it is possible to break this symmetry, i.e., if one can realize a unidirectional interaction between two quantum systems? This is indeed possible, as we found that any factorisable (coherent) Hamiltonian interaction can be rendered directional if balanced with the corresponding dissipative interaction. This powerful concept can be exploited to engineer nonreciprocal devices for quantum information processing, computation and communication protocols, e.g., to achieve control over the direction of propagation of photonic signals, enabling to construct circulators, optical isolators or directional amplifiers. In this talk I will introduce the basic concept and discuss possible implementations for nonreciprocal devices in superconducting circuit and optomechanical architectures.

11:00 - 11:15 [MON] **Nathan Shammah**
RIKEN, Saitama, Japan

Efficient numerical simulation of driven-dissipative dynamics in qubit ensembles

The permutational invariance of Lindblad superoperators allows for an exponential reduction in the computational resources required to study large spin-boson ensembles under the effect of both collective incoherent processes and local noise [1-6].
We take advantage of this speedup to develop the Permutational-Invariant Quantum Solver (PIQS), an open-source library in Python, which can be used to study the driven-dissipative dynamics of open quantum systems out of equilibrium [7].
I will address the robustness of various collective phenomena, e.g., spin squeezing, lasing, superradiance, and phase transitions, against local dissipation processes in the weak, strong, and ultrastrong-coupling regimes [8].

[1] B. A. Chase and J. M. Geremia, Phys. Rev. A 78, 052101 (2008)
[2] M. Xu, D. A. Tieri, and M. J. Holland, Phys. Rev. A 87, 062101 (2013)
[3] S. Hartmann, Quantum Inf. Comput. 16, 1333 (2016)
[4] P. Kirton and J. Keeling, Phys. Rev. Lett. 118, 123602 (2017)
[5] M. Gegg and M. Richter, Scientific Reports 7, 16304 (2017)
[6] N. Shammah, N. Lambert, F. Nori, and S. De Liberato, Phys. Rev. A 96, 023863 (2017)
[7] N. Shammah and S. Ahmed, https://github.com/nathanshammah/piqs
[8] N. Shammah, S. Ahmed, N. Lambert, S. De Liberato, and F. Nori, arXiv:1805.05129

11:45 - 12:10 [MON] **Alejandro González-Tudela**
MPI of Quantum Optics, Garching, Germany

Quantum optics in structured photonic environments

Recent experimental developments in nanophotonics [1], circuit QED [2] and atomic physics [3] allow one to engineer systems where atoms (or other quantum emitters) couple to structured photonic environments.
In this talk, I will discuss several phenomena emerging in these setups such as the emergence of photon bound states, which allow one to mediate tunable and long-range interactions [4], or the emergence of novel super/subradiance phenomena [5].

[1] Nature 508, 241 (2014); Nature Communications 5, 3808 (2014); Rev. Mod. Phys. 87, 347 (2015)
[2] Nature Physics 13 (1), 48 (2017)
[3] Phys. Rev Lett. 101, 260404 (2010); Nature Physics 8, 267 (2012); arXiv:1712.07791
[4] Phys. Rev. X 6, 021027 (2016); Nature Photonics 9, 320 (2015); PNAS, 201603777 (2016)
[5] Phys. Rev. Lett. 119, 143602 (2017); Phys. Rev. A 96 (4), 043811 (2017)

12:10 - 12:35 [MON] **Jan Carl Budich**
TU Dresden, Germany

Quench dynamics in ultracold topological quantum matter

Topological states of quantum matter such as topological insulators and superconductors have been an active field of research in physics for many years. The recent experimental progress on their realization with ultracold atomic gases in optical lattices raises natural questions about the notion of topological quantum matter far from thermal equilibrium. In this talk, we present our theoretical findings in this context, focusing on the quench dynamics of interacting topological insulators. Specifically, we discuss the non-equilibrium Hall response of a system initialized in a topologically trivial state before its Hamiltonian is ramped into a Chern insulator phase, comparing the free coherent dynamics with effects of dephasing and interaction induced thermalization, respectively.

12:35 - 12:50 [MON] **Markus Schmitt**
MPI for the Physics of Complex Systems, Dresden, Germany

Quantum dynamics from classical networks

The efficient representation of quantum many-body states with classical resources is a key challenge in quantum many-body theory. In our work we explore the possibility to encode the time-evolved wave function in networks of classical degrees of freedom, which can be sampled efficiently using Monte Carlo techniques. We analytically construct classical networks for the description of the quantum dynamics in Ising models with external magnetic field, allowing us to compute transient dynamics in one, two, and three dimensions [1]. We include a mapping to equivalent artificial neural network wave functions (as introduced in [2]) and we explore the utility of the obtained network structures for numerical time-evolution using a time-dependent variational principle.

[1] M. Schmitt and M. Heyl, SciPost Pys. 4, 013 (2018)
[2] G. Carleo and M. Troyer, Science 355, 602 (2017)

14:30 - 14:55 [MON]	**Zakki Leghtas** Mines ParisTech, Paris, France

Quantum computing with Schrödinger cat states

Superconducting qubits are one of the most promising platforms to implement quantum technologies. Quantum processors of tens of qubits are now available, and exciting applications with these intermediate size systems are in perspective. However, many algorithms, including all those with a proved quantum speed-up, require extremely low error rates. This will most likely require quantum error correction (QEC). Unfortunately, current QEC architectures require daunting overheads in physical qubits and control electronics. The goal of this research is to reduce this overhead, and our approach is based on two key ideas. First, we use high Q resonators to redundantly encode quantum information. Second, we engineer non-linear dissipation to protect and manipulate this information.

14:55 - 15:10 [MON]	**Jonas Larson** Stockholm University, Sweden

Symmetry breaking and driven-dissipative phase transitions

Symmetry breaking is deeply rooted in our understanding of equilibrium continuous phase transitions. Topological phase transitions is an example of transitions that cannot be assigned a local order parameter and an accompanying symmetry breaking. In this talk I present a model supporting a driven-dissipative quantum phase transition that is continuous but NO symmetry is broken. The physical model is one of optical bistability, which normally is connected to first order phase transitions. In the bad cavity limit I argue that this transition can indeed become second order.

15:40 - 16:05 [MON]	**Monika Aidelsburger** LMU Munich, Germany

Floquet engineering with interacting ultracold atoms

Floquet engineering is an important tool for the engineering of novel band structures with intruiguing properties that go beyond those offered by static systems. Recently, Floquet systems have enabled the generation of Bloch bands with non-trivial topological properties, such as the Hofstadter and Haldane model. This led to the observation of chiral Meissner currents and the first Chern-number measurement with charge-neutral atoms.
Besides this success, studies of many-body phases in driven systems remain experimentally challenging in particular due to the interplay between periodic driving and interactions. In a driven system energy is not conserved which can lead to severe heating. In order to find stable parameter regimes for the generation of driven many-body phases it is essential to develop a deeper understanding of the underlying processes.
In this talk, I briefly review recent experimental advances in the generation of topological band structures in the non-interacting regime using Floquet engineering and present first studies of interacting atoms in driven 1D lattices.

16:05 - 16:20 [MON]	**Swati Singh** Williams College, MA, USA

Detecting continuous gravitational waves with superfluid helium

We study the sensitivity to continuous-wave strain fields of a kg-scale optomechanical system formed by the acoustic motion of superfluid helium-4 parametrically coupled to a superconducting microwave cavity. This narrowband detection scheme can operate at very high Q-factors, while the resonant frequency is tunable through pressurization of the helium in the 0.1–1.5 kHz range. The detector can therefore be tuned to a variety of astrophysical sources and can remain sensitive to a particular source over a long period of time. For thermal noise limited sensitivity, we find that strain fields on the order of h~10-23 / √Hz are detectable. We show that the proposed system can compete with interferometric detectors and potentially surpass the gravitational strain limits set by them for certain pulsar sources within a few months of integration time.

Tuesday, July 17th [TUE]

10:00 - 10:35 [TUE]	**Iacopo Carusotto** INO-CNR BEC Center, Trento, Italy.

Non-equilibrium physics with quantum fluids of light

In this talk I will review the recent advances in the theoretical and experimental study of quantum fluids of light, that is assemblies of photons confined in suitable material platforms that display collective many-body effects as a result of the interactions mediated by the optical nonlinearity of the underlying material.
I will start with a survey of early results on Bose-Einstein condensation and superfluid hydrodynamical effects with an emphasis on those non-equilibrium features that are characteristic of these driven-dissipative optical systems. Open questions related to the nature of the phase transition towards a superfluid state will be addressed.
I will then move towards the on-going challenge of using quantum fluids of light to generate strongly correlated states of matter, such as Mott insulators or fractional quantum Hall fluids in a completely new non-equilibrium framework. The main challenges and the potential of optical systems in this direction will be highlighted.

10:35 - 11:00 [TUE]	**Johannes Majer** TU Vienna, Austria

Coupling Diamond Color Centers to Superconducting Cavities

Hybrid quantum systems based on spin-ensembles coupled to superconducting microwave cavities are promising candidates for robust experiments in cavity quantum electrodynamics (cQED) and for future technologies employing quantum mechanical effects. We use a dispersive detection scheme based on cQED to observe the spin relaxation of the negatively charged nitrogen vacancy center in diamond. We observe exceptionally long longitudinal relaxation times T1 of up to 8h. To understand the fundamental mechanism of spin-phonon coupling in this system we develop a theoretical model and calculate the relaxation time ab-initio. The calculations confirm that the low phononic density of states at the NV− transition frequency enables the spin polarization to survive over macroscopic timescales.

11:00 - 11:15 [TUE]	**Inés de Vega** LMU Munich, Germany

TBA

11:45 - 12:20 [TUE]	**Christine Silberhorn** Padeborn University, Germany
TBA	

12:20 - 12:45 [TUE]	**Beatriz Olmos** University of Nottingham, UK

Subradiant propagation in a dense atomic lattice gas

Abstract: The coupling of atoms in a dense atomic lattice gas to the radiation field gives rise to dissipation and a non-trivial coherent long-range exchange interaction whose form goes beyond a simple power-law. In this talk, we investigate the potential of a 1D chain of atoms excited to low-lying states for the storage and read-out of quantum states. We show that a single excitation in a 1D chain can be created on one end of the chain such that it naturally gets stored in one of the subradiant states of the many-body system. By tuning an external magnetic field such that the exchange interaction becomes negligible we are able to store the excitation for long times inside the chain's bulk and read it out on the other end of the chain. Moreover, we show that the coupling of this system to a nearby metallic or dielectric surface, can result in unexpected increase or decrease of the interactions among the atoms and also in the suppression of the non-locality of the emission, making the storage more efficient in some cases.

12:45 - 13:00 [TUE]	**Augustine Kshetrimayum** Free University of Berlin, Germany

A simple tensor network algorithm for two-dimensional steady states

Understanding dissipation in 2D quantum many-body systems is an open challenge which has proven remarkably difficult. Here we show how numerical simulations for this problem are possible by means of a tensor network algorithm that approximates steady states of 2D quantum lattice dissipative systems in the thermodynamic limit. Our method is based on the intuition that strong dissipation kills quantum entanglement before it gets too large to handle. We test its validity by simulating a dissipative quantum Ising model, relevant for dissipative systems of interacting Rydberg atoms, and benchmark our simulations with a variational algorithm based on product and correlated states. Our results support the existence of a first order transition in this model, with no bistable region. We also simulate a dissipative spin 1/2 XYZ model, showing that there is no re-entrance of the ferromagnetic phase. Our method enables the computation of steady states in 2D quantum lattice systems.

14:30 - 14:55 [TUE]	**Hannes Pichler** Harvard University, MA USA

TBA

14:55 - 15:10 [TUE]	**Amit Rai** NIT Rourkela, India

Quantum walks in Glauber Fock photonic lattices

The main objective of this work is to investigate, analyze and examine in detail the behavior of quantum light in a photonic lattice having square root law distribution for the coupling constant known as Glauber-Fock photonic lattice. We investigate both small and large size lattices for the case of spatially extended path entangled input state. For the squeezed state input we focus on the finite size lattices. We have examined and studied the non-classical features such as squeezing and photon correlation function at the output of the photonic lattice system. The results and findings show the transport and revival of these features as light propagates across the waveguide array.

15:40 - 16:05 [TUE]	**Christine Muschik** University of Waterloo, Canada

How to simulate models from high energy physics in atomic physics experiments

Gauge theories are fundamental to our understanding of interactions between the elementary constituents of matter as mediated by gauge bosons. However, computing the real-time dynamics in gauge theories is a notorious challenge for classical computational methods. In the spirit of Feynman's vision of a quantum simulator, this has recently stimulated theoretical effort to devise schemes for simulating such theories on engineered quantum-mechanical devices, with the difficulty that gauge invariance and the associated local conservation laws (Gauss laws) need to be implemented. Here we report on a proposal and the experimental demonstration of a digital quantum simulation of a lattice gauge theory, by realising 1+1-dimensional quantum electrodynamics (Schwinger model) on a few-qubit trapped-ion quantum computer. We are interested in the real-time evolution of the Schwinger mechanism, describing the instability of the bare vacuum due to quantum fluctuations, which manifests itself in the spontaneous creation of electron-positron pairs. We explore the Schwinger mechanism of particle-antiparticle generation by monitoring the mass production and the vacuum persistence amplitude. Our work represents a first step towards quantum simulating high-energy theories with atomic physics experiments, the long-term vision being the extension to real-time quantum simulations of non-Abelian lattice gauge theories.

16:05 - 16:30 [TUE]	**Tao Shi** Institute of Theoretical Physics, Beijing, China

Variational Study of Fermionic and Bosonic Systems with Non-Gaussian States: Theory and Applications

We present a new variational method for investigating the ground state and out of equilibrium dynamics of quantum many-body bosonic and fermionic systems. Our approach is based on constructing variational wavefunctions which extend Gaussian states by including generalized canonical transformations between the fields. The key advantage of such states compared to simple Gaussian states is presence of non-factorizable correlations and the possibility of describing states with strong entanglement between particles. In contrast to the commonly used canonical transformations, such as the polaron or Lang-Firsov transformations, we allow parameters of the transformations to be time dependent, which extends their regions of applicability. We derive equations of motion for the parameters characterizing the states both in real and imaginary time using the differential structure of the variational manifold. The ground state can be found by following the imaginary time evolution until it converges to a steady state. Collective excitations in the system can be obtained by linearizing the real-time equations of motion in the vicinity of the imaginary time steady-state solution. Our formalism allows us not only to determine the energy spectrum of quasiparticles and their lifetime, but to obtain the complete spectral functions and to explore far out of equilibrium dynamics such as coherent evolution following a quantum quench. We illustrate and benchmark this framework with several examples: Kondo models and lattice gauge theory.

Wednesday, July 18th [WED]

10:00 - 10:35 [WED]	**Giovanna Morigi** Saarland University, Saarbruecken, Germany

Collective dynamics of atomic ensembles confined within high-finesse optical cavities

In this talk we will present recent theoretical work on cooling and spontaneous spatio-temporal pattern formation of atomic and molecular ensembles in optical resonators, where the key ingredient of the dynamics are the coherent and dissipative long-range optomechanical forces mediated by multiple scattering of the cavity photons. These dynamics reveal the existence of prethermalized states which are expected to be stable over the experimental time scales. We then present an analysis of this behaviour deep in the quantum limit, and study the role of quantum fluctuations on the stability of these spatio-temporal structures.

10:35 - 11:00 [WED]	**Johannes Fink** Institute of Science and Technology, Vienna, Austria

Stationary Entangled Radiation from Micromechanical Motion

Utilizing ultra-high impedance LC circuits enables efficient electromechanical coupling to nano-string oscillators compatible with integrated photonics [1]. With our new silicon-on-insulator platform [2] we demonstrate motional ground state cooling, voltage tuneable microwave frequency conversion, superconducting qubit integration [3], and the realization of highly nonreciprocal on-chip isolators and circulators [4]. Very recently we made significant progress to mechanically generate two-mode squeezed light in spatially separated signal paths, fulfilling the non-separability criterion.

[1] J. M. Fink, M. Kalaee, A. Pitanti, R. Norte, L. Heinzle, M. Davanço, K. Srinivasan, and O. Painter, Nature Communications 7, 12396 (2016)
[2] Paul B. Dieterle, Mahmoud Kalaee, Johannes M. Fink, and Oskar Painter, Phys. Rev. Applied 6, 014013 (2016)
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11:30 - 11:55 [WED]	**Karolina Słowik** Nicolaus Copernicus University, Torun, Poland

Quantum optical realization of arbitrary linear transformations

Unitary transformations are routinely modelled and implemented in the field of quantum optics. In contrast, nonunitary transformations, which can involve loss and gain, require a different approach. In the talk, a universal method to deal with nonunitary networks will be presented. An input to the method is an arbitrary linear transformation matrix of optical modes that does not need to adhere to bosonic commutation relations. The method constructs a transformation that includes the network of interest and accounts for full quantum optical effects related to loss and gain. Furthermore, through a decomposition in terms of simple building blocks, it provides a step-by-step implementation recipe, in a manner similar to the decomposition by Reck et al. [1] but applicable to nonunitary transformations. Applications of the method include the implementation of positive operator-valued measures, the design of probabilistic optical quantum information protocols, or quantum simulations of realistic systems.

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11:55 - 12:10 [WED]	**Kanupriya Sinha** MPI for the Physics of Complex Systems, Dresden, Germany

Collective effects in Casimir-Polder forces

Fluctuation forces arising between neutral objects due to the quantum fluctuations of the vacuum electromagnetic field are a fascinating feature of quantum electrodynamics. When considering atom-surface interactions at nanoscales, such short-ranged fluctuation forces, or Casimir-Polder forces become an imperative element of consideration in understanding and designing photonic systems. It is therefore an interesting question to explore whether and how these forces can be engineered in a way to achieve better control and coherence of quantum systems interacting at nanoscales.

In this talk, I would like to motivate and introduce the use of collective effects as a means to tailor Casimir-Polder forces. We analyze cooperative phenomena in the fluctuation-induced forces between a surface and a system of neutral two-level quantum emitters prepared in a coherent collective state, showing that the total Casimir-Polder force on the emitters can be modified via their mutual correlations. Particularly, we find that a collection of emitters prepared in a super- or subradiant state experiences an enhanced or suppressed collective vacuum-induced force, respectively. The collective nature of dispersion forces can be understood as resulting from the interference between the different processes contributing to the surface-modified resonant dipole-dipole interaction. Such cooperative fluctuation forces depend singularly on the surface response at the resonance frequency of the emitters, thus being easily maneuverable. Our results demonstrate the potential of collective phenomena as a new tool to selectively modify vacuum forces.

14:00 - 14:25 [WED]	**Markus Heyl** MPI for the Physics of Complex Systems, Dresden, Germany

Dynamical quantum phase transitions

The theory of phase transitions plays a central role for the understanding of equilibrium physical systems. In this talk I will introduce a dynamical analogue in quantum many-body systems, termed dynamical quantum phase transitions, that occur during coherent nonequilibrium real-time evolution. The recent achieved advances will be summarized starting from the first experimental observations in so-called quantum simulators such as ultracold atomic gases and trapped ions. I will furthermore discuss how important concepts of equilibrium criticality can be extended including scaling and universality as well as how these transitions can control the general dynamical properties.

14:25 - 14:40 [WED]	**Matteo Brunelli** University of Cambridge, UK

Linear-and-quadratic reservoir engineering of non-Gaussian states in cavity optomechanics

Reservoir engineering is a powerful tool that enables the robust preparation of pure quantum states in noisy environments. In the context of bosonic systems, it has been successfully employed for the stabilization of squeezed and entangled states in trapped atoms and ions, circuit quantum electrodynamics and optomechanics. However, despite the success, bosonic reservoir engineering is currently limited by the linear character of the evolution, which restricts the set of target states to Gaussian ones.

I will discuss a dissipative scheme for the unconditional preparation of pure non-Gaussian states of a target system. The target mode is coupled both linearly and quadratically to an auxiliary damped mode, which acts as an engineered reservoir. I will show that any pure state that can be prepared unconditionally, i.e. without requiring initialization, is either (i) a cubic phase state, namely a state given by the action of a non-Gaussian (cubic) unitary on a squeezed vacuum or (ii) a (squeezed and displaced) finite superposition of Fock states. State (i) plays a fundamental role in continuous variable quantum computation, where it allows to realize any arbitrary unitary operation. Class (ii) represents a novel family of bosonic states that encompasses both (displaced) single Fock states and Schrodinger-cat-like states, namely the two main prototypes of nonclassicality for bosonic systems. These states can be stabilized in an optomechanical cavity that is parametrically coupled to both the mechanical displacement and the displacement squared. The mechanical resonator is prepared in the desired state by driving the cavity with multiple coherent drives and adjusting their relative strengths and phases. The scheme enables the unconditional preparation of several nonclassical states of a macroscopic object, and I will explicitly discuss the case of a mechanical cubic phase state, an arbitrary phonon number state and a macroscopic quantum superposition.

14:40 - 15:05 [WED]	**Simon Gröblacher** TU Delft, The Netherlands

Quantum information processing with optomechanical systems

Mechanical oscillators coupled to light via the radiation pressure force have attracted significant attention over the past years for allowing tests of quantum physics with massive objects and for their potential use in quantum information processing. Recently demonstrated quantum experiments include entanglement and squeezing of both the mechanical and the optical mode. So far these quantum experiments have almost exclusively operated in a regime where the light field oscillates at microwave frequencies. Here we would like to discuss recent experiments where we demonstrate various non-classical mechanical states by coupling a mechanical oscillator to single optical photons. These results are a promising route towards using mechanical systems as quantum memories, for quantum communication purposes and as light-matter quantum interfaces.