SFB

FoQuS

Foundations and Applications of Quantum Science

International Conference
February 4 – 8, 2019, Innsbruck

Contents

General information

Reception & registration

The reception and registration will take place on Sunday February 3rd, 16-19:00, at the foyer of the auditorium (Aula) on the first floor of the University main building (Innrain 52, 6020 Innsbruck).

Registration will be further possible on Monday 08:00 – 08:45, and from Tuesday to Friday 08:45 – 09:00, at the foyer of the auditorium.

WiFi

Click on the WiFi-symbol in the taskbar, choose network *UIBK* and type in the required information:

User: c115135
Password (WPA2-Enterprise): 20FoQuS19

Most computers keep this configuration and connect with the network again when it is within reach. Please make sure that your network interface card is activated and you are within reach of the router. According to the settings of your operating system maybe you are asked two times for the network key (WPA2-Password), some computers never ask for that.

Cloakroom

A cloakroom is available at the lecture hall throughout the conference.

Emergency contact

For inquiries with respect the conference please contact Verena Tanzer at
+43 (512) 50752415 (available 08:00-17:00).

In case of a medical emergency please dial the European emergency number **112** from any landline, or mobile phone.

Program

Monday, February 4th	
08:00 – 08:45	Registration
08:45 – 09:00	Welcome
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09:00 – 09:45	Rainer Blatt, University of Innsbruck & IQOQI Innsbruck *Quantum Computation and Entanglement with Ion Strings*
09:45 – 10:30	Peter Zoller, University of Innsbruck & IQOQI Innsbruck *Programming Quantum Simulators*
10:30 – 11:00	Coffee break
Chair: Tracy Northup	
11:00 – 11:30	John L. Hall, JILA/NIST, University of Colorado *TBA*
11:30 – 12:00	Arno Rauschenbeutel, Humboldt-Universität zu Berlin & TU Wien *Chiral Quantum Optics*
12:00 – 12:30	Eugene S. Polzik, Niels Bohr Institute, University of Copenhagen *Quantum mechanics in the negative mass reference frame: from nano-mechanics to gravitational wave detection*
12:30 – 14:00	Lunch break
Chair: Oriol Romero-Isart	
14:00 – 14:30	Barbara Terhal, Delft University of Technology *Scalable quantum error correction with the bosonic GKP code*
14:30 – 15:00	Frank Verstraete, Ghent University & University of Vienna *Quasiparticle excitations in strongly correlated system*
15:00 – 15:30	Hans Briegel, University of Innsbruck *Learning and artificial intelligence in the quantum domain*
15:30 – 16:00	Coffee break
Chair: Gerhard Kirchmair	
16:00 – 16:30	Michelle Y. Simmons, University of New South Wales Sydney *Atomic qubits in silicon*
16:30 – 17:00	Matthias Troyer, Microsoft *TBA*
17:00 – 17:30	Birgitta Whaley, UC Berkeley *Continuous Quantum Error Correction for Quantum Annealing*

Tuesday, February 5th	
Chair: Francesca Ferlaino	
09:00 – 09:45	David Wineland, University of Oregon & NIST *Trapped-Ion Quantum Information Processing at NIST*
09:45 – 10:30	Jeff Kimble, Caltech *Quantum matter built from nanoscopic lattices of atoms and photons*
10:30 – 11:00	Coffee break
Chair: Andreas Läuchli	
11:00 – 11:30	Marko Cetina, Joint Quantum Institute and University of Maryland *(Quantum) Engineering of Trapped Ions*
11:30 – 12:00	Helmut Ritsch, University of Innsbruck *Cavity QED with ultracold quantum gases*
12:00 – 12:30	Tracy Northup, University of Innsbruck *An ion-based quantum sensor for cavity photons*
12:30 – 14:00	Lunch break
14:00 – 16:00	Poster session I, Chair: Martin Ringbauer, Pavel Hrmo
Chair: Jörg Schmiedmayer	
16:00 – 16:30	Hanns-Christoph Nägerl, University of Innsbruck *Quantum control of ultracold molecular samples*
16:30 – 17:00	Andreas Läuchli, University of Innsbruck *Large scale numerical simulations of quantum matter*
17:30 – 17:30	Rudolf Grimm, IQOQI Innsbruck & University of Innsbruck *Ultracold fermion mixtures tuned into resonance*

Wednesday, February 6th	
Chair: Hanns-Christoph Nägerl	
09:00 – 09:45	Michel Brune, Laboratoire Kastler Brossel and Collège de France *From cavity QED to quantum simulations with slow or trapped Rydberg atoms*
09:45 – 10:30	Jean Dalibard, Laboratoire Kastler Brossel and Collège de France *Exploring Scale Invariance in Flatland*
10:30 – 11:00	Coffee break
Chair: Arno Rauschenbeutel	
11:00 – 11:30	Antoine Browaeys, Institut d'Optique, CNRS *Many-body physics with arrays of individual Rydberg atoms*
11:30 – 12:00	Markus Hennrich, Stockholm University *Interacting Rydberg ions*
12:00 – 12:30	John Doyle, Harvard University *Cold and ultracold molecules for quantum information and particle physics*
12:30 – 12:45	Conference photo
12:45 – 14:00	Lunch break
13:00, 17:00	City tour (see directions on page 35)
14:00	Lab tours (see directions on page 35) Chair: Christian Roos

19:00 – 20:00	Public Evening Talk (in German) Anton Zeilinger, University of Vienna/IQOQI *Von Quantenrätseln zu Quantentechnologie* Chair: Thomas Lackner

Thursday, February 7th	
Chair: Peter Zoller	
09:00 – 09:45	Ana Maria Rey, JILA/NIST, University of Colorado *Collective Spin Dynamics of Weakly Interacting Fermions: From Dynamical Phase Transitions to Spin Squeezing*
09:45 – 10:30	Ignacio Cirac, Max Planck Institute of Quantum Optics *Quantum optics in structured reservoirs: from exotic emission to quantum chemistry simulation*
10:30 – 11:00	Coffee break
Chair: Rudolf Grimm	
11:00 – 11:30	Eugene Demler, Harvard University *New perspectives on quantum matter: bringing together quantum simulations and machine learning*
11:30 – 12:00	Jörg Schmiedmayer, TU Wien *Universal dynamics far from equilibrium*
12:00 – 12:30	Misha Lukin, Harvard University *Exploring quantum dynamics in Rydberg atom arrays*
12:30 – 14:00	Lunch break
14:00 – 16:00	Poster session II, Chair: Martin Ringbauer, Pavel Hrmo
Chair: Barbara Kraus	
16:00 – 16:30	Gemma de las Cuevas, University of Innsbruck *Matrix product density operators of bond dimension two are separable*
16:30 – 17:00	Antonio Acin, The Institute of Photonic Sciences *Certification of many-body quantum states*
17:30 – 17:30	Renato Renner, ETH Zürich *Information-theoretic limits to the accuracy of clocks*

19:00 –	Conference dinner (see directions on page 35)

Friday, February 8th	
Chair: Markus Arndt	
09:00 – 09:45	Jun Ye, JILA/NIST, University of Colorado *Engineering quantum states of matter for atomic clocks*
09:45 – 10:30	Immanuel Bloch, Max Planck Institute of Quantum Optics *From Quantum Magnetism to Quantum Chemistry - New Avenues for Ultracold Quantum Gases*
10:30 – 11:00	Coffee break
Chair: Philip Walther	
11:00 – 11:20	Simon Gröblacher, Kavli Institute of Nanoscience & Delft University of Technology *Quantum acoustics experiments*
11:20 – 11:40	Philipp Haslinger, TU Wien *Attractive force on atoms due to blackbody radiation*
11:40 – 12:00	Francesca Ferlaino, IQOQI & University of Innsbruck *The quantum phases of ultracold dipolar gases near a Roton excitation*
12:00 – 12:20	Barbara Kraus, University of Innsbruck *Entanglement and Compressed Quantum Simulation*

Invited talks

Monday, February 4th, 09:00-10:30
Chair: Rainer Blatt

09:00

Quantum Computation and Entanglement with Ion Strings

Rainer Blatt, IQOQI & University of Innsbruck

The state-of-the-art of the Innsbruck trapped-ion quantum computer is reviewed. First, we present an overview on the available quantum toolbox and discuss the scalability of the approach. Fidelities of quantum gate operations are evaluated and optimized by means of cycle-benchmarking [1] and we show the generation of a 16-qubit GHZ state. Entangled states of a fully controlled 20-ion string are investigated and used for quantum simulations. We will discuss, how with long strings, an implementation of quantum error correction and an improved trap setup a scalable quantum information processor architecture can be built.

[1] A. Erhard *et al.*, to be published.

09:45

Programming Quantum Simulators

Peter Zoller, IQOQI & University of Innsbruck

Our SFB FOQUS aims at a collaborative “quantum advantage”, and I will focus on two examples taken from the last year, where new theoretical ideas and concepts found immediate realization in Innsbruck ion trap experiments. The first example is around the paradigm of randomized measurements and its application to atomic quantum many-body physics. I will discuss measurement of entanglement entropy in quench dynamics in a protocol employing single qubit (spin) rotations, and provide a theory outlook. The second example is variational quantum simulation of lattice models. Here families of entangled variational wavefunctions are generated on a programmable 20 ion analog quantum simulator as a quantum resource, and a classical-quantum feedback loop finds the ‘best’ ground state of - in our case - the Schwinger lattice model for the given resources. We provide a first demonstration of self-verification of quantum simulation by measuring the variance of the target Hamiltonian on our quantum device.

[1] T. Brydges *et al.*, *arXiv*:1806.05747.
[2] C. Kokail *et al.*, *arXiv*:1810.03421.

Monday, February 4^{th}, 11:00-12:30
Chair: Tracy Northup

11:00

TBA

John L. Hall, JILA/NIST, University of Colorado

11:30

Chiral Quantum Optics

Arno Rauschenbeutel, Humboldt-Universität zu Berlin & TU Wien

Controlling the interaction of light and matter is the basis for diverse applications ranging from light technology to quantum information processing. Nowadays, many of these applications are based on nanophotonic structures. It turns out that the confinement of light in such nanostructures imposes an inherent link between its local polarization and its propagation direction, also referred to as spin?momentum locking of light [1]. Remarkably, this leads to chiral, i.e., propagation direction-dependent emission and absorption of light [2]. In our group, we observed this effect in the interaction between single rubidium atoms and the evanescent part of a light field that is confined by continuous total internal reflection in a whispering-gallery-mode microresonator [3]. In the following, this allowed us to realize an integrated optical isolator [4] as well as an integrated optical circulator [5] which operate at the single-photon level and which exhibit low loss. The latter are the first two examples of a new class of nonreciprocal nanophotonic devices which exploit the chiral interaction between single quantum emitters and transversally confined photons. Finally, we showed that chiral effects even occur in standard imaging systems like an optical microscope. There, they lead to a shift of the image of an elliptically polarized point-like emitter with respect to the emitter's real position [6].

[1] K. Y. Bliokh, F. J. Rodríguez-Fortuño, F. Nori, and A. V. Zayats, *Nat. Photon.* **9**, 796 (2015).
[2] P. Lodahl *et al.*, *Nature* **541**, 473, (2017).
[3] C. Junge, D. O'Shea, J. Volz, and A. Rauschenbeutel, *Phys. Rev. Lett.* **110**, 213604 (2013).
[4] C. Sayrin *et al.*, *Phys. Rev. X* **5**, 041036 (2015).
[5] M. Scheucher *et al.*, *Science* **354**, 1577 (2016).
[6] G. Araneda *et al.*, *Nature Physics* **15**, 17 (2019).

12:00

Quantum mechanics in the negative mass reference frame: from nano-mechanics to gravitational wave detection

Eugene S. Polzik, Niels Bohr Institute, University of Copenhagen

A continuous measurement of a position of an object imposes a random quantum back action (QBA) perturbation on its momentum. This randomness translates with time into position uncertainty, thus leading to the well known uncertainty of the measurement of motion. As a consequence, and in accordance with the Heisenberg uncertainty principle, the QBA puts a limitation – the so-called standard quantum limit (SQL) – on the precision of sensing of position, velocity and force. In this talk I will first present the results of the experiment [1] where motion of a mechanical oscillator is tracked with the precision not restricted by the QBA. This is achieved by measuring the motion in a special reference frame linked to an atomic spin system with an effective negative mass. Progress towards employing this principle towards generation of entanglement between disparate macroscopic objects [2,3] and towards reaching beyond the SQL precision with Gravitational Wave Detectors [4] will be presented.

[1] C. B. Møller *et al.*, *Nature* **547**, 191 (2017).
[2] K. Hammerer*et al.*, *Phys. Rev. Lett.* **102**, 020501 (2009).
[3] X. Huang *et al.*, *Phys. Rev. Lett.* **121**, 103602 (2018).
[4] F. Ya. Khalili and E. S. Polzik, *Phys. Rev. Lett.* **121**, 031101 (2018).

Monday, February 4th, 14:00-15:30
Chair: Oriol Romero-Isart

14:00

Scalable quantum error correction with the bosonic GKP code

Barbara Terhal, Delft University of Technology

We review the bosonic GKP (Gottesman-Kitaev-Preskill) code which encodes a qubit into an oscillator and its possible implementation in a microwave mode in circuit-QED hardware. We discuss how GKP code states can be created from Schroedinger cat states or from a dispersive interaction with a qubit. We propose a scalable architecture which uses a surface code on top of the GKP qubits. For a noise model of Gaussian stochastic displacement errors, we discuss how to decode such toric-GKP code and give estimates for the threshold standard deviation, corresponding to a low (4 or more) number of average photons in the GKP code states.

14:30

Quasiparticle excitations in strongly correlated system

Frank Verstraete, Ghent University & University of Vienna

Using the formalism of tensor networks, it is possible to construct a precise ansatz for elementary excitations in strongly correlated systems. This talk will give an overview of this construction in the case of topological nontrivial excitations in 1 and 2 dimensional quantum spin systems.

15:00

Learning and artificial intelligence in the quantum domain

Hans Briegel, University of Innsbruck

I will discuss some of the possible roles of quantum information for artificial intelligence, and vice versa. These include the use of reinforcement-learning agents in quantum physics laboratories, as well as the use of quantum information in machine learning and artificial-agent design. I will focus on the model of projective simulation (PS), which employs random-walk processes in the agent?s memory for learning and decision-making. Projective simulation has been applied, e.g., in autonomous robotic playing and in the design of quantum experiments. The PS model can be naturally quantized, allowing for a quantum speed-up of the agent?s decision process. I will review some recent results of our research on (classical and) quantum-enhanced learning agents, including applications in quantum experiment and quantum error correction.

Monday, February 4th, 16:00-17:30
Chair: Gerhard Kirchmair

16:00

Atomic qubits in silicon

Michelle Y. Simmons, University of New South Wales Sydney

Extremely long electron and nuclear spin coherence times have been demonstrated in isotopically pure Si-28 [1,2] making silicon a promising semiconductor material for spin-based quantum information. The two-level spin state of single electrons bound to shallow phosphorus donors in silicon in particular provide well defined, reproducible qubits [3]. An important challenge in these systems is the realisation of an architecture, where we can position donors within a crystalline environment with approx. 20-50nm separation, individually address each donor, manipulate the electron spins using ESR techniques and read-out their spin states.

We have developed a unique fabrication strategy for a scalable quantum computer in silicon using scanning tunneling microscope lithography to precisely position individual P donors in Si [4] aligned with nanoscale precision to local control gates [5] necessary to initialize, manipulate, and read-out the spin states [6-8]. We have published our approach to scale-up using 3D architectures for implementation of the surface code [9].

During this talk I will focus on demonstrating fast, high fidelity single-shot spin read-out [10], ESR control of precisely-positioned P donors in Si [11] and our results to demonstrating a two-qubit gate in donor qubits in silicon [12,13]. With important advances in control at the atomic-scale, I will attempt to highlight the benefits of single atom qubits in silicon.

[1] K. Saeedi *et al.*, *Science* **342**, 830 (2013).
[2] J. T. Muhonen *et al.*, *Nature Nanotechnology* **9**, 986 (2014).
[3] B. E. Kane, *Nature* **393**, 133 (1998).
[4] M. Fuechsle *et al.*, *Nature Nanotechnology* **7**, 242 (2012).
[5] B. Weber *et al.*, *Science* **335**, 6064 (2012).
[6] H. Büch *et al.*, *Nature Communications* **4**, 2017 (2013).
[7] B. Weber *et al.*, *Nature Nanotechnology* **9**, 430 (2014).
[8] T. F. Watson *et al.*, *Science Advances* **3**, e1602811 (2017).
[9] C. Hill *et al.*, *Science Advances* **1**, e1500707 (2015).
[10] D. Keith *et al.*, paper submitted (2018).

[11] S. Hile *et al.*, *Science Advances* **4**, eaaq1459 (2018).
[12] M. A. Broome *et al.*, *Nature Communications* **9**, 980 (2018).
[13] S. Gorman, Y. He *et al.*, paper in preparation (2018).

16:30

TBA

Matthias Troyer, Microsoft

17:00

Continuous Quantum Error Correction for Quantum Annealing

Birgitta Whaley, UC Berkeley

Quantum error correcting codes can be combined with weak measurements and quantum feedback operations to implement quantum error correction continuously in time. We demonstrate that this can be applied to devise continuous error correction schemes for quantum annealing problems. We analyze the relative efficacy of several error detecting and error correcting codes, and illustrate the relative benefits of different paradigms of quantum encoding via subspace and subsystem codes.

Tuesday, February 5th, 09:00-10:30
Chair: Francesca Ferlaino

09:00

Trapped-Ion Quantum Information Processing at NIST

David Wineland, University of Oregon & NIST

Some of the recent work in the Ion-Storage group of NIST will be described. Logic gate teleportation between spatially separated qubits is achieved through interaction with a shared Bell pair of ancilla qubits and classical information transfer. We investigate the mechanical harmonic oscillator associated with a single trapped ion; we study its coupling to the ion?s internal states using magnetic fields and explore its limits for force sensing. We briefly summarize current work on atomic and molecular ion spectroscopy and integrated superconducting nanowire single photon detectors.

09:45

Quantum matter built from nanoscopic lattices of atoms and photons

Jeff Kimble, Caltech

New paradigms for optical physics emerge with lattices of atoms trapped in one and two-dimensional photonic crystals [1]. Exemplary experimental platforms include photonic crystal waveguides and cavities. Owing to their small optical loss and tight field confinement, these nanoscale dielectric devices are capable of mediating long-range atom-atom interactions using photons propagating in their guided modes. In a complimentary fashion, long-range interactions between photons can be mediated by an underlying lattice of atoms. Such systems have the potential to provide new tools for quantum phases of light and matter, scalable quantum networks, and quantum metrology.

[1] D. Chang *et al.*, *Rev. Mod. Phys.* **90**, 031002 (2018).

Tuesday, February 5th, 11:00-12:30
Chair: Andreas Läuchli

11:00

(Quantum) Engineering of Trapped Ions

Marko Cetina, Joint Quantum Institute and University of Maryland

I will describe the progress in Maryland in developing large-scale, high-fidelity ion trapping systems for quantum computing and quantum simulations.

11:30

Cavity QED with ultracold quantum gases

Helmut Ritsch, University of Innsbruck

We study emerging ordered quantum phases of ultracold spinor quantum particles in multimode cavities to synthesize dynamic gauge fields, spin orbit coupling, or long range spin interactions. Quantum particles coupled to field modes of optical resonators hybridize with cavity photons, which collectively couple spin and motional dynamics. By help of multiple polarization modes one is able to engineer spin-dependent dynamic optical potentials and tailored long-range density and spin-spin interactions towards a versatile analogue quantum simulator. The emerging spin-and-density-ordered complex quantum phases can often be characterized in situ via properties of the cavity output spectra. For larger interaction strength the light induced long range coupling of the particles can induce regular crystallization of the particles bound by light and the appearance of new exotic quantum phases with short and long range order as found in a supersolid. The system also offers unique properties as a future general purpose quantum simulator.

12:00

An ion-based quantum sensor for cavity photons

Tracy Northup, University of Innsbruck

Over the past two decades of SFB research, trapped ions coupled to optical cavities have provided an experimental platform for studying light-matter interactions, open quantum systems, and quantum network interfaces. In this talk, I will discuss the dispersive coupling of a single trapped ion to an optical cavity, which we have recently used to extract information about cavity photons in a nondestructive way. Via Ramsey spectroscopy of the ion, we probe the ion-cavity interaction and are able to reconstruct the cavity photon-number distribution, distinguishing between coherent states and mixed thermal-coherent statistics. This technique offers a potential route to engineer nonclassical cavity-field states in the optical domain.

Tuesday, February 5th, 14:00-16:00
Postersession I
Chair: Martin Ringbauer, Pavel Hrmo

Tuesday, February 5th, 16:00-17:30
Chair: Jörg Schmiedmayer

16:00

Quantum control of ultracold molecular samples

Hanns-Christoph Nägerl, University of Innsbruck

We present our ultracold-molecule platform for purposes of quantum simulation and quantum computing. We detail our quantum engineering approach to generate ultracold samples of polar molecules in the regime of quantum degeneracy. Such samples are ideal for quantum simulation purposes with many-body spin systems and for probing novel phases and phase transitions in view of the long-range dipole-dipole interactions between the molecules. Our choice of molecule is the RbCs molecule, which is a boson, and we have started a project on fermionic KCs. The crucial step in producing low-entropy samples of ground-state RbCs molecules is to efficiently form Rb-Cs atom pairs out of quantum degenerate Rb resp. Cs samples as precursors to molecule formation. This formation is done in the presence of an optical lattice potential. Specifically, the atom pairs are created by suitably mixing a Cs Mott insulator with a superfluid Rb sample [1]. We give an outlook on our goal to produce a molecular quantum simulator.

[1] L. Reichsöllner *et al.*, *Phys. Rev. Lett.* **118**, 073201 (2017).

16:30

Large scale numerical simulations of quantum matter

Andreas Läuchli, University of Innsbruck

In this talk I will report and discuss a selection of results obtained by our group within the SFB FoQus:

(i) Exotic states of matter in SU(N) quantum magnets [1].

(ii) (Computational) Spectroscopy of quantum critical matter [2].

(iii) Observing the space- and time-dependent growth of correlations in a quantum many body system [3].

[1] P. Nataf *et al.*, *Phys. Rev. Lett.* **117**, 167202 (2016).
[2] M. Schuler *et al.*, *Phys. Rev. Lett.* **117**, 210401 (2016).
[3] V. Lienhard *et al.*, *Phys. Rev. X* **8**, 021070 (2018).

17:00

Ultracold fermion mixtures tuned into resonance

Rudolf Grimm, IQOQI Innsbruck & University of Innsbruck

Ultracold mixtures involving fermionic atoms and featuring tunable interaction have opened up a wealth of intriguing possibilities to explore novel many-body quantum systems. A prominent example is the realization of superfluidity near a Feshbach resonance in spin mixtures of ^{6}Li atoms. In such a system, we observed the phenomenon of second sound [1]. Our main research line within the SFB emerged from general questions of few- and many-body physics in a mixture of different fermionic species, where mass imbalance introduces a new degree of freedom into the problem. In a mixture of ^{6}Li with ^{40}K atoms, we have studied several basic properties and phenomena, including the stability of dimers, few-body interactions, and impurity physics. We have demonstrated the repulsive polaron as a metastable quasiparticle [2], and we have developed spectroscopy in the time domain to study the formation dynamics of quasiparticles [3]. In recent work, we have also studied the static and dynamic properties of a mesoscopic impurity, realized with a small-sized ^{41}K Bose-Einstein condensate immersed in a large Fermi sea [4]. A “spin off” of the SFB project is a new experiment on mixtures of ^{161}Dy and ^{40}K atoms with exciting prospects for the realization of novel superfluids.

[1] L. A. Sidorenkov *et al.*, *Nature* **498**, 78 (2013).
[2] C. Kohstall *et al.*, *Nature* **485**, 615 (2012).
[3] M. Cetina *et al.*, *Science* **354**, 96 (2016).
[4] R. S. Lous *et al.*, *Phys. Rev. Lett.* **120**, 243403 (2018).

Wednesday, February 6th, 09:00-10:30
Chair: Hanns-Christoph Nägerl

09:00

From cavity QED to quantum simulations with slow or trapped Rydberg atoms

Michel Brune, Laboratoire Kastler Brossel and Collège de France

Rydberg atoms and microwave photons stored in a high Q cavity constitute a nearly ideal system for realizing experiments illustrating fundamental features of quantum measurement theory, such as state projection and decoherence. We will present a new experiment performed with slow circular Rydberg atoms prepared from a 2D-MOT rubidium beam. We observe the main features of the resonant atom-cavity interaction like vacuum Rabi oscillations on unprecedented timescales and observe collapse and revival of the Rabi oscillations involving unprecedented photon numbers. We observe the decoherence of cat state with a phase-space separation up to 40 photons. We also show that this slow-atom experiment reaches long-enough interaction times to resolve spectroscopically the atom cavity dressed states opening new perspectives for the preparation of non-classical states and manipulation of quantum information.

We will then show that the perspective of even laser trapping single circular Rydberg atoms opens fascinating perspectives for cavity QED and quantum simulation experiments. We have prepared ultracold, long-lived circular Rydberg atoms in a cryogenic environment. We will show that trapped circular Rydberg atoms in optical tweezers have a high potential for building a quantum simulator of 1D or 2D XXZ spin Hamiltonian over unprecedented timescales.

09:45

Exploring Scale Invariance in Flatland

Jean Dalibard, Laboratoire Kastler Brossel and Collège de France

A fluid is said to be scale-invariant when its interaction and kinetic energies have the same scaling in a dilation operation. This symmetry has profound consequences both on the equilibrium properties of the fluid and its dynamics. In this talk, I will present recent experimental investigations of this phenomenon using an initially uniform, two-dimensional gas of rubidium atoms which is suddenly immersed in a harmonic potential. I will also show a further, unexpected result for this setup: there exist specific initial shapes - equilateral triangles or disks - that lead to a periodic evolution of the interacting system. They correspond to novel types of breathers for the two-dimensional Gross-Pitaevskii equation.

Wednesday, February 6th, 11:00-12:30
Chair: Arno Rauschenbeutel

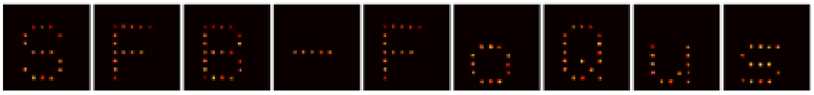
11:00

Many-body physics with arrays of individual Rydberg atoms

Antoine Browaeys, Institut d'Optique, CNRS

This talk will present our effort to control and use the dipole-dipole interactions between cold Rydberg atoms in order to implement spin Hamiltonians useful for quantum simulation of condensed matter situations. In our experiment, we trap individual atoms in arrays of optical tweezers separated by few micrometers and excite them to Rydberg states using lasers. The arrays are produced by a spatial light modulator, which shapes the dipole trap beam. We can create almost arbitrary geometries of the arrays with near unit filling in two and three dimensions up to about 70 atoms.

We have demonstrated the coherent energy exchange in chains of Rydberg atoms resulting from their resonant dipole-dipole interaction and its control by addressable lasers. This interaction realizes the XY spin model. We use this control to study elementary excitations in a dimerized spin chain featuring topological properties, thus implementing the Su-Schrieffer-Heeger model. We have observed the edge states in the topological condition and their hybridization by studying their dynamics. We explored the regime beyond the linear response by adding several excitations, which act as hard-core bosons. Using the van der Waals interaction between atoms, we have also implemented the quantum Ising model in one-dimensional chains with periodic boundary conditions and two-dimensional arrays containing up to about 50 atoms. We measure the dynamics of the excitation for various strengths of the interactions and compare the data to numerical simulations of this many-body system.



Fluorescence images of individual atoms trapped in arrays of optical tweezers separated by a few micrometers

11:30

Interacting Rydberg ions

Markus Hennrich, Stockholm University

Trapped Rydberg ions are a novel approach for quantum information processing [1]. This idea merges two highly developed quantum technologies, trapped ions and Rydberg atoms, with advantages from both sides. In particular, it combines the precise quantum control of trapped ions and the strong dipolar interactions of Rydberg atoms [1–3].

I will present our experimental progress in controlling the quantum state of trapped Rydberg ions. Specifically, I will show several recent results, including the realization of a single-qubit Rydberg phase gate [4], and the observation of strong Rydberg interaction between two ions. These are important steps towards realizing entanglement operations and quantum gates with trapped Rydberg ions.

[1] M. Müller, L. Liang, I. Lesanovsky, P. Zoller, *New J. Phys.* **10**, 093009 (2008).
[2] T. Feldker *et al.*, *Phys. Rev. Lett.* **115**, 173001 (2015).
[3] G. Higgins *et al.*, *Phys. Rev. X* **7**, 021038 (2017).
[4] G. Higgins *et al.*, *Phys. Rev. Lett.* **119**, 220501 (2017).

12:00

Cold and ultracold molecules for quantum information and particle physics

John Doyle, Harvard University

Wide-ranging scientific applications have created growing interest in ultracold molecules. Heteronuclear bialkali molecules, assembled from ultracold atoms, enabled the study of long-range dipolar interactions and quantum-state-controlled chemistry [1, 2], and recently have been brought to quantum degeneracy [3]. Assembling such molecules one-by-one in tweezers for quantum information applications is one exciting avenue of this work [4]. Beyond bialkalis, there are a range of molecules with advantageous properties for applications in quantum simulation [5, 6, 7] and quantum information [8, 9]. For example, polar molecules that feature unpaired electron spins are sought after because they can possess both non-zero electric and magnetic moments providing an additional degree of freedom. They can be used to simulate a large variety of lattice spin models [10], some of which host topological phases, opening up the possibility of topologically protected quantum memories and gates [11].

We will describe in this talk our recent results on optical trapping and Λ-enhanced laser cooling and imaging of CaF molecules [12], the laser cooling of SrOH molecules [13], and the prospects for laser cooling of larger polyatomic molecules [14], such as $CaOCH_3$, $YbOCH_3$, CaCCCa, $SrOCF_2CF_2OCa$, and $CaO(CH_2)_n$ OR, where R is a radical termination ligand. We also will very briefly mention recent progress in the field of electron electric dipole moment searches using heavy diatomic molecules, in particular the recent ACME result [15], and future prospects, including the use of polyatomic molecules [16].

[1] B. Yan *et al.*, *Nature* **501**, 521 (2013).
[2] S. Ospelkaus *et al.*, *Science* **327**, 853 (2010).
[3] J. Ye, DAMOP, Session J02 (2018).
[4] L. R. Liu *et al.*, *Science* **360**, 6391 (2018).
[5] L. D. Carr *et al.*, *New J. Phys.* **11**, 055049 (2009).
[6] G. Pupillo *et al.*, *Phys. Rev. Lett.* **100**, 050402 (2008).
[7] H. P. Büchler *et al.*, *Phys. Rev. Lett.* **98**, 060404 (2007).
[8] D. DeMille, *Phys. Rev. Lett.* **88**, 067901 (2002).
[9] S. F. Yelin *et al.*, *Phys. Rev. A* **74**, 050301 (2006).
[10] A. Micheli *et al.*, *Nat. Phys.* **2**, 341 (2006).
[11] N. Y. Yao *et al.*, *Nat. Comm.* **4**, 1585 (2013).
[12] L. Cheuk *et al.*, *Phys. Rev. Lett.* **121** (2018).
[13] I. Kozyryev *et al.*, *Phys. Rev. Lett.* **118**, 173201 (2017).
[14] I. Kozyryev *et al.*, *Chem. Phys. Chem.* **17**, 3641 (2016).
[15] ACME Collaboration*et al.*, *Nature* **562**, 355 (2018).
[16] I. Kozyryev *et al.*, *Phys. Rev. Lett.* **119**, 133002 (2017).

Wednesday, February 6th, 14:00-16:00
Lab tours, Chair: Christian Roos

Lab tours
For details and directions see page 32.

Wednesday, February 6th, 19:00-20:00
Chair: Thomas Lackner

Von Quantenrätseln zu Quantentechnologie
Anton Zeilinger, IQOQI & University of Vienna
Public evening talk in German

Thursday, February 7th, 09:00-10:30
Chair: Peter Zoller

09:00

Collective Spin Dynamics of Weakly Interacting Fermions: From Dynamical Phase Transitions to Spin Squeezing

Ana Maria Rey, JILA/NIST, University of Colorado

Ultracold atoms offer an ideal system to shed light on the organizing principles and universal behaviors of out-of-equilibrium quantum systems due to their long-lived coherence and controllable interactions. One emerging new paradigm is the dynamical phase transition (DPT) characterized by the existence of a long-time-average order parameter that distinguishes two non-equilibrium phases. In this talk I will report the observation of a DPT in a trapped quantum degenerate Fermi gas [1]. Above a critical interaction strength, a non-equilibrium magnetization is long lived, and protected by an energy gap against inhomogeneous field-induced dephasing. Through detailed comparisons to theory and by testing the reversibility of the collective many-body dynamics, we identify a regime in which the complex far-from-equilibrium dynamics of interacting fermions is quantitatively described by a collective Heisenberg model with an inhomogeneous axial field, a canonical model for magnetism recently used to describe quenched superconductors. Our quantum simulation of this model reveals the "phase-I" to "phase-II" transition predicted to exist but not yet directly observed in s-wave superconductors.

While the reduced coherence time of potassium atoms limits the observed dynamics to times where a mean-field description is enough to reproduce the experiment, I will discuss our proposal to explore quantum effects by considering weakly interacting fermions in the state-of-the-art 3D optical lattice clock with dynamics governed by the Hubbard model. This clock has demonstrated coherence times of the order of 10 sec. The basic idea is to use atomic interactions to generate an energy gap which in this case protects the the clock transition in this case against the dephasing effect of spin-orbit coupling [2] and transforms it into a collective spin-squeezing process. I will discuss how even with realistic experimental imperfections this scheme may generate $\sim$12–14 dB of spin squeezing in $\sim$1 second with 10^2–10^3 atoms.The proposed squeezing protocol requires no trade-offs in atom numbers or coherence times for currently operational state-of-the-art clocks. In addition to advancing the achievable precision of atomic clocks, it showcases a new paradigm of using driven, non-equilibrium systems to overcome current limitations in quantum metrology.

[1] S. Smale *et al.*, *arXiv*:1806.11044 (2018).
[2] S. L. Bromley *et al.*, *Nature Physics*, **14**, 399, (2018).

09:45

Quantum optics in structured reservoirs: from exotic emission to quantum chemistry simulation

Ignacio Cirac, Max Planck Institute of Quantum Optics

Recent progress in both nano-fabrication and atomic physics allows one to couple atoms (or other emitters) to structured waveguides. In this talk I will report on different opportunities that are opened up by those systems, including the observation of many-photon bound states, the preparation of Fock states, the simulation of long-range spin interacting models, or the observation of exotic features in collective decays. I will also explain how the same phenomena could be observed in a completely different setup consisting of atoms in state-dependent optical lattices. Here the role of the emitters and the photons in the waveguide are played by atoms in different internal states. The special interactions mediated in this setup opens up the possibility of simulating molecules in an analog way.

Thursday, February 7th, 11:00-12:30
Chair: Rudolf Grimm

11:00

New perspectives on quantum matter: bringing together quantum simulations and machine learning

Eugene Demler, Harvard University

What can we learn about a many-body system when we measure every constituent particle? Current experiments with ultracold atoms provide snapshots of many-body states with single particle resolution. This calls for new approaches to studying quantum many-body systems with a focus on analyzing patterns and using machine learning techniques. I will present a recent application of this method to study magnetic polarons in antiferromagnetic Mott insulators. Results indicate that magnetic polarons can be accurately described as spinon-chargon pairs bound by geometric strings, in close analogy to quark-antiquark bound pairs forming mesons in QCD. I will also discuss application of neural networks to compare different microscopic theories of doped Mott insulators.

11:30

Universal dynamics far from equilibrium

Jörg Schmiedmayer, TU-Wien

We provide experimental evidence of universal dynamics far from equilibrium during the relaxation of an isolated one-dimensional Bose gas. Following a rapid cooling quench, the system exhibits universal scaling in time and space, associated with the approach of a non-thermal fixed point. The time evolution within the scaling period is described by a single universal function and scaling exponent, independent of the species of the initial state. Our results provide a quantum simulation in a regime, where to date no theoretical predictions are available. This constitutes a crucial step in the verification of universality far from equilibrium. If successful, this will lead to a comprehensive classification of systems far from equilibrium based on their universal properties similar to the universality classes in phase transitions. This can be the basis for a new type of quantum simulation that let us explore a large variety of systems at different scales.

[1] S. Erne *et al.*, *Nature* **253**, 225 (2018).
[2] For a similar experiment in a spin system see: M. Prüfer *et al.*, *Nature* **253**, 217 (2018).

12:00

Exploring quantum dynamics in Rydberg atom arrays

Misha Lukin, Harvard University

We will discuss recent advances in manipulating quantum many-body systems composed from individually trapped, strongly interacting cold neutral atoms. Using this approach we realize a programmable Ising-type quantum spin model with tunable interactions and system sizes exceeding 50 qubits. Within this model we observe transitions into ordered states that break various discrete symmetries, verify high-fidelity preparation of ordered states, and investigate dynamics across the different phase transition. Recent progress towards probing non-equilibrium dynamics and quantum Kibble-Zurek mechanism, realization of large-scale entangled states and testing quantum optimization algorithms will be discussed.

Thursday, February 7th, 14:00-16:00
Postersession II
Chair: Martin Ringbauer, Pavel Hrmo

Thursday, February 7th, 16:00-17:30
Chair: Barbara Kraus

16:00

Matrix product density operators of bond dimension two are separable

Gemma De las Cuevas, University of Innsbruck

Mixed states can contain both classical and quantum correlations, and it is generally hard to determine which correlations are present. In this talk I will show that mixed states which can be written as a sum of only two terms on each site (i.e. whose operator Schmidt rank is 2) can only contain classical correlations, that is, they are separable. Moreover, they can be written as a sum of only two positive semidefinite matrices at each site, and thus contain "very few" classical correlations. This implies that matrix product density operators of bond dimension two are separable. This is in contrast to matrix product density operators of bond dimension three, which can contain an unbounded amount of classical correlations. Our proof leverages a newly explored connection with decompositions of nonnegative matrices, and uses results from the theory of free spectrahedra.

16:30

Certification of many-body quantum states

Antonio Acin, The Institute of Photonic Sciences

A ubiquitous question in quantum physics is to certify that a given many-body quantum system satisfies an operational property: is this given system in an entangled state? Does it display non-classical correlations? Does it provide a good approximation to the ground state of a relevant Hamiltonian? Does it contain the solution to a classical optimisation problem? In the talk, we first provide a method for device-independent entanglement detection that involves a polynomial numbe of correlation functions. Second, we move to the computation of ground states of classical spin systems. These systems are relevant because they can encode the solution to classical optimisation problems and are often used to benchmark quantum annealers. We present a method that provides upper and lower bounds to the ground-state energy, so that the error in the approximation is under control. We use it to verify the output of a D-Wave 2000Q device and identify instances where our method provides the exact ground state, while the annealer gives a configuration of higher energy.

17:00

Information-theoretic limits to the accuracy of clocks

Renato Renner, ETH Zürich

A clock is, from an information-theoretic perspective, a system that emits time information. One may therefore ask whether the theory of information imposes any constraints on the maximum precision of clocks. In this talk, I will show that, indeed, the accuracy of the time information generated by a clock fundamentally depends on the clock's size or, more precisely, the dimension d of its quantum-mechanical state space. Furthermore, a genuine quantum clock can achieve a quadratically improved accuracy compared to a classical clock, whose evolution is restricted to stochastic jumps between d perfectly distinguishable states.

[1] M. P. Woods *et al.*, *arXiv*:1806.00491 (2018).

Friday, February 8th, 09:00-10:30
Chair: Markus Arndt

09:00

Engineering quantum states of matter for atomic clocks

Jun Ye, JILA/NIST, University of Colorado

09:45

From Quantum Magnetism to Quantum Chemistry - New Avenues for Ultracold Quantum Gases

Immanuel Bloch, Max Planck Institute of Quantum Optics

Recent experiments with quantum gas microscopes allow for an unprecedented view and control of quantum matter in new parameter regimes and with new probes. In our fermionic quantum gas microscope, we can detect both charge and spin degrees of freedom simultaneously, thereby gaining maximum information on the intricate interplay between the two in the paradigmatic Hubbard model. In my talk, I will show how we can reveal hidden magnetic order, directly image individual polarons or probe the fractionalisation of spin and charge in dynamical experiments. For the first time we therefore have access to non-local "hidden" correlation properties of quantum matter. Furthermore, I will show how quantum gas microscopy can open new avenues for the for field of quantum chemistry when probing and controlling the formation of huge Rydberg macrodimers in optical lattices.

Friday, February 8th, 11:00-12:20
Chair: Philip Walther

11:00

Quantum acoustics experiments

Simon Gröblacher, Kavli Institute of Nanoscience & Delft University of Technology

Mechanical systems have recently attracted significant attention for their potential use in quantum information processing tasks, for example, as compact quantum memories or as transducers between different types of quantum systems. Early experiments included ground-state cooling of the mechanical motion and squeezing of the optical field. Recent advances have allowed to perform measurements which realize various mechanical quantum states.

Here, we would like to discuss several experiments where we demonstrate non-classical behavior of mechanical motion by coupling a micro-fabricated acoustic resonator to single optical photons. Our approach is based on optomechanical crystals, which possess engineered mechanical resonances in the Gigahertz regime that can be addressed optically from the conventional telecom band. Our measurements establish quantum control over acoustic motion, including the heralded generation and on-demand read-out of single phononic excitations. We further demonstrate high quality light-matter entanglement as well as heralded entanglement between two mechanical modes employing quantum optics protocols. These results are a promising step towards using such devices for quantum information processing tasks and testing quantum physics with massive objects.

11:20

Attractive force on atoms due to blackbody radiation

Philipp Haslinger, TU Wien

Atom interferometry has proven within the last decades its surprising versatility to sense with high precision tiniest forces. In this talk I will present our recent work, using an optical cavity enhanced atom interferometer to sense for an on the first-place counter-intuitive inertial property of blackbody radiation [1].

Blackbody (thermal) radiation is emitted by objects at finite temperature with an outward energy-momentum flow, which exerts an outward radiation pressure. At room temperature, e.g., a cesium atom scatters on average less than one of these blackbody radiation photons every 10^8 years. Thus, it is generally assumed that any scattering force exerted on atoms by such radiation is negligible. However, particles also interact coherently with the thermal electromagnetic field [2] and this leads to a surprisingly strong force acting in the opposite direction of the radiation pressure. Using atom interferometry, we find that this force scales with the temperature of the heated source object (293 – 450 K) to fourth power [1]. The force is in good agreement with that predicted from an ac Stark shift gradient of the atomic ground state in the thermal radiation field [2].

[1] P. Haslinger *et al.*, *Nat. Phys.* **14**, 257?260 (2018).

[2] M. Sonnleitner, M. Ritsch-Marte, H. Ritsch, *Phys. Rev. Lett.* **111**, 23601 (2013).

11:40

The quantum phases of ultracold dipolar gases near a Roton excitation

Francesca Ferlaino, IQOQI & University of Innsbruck

Discovered in liquid helium about 80 years ago, superfluidity is a counterintuitive phenomenon, in which quantum physics and particle-wave duality manifest at the macroscopic level. Since then, it has yielded many advances in understanding quantum matter, yet leaving mysterious some of its features. A hallmark of superfluidity is the existence of so-called "quasi-particles", i.e. elementary excitations dressed by interactions. Laudau predicted two type of quasi-particles, the first ones being the well-known phonon mode. The second ones, much more bizarre and intriguing, are massive quasi-particles named rotons. They have large momenta, and, contrarily to ordinary (quasi)particles with energy increasing with the momentum, the roton dispersion relation exhibits a minimum at a finite momentum. This unusual behavior expresses the tendency of the fluids to build up short-wavelength density modulation in space, precursor of a crystallization instability and eventually to the elusive and highly-debated supersolid quantum phase. In 2003, theoreticians suggested that a similar rotonic excitation might also occur in dipolar Bose-Einstein condensates because of the special properties of the long-rang and anisotropic dipole-dipole interaction. We here report on the observation of roton quasiparticles in a dipolar gas of high magnetic Er atoms and first steps towards the realization of a supersolid quantum state using a Bose-Einstein condensate of Er atoms.

12:00

Entanglement and Compressed Quantum Simulation

Barbara Kraus, University of Innsbruck

In this talk I will first discuss some new developments in multipartite entanglement theory. Then, I will present some results on compressed quantum computation and simulation. The idea of compressed computation is to use an exponentially smaller system to simulated a large system. It has been shown that such a compression is possible in case the gate set used in the original circuit is restricted. I will discuss various applications of compressed quantum computation including the possibility of using it to verify quantum computations.

Poster session I

Tuesday, February 5th, 14:00-16:00
Chair: Martin Ringbauer, Pavel Hrmo, University of Innsbruck

1. **Super- and subradiance of clock atoms in multimode optical waveguides**
   Laurin Ostermann, University of Innsbruck
2. **A cesium interferometer for quantum metrology**
   Benedikt Gerstenecker, TU Wien
3. **Wavelength-scale errors in optical localization due to spin-orbit coupling of light**
   Magister Stefan Walser, TU Wien
4. **Superradiant emission from colour centres in diamond**
   Andreas Angerer, TU Wien
5. **VUV Characterization of 229Th:CaF2 for an optical clock**
   Marion Mallweger, TU Wien
6. **Wavefront-shaping for electron microscopy**
   Philipp Weber, University of Vienna
7. **Superradiance in ensembles of Strontium-88 with inhomogeneous broadening**
   Georgy Kazakov, TU Wien
8. **Reaching the optimal sensitivity of non-gaussian spin states using individual sub-level resolution**
   Alexandre Evrard, Laboratoire Kastler Brossel and Collège de France
9. **A cesium interferometer for quantum metrology**
   Maximilian Lerchbaumer, TU Wien
10. **Quantum advantage for probabilistic one-time programs**
    Marie-Christine Röhsner, University of Vienna
11. **Matchgate circuits and compressed quantum computation**
    Martin Hebenstreit, University of Innsbruck
12. **Characterizing multi-qubit operations in an ion-trap quantum computer**
    Alexander Erhard, University of Innsbruck
13. **Estimating spatial correlations in a trapped ion quantum information processor**
    Lukas Postler, University of Innsbruck
14. **Constructing k-uniform states and study the graph state representation**
    Zahra Raissi, The Institute of Photonic Sciences

15. **Scalable quantum computation - Keeping a qubit alive**
Lukas Gerster, University of Innsbruck
16. **A hybrid quantum-classical learning agent**
Sabine Wölk, University of Innsbruck
17. **Machine learning for designing new quantum experiments**
Alexey Melnikov, University of Innsbruck
18. **Learning and Planning in Quantum Experiments**
Lea Marion Trenkwalder, University of Innsbruck
19. **Locust collective motion modelled with Projective Simulation**
Andrea López-Incera, University of Innsbruck
20. **Rydberg Excitations in Lanthanoid Atoms for Quantum Simulation**
Arno Trautmann, IQOQI Innsbruck
21. **Quantum simulation of non-perturbative cavity quantum electrodynamics**
Tuomas Jaako, TU Wien
22. **Towards Quantum Simulation of 2D Spin Lattices with Ion Crystals**
Dominik Kiesenhofer, IQOQI Innsbruck
23. **Quantum Simulation of spin models using assembled arrays of Rydberg atoms**
Sylvain De Leseleuc, Institut d'Optique Graduate Schools
24. **Experimental Greenberger-Horne-Zeilinger Entanglement Beyond QuBits**
Manuel Erhard, IQOQI Vienna
25. **Entanglement by Path Identity**
Jaroslav Kysela, University of Vienna
26. **Experimental few-copy multi-particle entanglement detection**
Valeria Saggio, University of Vienna
27. **Probing the Rényi Entanglement Entropy via Randomised Measurements**
Christine Maier, IQOQI Innsbruck
28. **Entanglement of stabilizer states**
Matthias Englbrecht, University of Innsbruck
29. **Changing SLOCC class using multiple copy transformations**
David Gunn, University of Innsbruck
30. **Entanglement entropies and OTOCs from randomized measurements**
Andreas Elben, IQOQI Innsbruck
31. **Wave-particle dualities of many-body quantum states**
Christoph Dittel, University of Innsbruck

32. **Anomalous energy transport and symmetry breaking in microscopic power grids**
    Julian Huber, TU Wien

33. **Cosmic Bell Test using Random Measurement Settings from High-Redshift Quasars**
    Dominik Rauch, IQOQI Vienna

34. **Satellite-Relayed Intercontinental Quantum Network**
    Johannes Handsteiner, IQOQI Vienna

35. **Certification and quantification of multilevel quantum coherence**
    Martin Ringbauer, University of Innsbruck

36. **Hidden Bridge between Quantum Experiments and Graph Theory**
    Xuemei Gu, IQOQI Vienna

37. **Chiral Heisenberg Gross-Neveu-Yukawa transition with a single Dirac cone**
    Thomas Lang, University of Innsbruck

38. **After all, are non-completely-positive maps physical or not? How causal models can clear up conceptual confusion**
    Katja Ried, University of Innsbruck

39. **Testing Foundations of Quantum Mechanics with a Waveguide Interferometer**
    Sebastian Gstir, University of Innsbruck

40. **Efficient non-Markovian quantum dynamics using time-evolving matrix product operators**
    Peter Kirton, TU Wien

41. **Universal dynamics in an isolated one-dimensional Bose gas far from equilibrium**
    Sebastian Erne, University of Nottingham

42. **The positivity problem in quantum many-body systems**
    Maria Balanzó-Juandó, University of Innsbruck

43. **Measuring non-classical paths with atom-cavities in the double-slit experiment**
    Jessica Oliveira de Almeida, The Institute of Photonic Sciences

Poster session II

Thursday, February 7th, 14:00-16:00
Chair: Martin Ringbauer, Pavel Hrmo, University of Innsbruck

44. **Plasmon Enhanced Third-Harmonic Generation with Graphene Nanoribbons**
Alessandro Trenti, University of Vienna

45. **Towards electrically injected parametric down-conversion in Bragg-reflection waveguides**
Alexander Schlager, University of Innsbruck

46. **An optical nanofiber-based interface for solid-state quantum emitters**
Sarah M. Skoff, TU Wien

47. **Direct and teleportation-based qubit interfaces between a single ion and near-IR photons**
Stephan Kucera, Universität des Saarlandes

48. **Interacting Rydberg ions**
Chi Zhang, Stockholm University

49. **Ultrafast coherent excitation of a Ca40+ ion**
Daniel Heinrich, IQOQI Innsbruck

50. **Polarization gradient cooling of one- and two-dimensional ion crystals**
Christian Roos, IQOQI Innsbruck

51. **Enhancing Optical/Electron Phase Microscopy for Biological Applications**
Thomas Juffmann, University of Vienna

52. **Energy determination of the Th-229 nuclear clock transition**
Benedict Seiferle, LMU Munich

53. **A direct nuclear laser excitation scheme for Th-229m**
Lars von der Wense, LMU Munich

54. **Prospects for a Cesium interferometer with tunable interactions**
Stephanie Manz, TU Wien

55. **Long Baseline Molecular Interferometry**
Yaakov Fein, University of Vienna

56. **Cavity and circuit QED in the non-perturbative regime**
Daniele de Bernardis, TU Wien

57. **The Roentgen-term and surprising effects in basic in atom-light interaction**
Matthias Sonnleitner, University of Innsbruck

58. **Observation of Multimode strong coupling of laser-cooled atoms to fiber-guided photons**
Aisling Johnson, TU Wien

59. **Chiral cavity quantum electrodynamics with whispering-gallery-modes**
Michael Scheucher, TU Wien

60. **Heating in Nanophotonic Traps for Cold Atoms**
Daniel Hümmer, IQOQI Innsbruck

61. **Studying collective effects in 3D waveguide QED with frequency and time-domain resolved spectroscopy**
Aleksei Sharafiev, IQOQI Innsbruck

62. **An ion-trap quantum network node**
Josef Schupp, IQOQI Innsbruck

63. **Towards quantum state transfer between two ions separated by 400m**
Yunfei Pu, University of Innsbruck

64. **Controlled photon generation and absorption in ion-cavity systems for quantum networks**
Maria Galli, University of Innsbruck

65. **Quantum network with fiber cavities**
Yueyang Zou, University of Innsbruck

66. **A cesium interferometer for quantum metrology**
Benedikt Gerstenecker, TU Wien

67. **Direct loading of levitated nanoparticles in a Paul trap in high vacuum**
Dmitry Bykov, University of Innsbruck

68. **New regimes of light-matter interaction in levitated nanoparticles**
Carlos Gonzalez-Ballestero, IQOQI Innsbruck

69. **Detection, charging and cooling of a levitating nanosphere in a Paul trap**
Lorenzo Dania, University of Innsbruck

70. **Quantum State Tomography of Levitated Nanoparticles**
Talitha Weiss, IQOQI Innsbruck

71. **Quantum measurement and control of levitated nano-particles**
Liam Walker, University of Strathclyde

72. **Dissipative Photon Blockade and Environment Induced Rabi Oscillations in the Optomechanical Boson-Boson Model**
Yuri Minoguchi, TU Wien

73. **Towards matter-wave interferometry experiments with nanoparticles**
Pietro Vahramian, University of Vienna

74. **Spin dynamics of dipolar fermions in an optical lattice**
Manfred Mark, University of Innsbruck

75. **Antiferromagnetic self-ordering of a Fermi gas in a ring cavity**
Elvia Colella, University of Innsbruck

76. **Static and dynamic properties of a repulsive Bose-Fermi mixture**
Isabella Fritsche, University of Innsbruck

77. **Accurate projective two-band description of topological superfluidity in spin-orbit-coupled Fermi gases**
Lauri Antero Toikka, University of Innsbruck

78. **Production of degenerate Fermi mixtures of dysprosium and potassium atoms**
Vincent Corre, University of Innsbruck

79. **Quasi-Particles in Flat Energy Bands**
Stuart Flannigan, University of Strathclyde

80. **Dissipative preparation of fermionic spin-entangled states in ultracold atoms**
Jorge Yago Malo, University of Strathclyde

81. **Roton mode in dipolar quantum Bose gases**
Lauriane Chomaz, University of Innsbruck

82. **Cavity-induced emergent topological spin textures in a Bose-Einstein condensate**
Stefan Ostermann, University of Innsbruck

83. **Observing the quantization of orbital angular momentum with toroidal Bose-Einstein condensates**
Filip Bartlomiej Kialka, University of Vienna & University of Duisburg-Essen

84. **Atomic double twin beams**
Filippo Borselli, TU Wien

85. **Tunable quantum matter in confined dimensions**
Bodhaditya Santra, University of Innsbruck

86. **Towards ultracold dipolar KCs molecules**
Michael Gröbner, University of Innsbruck

87. **Towards Pairs of Momentum Correlated Metastable Helium Atoms**
Kahan Dare, IQOQI Innsbruck

88. **Towards weak measurements on Bose-Einstein Condensates**
Mira Maiwöger, TU Wien

89. **Towards ultracold RbSr molecules in an optical lattice**
Severin Charpignon, University of Amsterdam

90. **Quantum Engineering of a Low-Entropy Gas of Heteronuclear Bosonic Molecules in an Optical Lattice**
Deborah Capecchi, University of Innsbruck

91. **Dipolar Quantum Mixtures of Erbium and Dysprosium**
Philipp Ilzhöfer, IQOQI Innsbruck

92. **Dephasing and Relaxation of Bosons in 1D to 3D cross over**
Chen Li, Chen Li

93. **Phonon excitations in a one dimensional Bose gas**
Federica Cataldini, TU Wien

Lunch options

Lunch options within walking distance (0–15 min) from the venue:

Mensen
https://www.uibk.ac.at/universitaet/mensa/

Mensa Atrium, Innrain 52
http://menu.mensen.at/index/index/locid/3

Uni Café 80-82, Innrain 80-82
http://menu.mensen.at/index/index/locid/62

Uni Café, Innrain 55
https://www.uni-cafe.at

Pizzeria Allora, Innrain 63
https://www.mjam.net/restaurant/innsbruck/allora/

KAI (Japanese), Blasius-Hueber-Straße 15, Universitätsbrücke
http://www.restaurant-kai.at

Leo's Ristorante, Anichstraße 36
http://www.leosristorante.at

Machete - Burrito Kartell, Anichstraße 29
http://www.machete-burritos.com

D-Werk, Innrain 30a
https://www.d-werk.at

Posidonas - Poseidon Der Grieche (Greek), Innrain 38
https://at.speisekarte.menu/restaurants/innsbruck-stadt/posidonas-poseidon-der-grieche

Pizzeria Salute, Innrain 35
https://www.pizzeria-salute.at

Teppan Wok, Bürgerstraße 2
https://www.teppanwok.at

Cammerlander Restaurants - Tapabar, Innrain 2
http://www.cammerlander.at

Events and Directions

Public evening lecture by Anton Zeilinger

Von Quantenrätseln zu Quantentechnologie (in German)
Wednesday 06.02., 19:00, in Saal Innsbruck on the 2nd floor at Congress, Rennweg 3, followed my a meet & greet. See map on page 35 for directions.

Conference dinner

Thursday 07.02., 19:00, Haus der Musik, 1st floor, Rennweg 2. See map on page 35 for directions.

City tours

The meeting point for the city tour on Wednesday afternoon is in front of the *Innsbruck Tourismus*, Burggraben 3. The duration is approximately one hour. See the tram/light-rail information below and the map on page 35 for directions.

Tour 1 for conference participants, who do not partake in the lab tours: Meet at 13:00.

Tour 2 for conference participants, who also take the lab tours: Meet at 17:00.

Lab tours

The lab tours start at 14:15 at the Viktor-Franz-Hess Haus at the Technik campus. See the tram/light-rail information below and the map on page 34 for directions. In addition, there will be a guide leaving at 14:00 in front of the Aula, who will direct you to the Technik campus.

Tram/light-rail

Tickets can be purchased with the driver (3.00EUR/direction, cash only), or at the ticket machines located at the stops (2.40EUR/direction, EC/Maestro card only). For more ticket options see https://www.ivb.at/en.html.

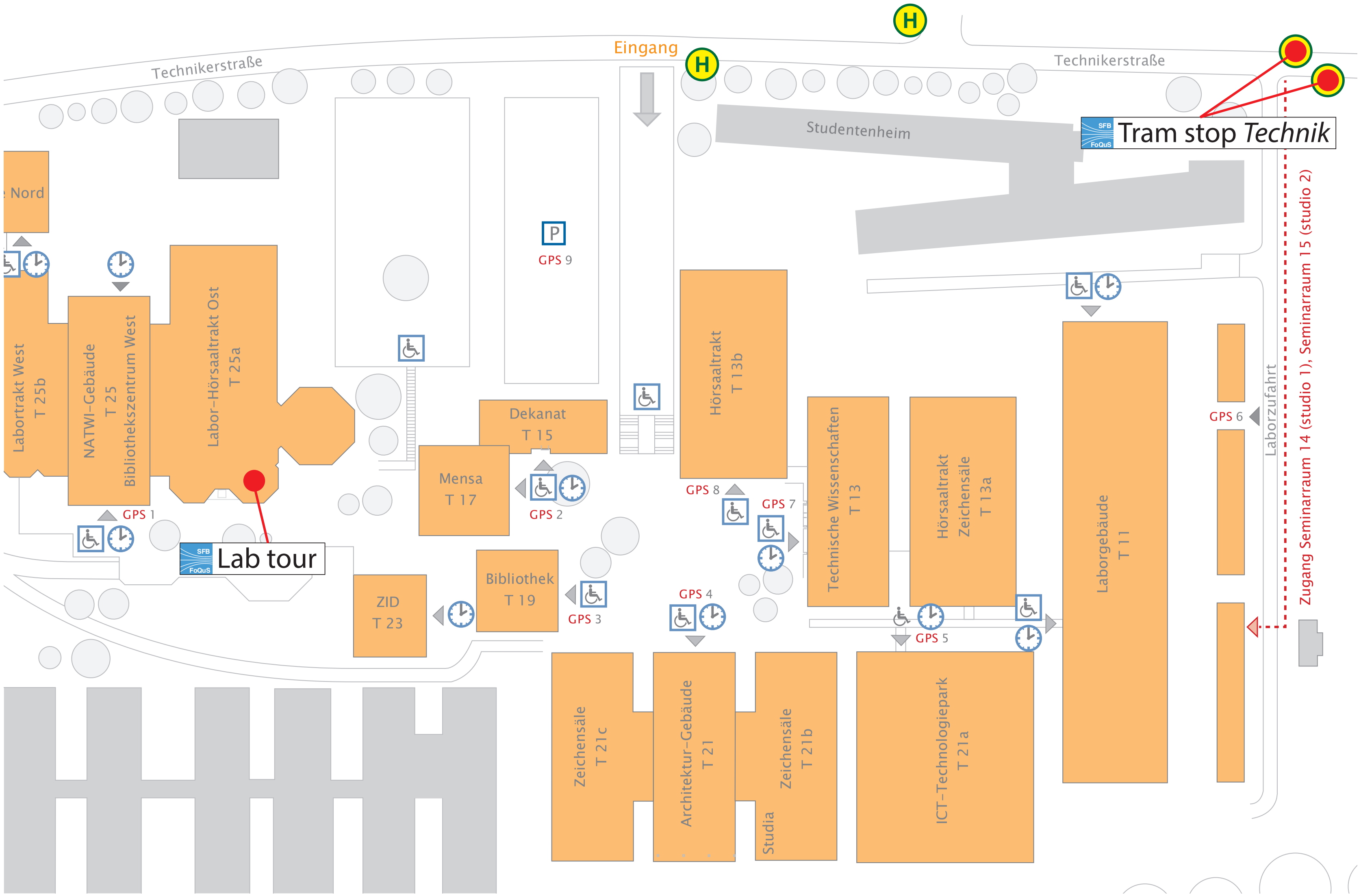
Hauptuni ↔ *Maria-Theresien-Straße*

Take tram #2 from *Klinik/Universität* in direction *Josef-Kerschbaumer-Straße*. Please alight at stop *Maria-Theresien-Straße* for the events downtown (c.f. map on page 35). The trip takes ~3 minutes. Use the same connection for your return trip in direction *Peerhofsiedlung/Technik West*.

Hauptuni ↔ Technik campus/IQOQI

Take tram #2 from *Klinik/Universität* in direction *Peerhofsiedlung/Technik West*. Please alight at stop *Innsbruck Technik* (c.f. map on page 34). The trip takes ∼11 minutes. Use the same connection for your return trip in direction *Josef-Kerschbaumer-Straße*.

Campus Technik



City map


1 Aula of the Univ. of Innsbruck, Innrain 52
2 Meeting point city tour, Burggraben 3
3 Public evening talk, Congress, Rennweg 3
4 Conference dinner, Haus der Musik, Rennweg 2
5 Hotel The Penz
6 Hotel Goldener Adler
7 Maria-Theresien-Straße
Inn
Innsbrucker Hofgarten
Congress Innsbruck - Dogana
Tiroler Landestheater Innsbruck
Dom zu St. Jakob
Museum Hofburg Innenhof
Stadtarchiv/Stadtmuseum
Best Western Plus Hotel Goldener Adler
Marktplatz
Markthalle Innsbruck
Town Square
The Penz Hotel
Post office
Tiroler Landesmuseum Ferdinandeum
Universität Innsbruck
Tirol Kliniken
University Hospital
Innrain
Anichstraße
Maria-Theresien-Straße
Mariahilfstraße
Höttinger Au

Time	Monday, 04.02	Tuesday, 05.02	Wednesday, 06.02	Thursday, 07.02	Friday, 08.02
08:00-08:45	Registration				
08:45-09:00	Welcome	Registration	Registration	Registration	Registration
09:00-09:45	Rainer Blatt	David Wineland	Michel Brune	Ana Maria Rey	Jun Ye
09:45-10:30	Peter Zoller	Jeff Kimble	Jean Dalibard	Ignacio Cirac	Immanuel Bloch
10:30-11:00	*Coffee break*	*Coffee break*	*Coffee break*	*Coffee break*	*Coffee break*
11:00-11:30	John L. Hall	Marko Cetina	Antoine Browaeys	Eugene Demler	11:00-11:20 Simon Gröblacher 11:20-11:40 Philipp Haslinger
11:30-12:00	Arno Rauschenbeutel	Helmut Ritsch	Markus Hennrich	Jörg Schmiedmayer	11:40-12:00 Francesca Ferlaino
12:00-12:30	Eugene Polzik	Tracy Northup	John Doyle	Misha Lukin	12:00-12:20 Barbara Kraus
12:30-14:00	*Lunch*	*Lunch*	*Conference photo* *Lunch*	*Lunch*	*Lunch*
14:00-14:30	Barbara Terhal	Poster session I	Lab tours, City tour, or free afternoon	Poster session II	
14:30-15:00	Frank Verstraete				
15:00-15:30	Hans Briegel				
15:30-16:00	***Break***				
16:00-16:30	Michelle Simmons	Hanns-Christoph Nägerl		Gemma de las Cuevas	
16:30-17:00	Matthias Troyer	Andreas Läuchli		Antonio Acin	
17:00-17:30	Birgitta Whaley	Rudolf Grimm		Renato Renner	
19:00-20:00			Public Evening Talk Anton Zeilinger	Conference Dinner	

Contact

Organization

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FWF

Der Wissenschaftsfonds.

universität innsbruck

universität wien

TU WIEN

IQI

ÖAW ÖSTERREICHISCHE AKADEMIE DER WISSENSCHAFTEN

Radiant Dyes Laser

TOPTICA PHOTONICS

M SQUARED

iv INDUSTRIELLEN VEREINIGUNG

INNS' BRUCK

Tirol