Be quantificated

save the date

Inauguration Ceremony of the Max Planck Harvard Research Center for Quantum Optics

Post-Doc Day MPHQ
11.01.2018, 14.00 o'clock
Institute for Advanced Study, Garching Campus

Inauguration Ceremony MPHQ
12.01.2018, 09.00 o'clock
Deutsches Museum, Ehrensaal

Students are welcome!

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Organizers

Gerhard Rempe & Frauke Logermann
Quantum Dynamics Division
Max Planck Institute of Quantum Optics
Hans- Kopfermann Str. 1
D-85748 Garching

General Information

11th of January
Venue: TUM Institute for Advanced Study (TUM IAS)

Program:
14 o'clock till 18.10 o'clock: Lecture hall
18.10 o'clock till 20.00 o'clock: Faculty club

12th of January
Venue: Deutsches Museum

Program:
09.30 o'clock till 18.00 o'clock: Ehrensaal

Conference Dinner, 19.00 o'clock:
Venue: Atelier Gourmet

13th of January
Venue: Max Planck Institute of Quantum Optics
Lab tours: starting at 11 o'clock
Each tour will take around 20 minutes

Closure Get –together:
Venue: Lovelace, 20.00h o'clock

Maps and Directions to all locations

The MVV journey planner (Munich public transportation) is a great way to plan your personal trip to Munich!

Thursday, 11th January

TUM Institute for Advanced Study (TUM IAS)
Lichtenbergstraße 2 a
85748 Garching
http://www.ias.tum.de/en/directions/

By Underground (U-Bahn)

From Munich Central Station (*Hauptbahnhof*) take the U4 or U5 (eastbound towards "Arabellapark" or "Neuperlach Süd") to *Odeonsplatz* Station. At *Odeonsplatz* change to the line U6 (northbound towards "*Garching Forschungszentrum*"). Exit at the final stop "Garching Forschungszentrum".

From the city center, take the U6 from *Marienplatz* (northbound towards "*Garching Forschungszentrum*"). Exit at the final stop "Garching Forschungszentrum".

Once at Garching Forschungszentrum, use the exit *"Lichtenbergstrasse".* You can see the IAS building right in front of you (Walking distance about 200 m / 3 minutes)

By Suburban Train (S-Bahn)

Coming from the North of Munich (e. g. Freising main station or Munich Airport) take the S1 (city bound towards „*Ostbahnhof*"). Exit in „*Neufahrn*" and change to Bus 690 towards „*Garching Forschungszentrum*".

Alternatively, you can take the S8 from Munich Airport. Exit in "*Ismaning*" and change to Bus 230 towards „*Garching Forschungszentrum*".

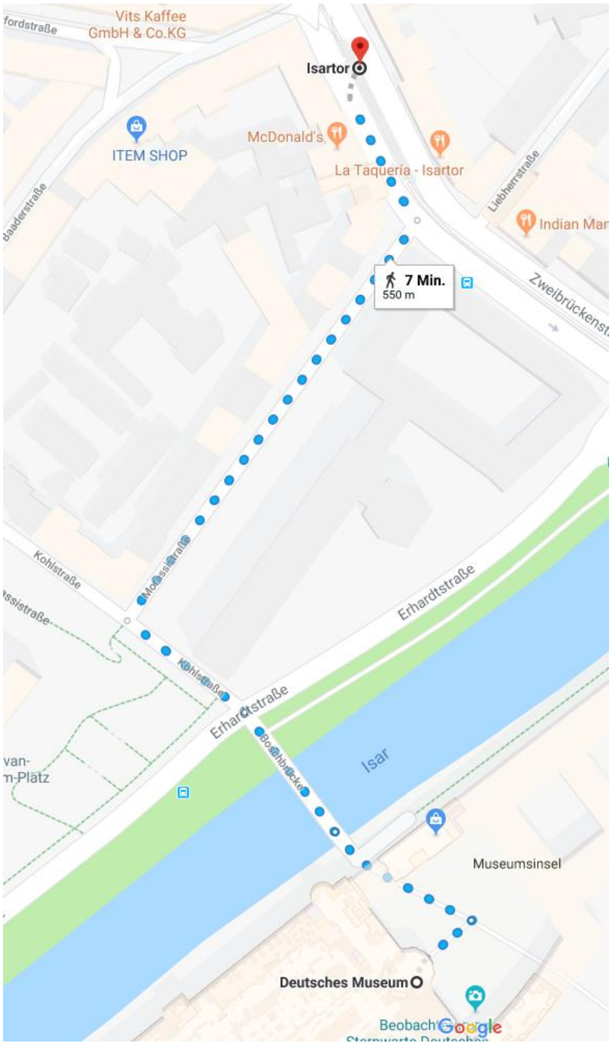
Friday, 12th January

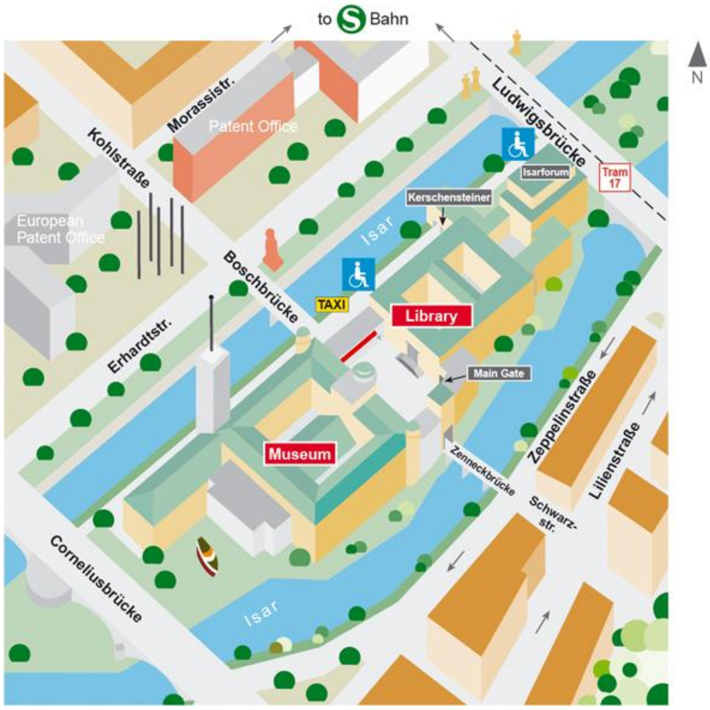
Deutsches Museum
Museumsinsel 1
80538 Munich
http://www.deutsches-museum.de/en/information/directions/

By Suburban Train (S-Bahn)

From Munich Central Station (*Hauptbahnhof*) or Munich city center (Marienplatz) take the Suburban Train S8 (eastbound towards Ostbahnhof) and exit at "*Isartor".* Once at Isartor, use the exit *"Deutsches Museum" (*walking distance 7 Minutes).

From the Isartor Trainstation you can also take Bus No. 132 (direction Forstenrieder Park, leaving at 8:14am or later). Exit at "*Boschbrücke"* and cross the bridge to the "*Deutsches Museum*".



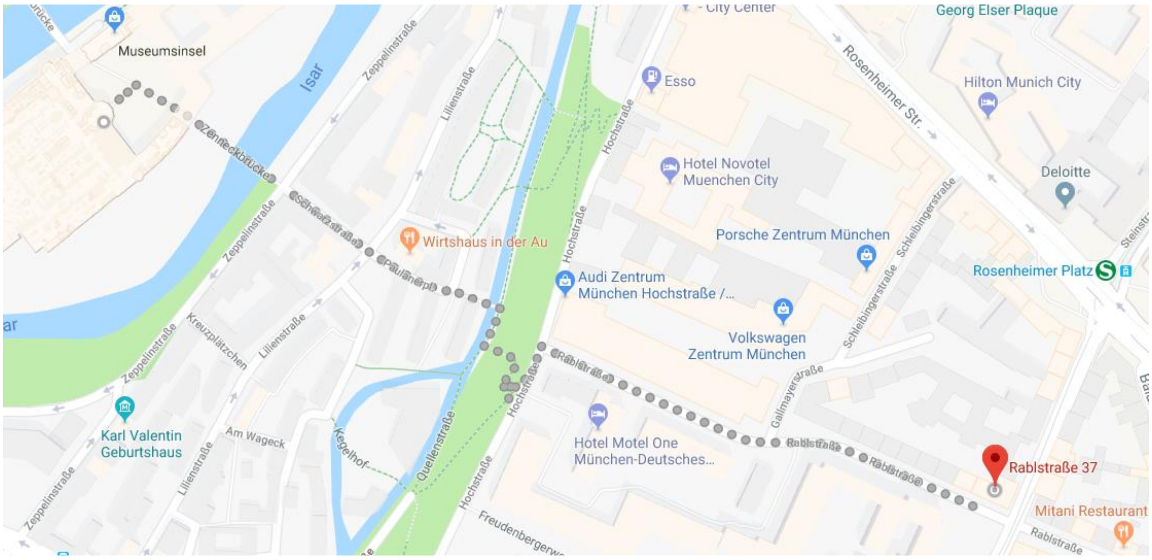


Conference Dinner on January 12th

Atelier Gourmet
Rablstraße 37
81669 München
http://ateliergourmet.de/

The restaurant is within walking distance (12 min) of the *"Deutsches Museum".*

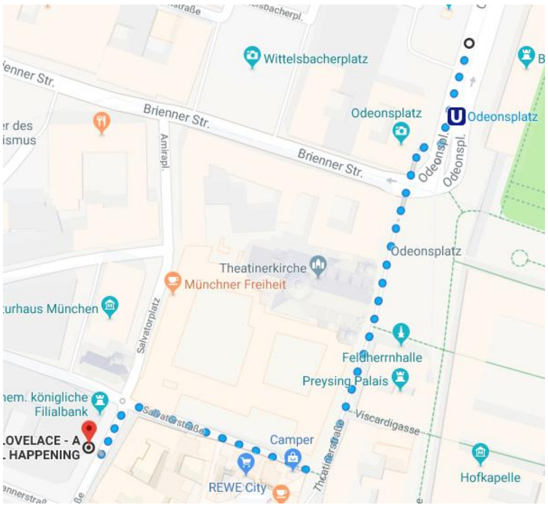
If you are arriving from the city center (*Marienplatz*) you can take the Suburban train (towards *Ostbahnhof*) and exit at "*Rosenheimer Platz".*



Get Together on January 13th, 20:00pm

Lovelace
Fever-Tree Lounge
Kardinal-Faulhaber-Straße 1
80333 München
http://thelovelace.com/

You can reach the "*Lovelace"* within a 6 Minute walking distance from the U-Bahnstations "Marienplatz" and "*Odeonsplatz"* which is the destination for the trains: U3, U4, U5 and U6, arriving from Munich city center and central station.



Program
Inauguration Ceremony Max Planck Harvard Research Center for Quantum Optics

11th till 12th of January 2018

11th of January (Location: Institute for Advanced Study)

Post-Doc Day

14.00h – 14.05h	Program Opening
14.05h – 14.30h	Dr. Fabian Grusdt (Harvard)
	Meson theory of magnetic polarons in hole-doped anti- ferromagnets
14.30h – 14.55h	Dr. Johannes Zeiher (MPQ)
	Coherent dynamics in Rydberg-dressed spin systems
14.55h – 15.20h	Dr. Daniel Greif (Harvard)
	New frontiers in fermionic quantum gas microscopy
15.20h – 15.55h	Dr. Erez Zohar (MPQ)
	Gauge Symmetries with Cold Atoms and PEPS: Quantum Simulation and Tensor Network Studies of Lattice Gauge Theories".
15.55h – 16.30h	Coffee Break
16.30h – 16.55h	Dr. Ephraim Shahmoon (Harvard)
´	*Optomechanical repsonse of a two-dimensional atomic array*
16.55h – 17.20h	Dr. Olivier Morin (MPQ)
	Coherence protection of a photonic-qubit memory
17.20h – 17.45h	Dr. Lawrence Cheuk (Harvard)
	Laser Cooling and Optical Trapping of CaF Molecules
17.45h – 18.10h	Dr. Renate Landig (Harvard)
	Time crystals in strongly interacting dipolar spin systems
18.10h – 20.00h	Poster session

12th of January (Location: Deutsches Museum)

MPHQ Inauguration Day

09.00h - 09.30h	Registration
09.30h – 09.40h	Opening MPHQ Inauguration Day Prof. Gerhard Rempe + Prof. Wolfgang Heckl
09.40h – 10.20h	Prof. Mikhail Lukin (Harvard)
	Exploring new frontiers of quantum science with past, present and future Harvard-MPQ collaboration
10.20h – 11.00h	Prof. Immanuel Bloch (MPQ)
	Large Scale Quantum Simulations Using Ultracold Atoms in Optical Lattices
11.00h – 11.20h	Coffee break
11.20h – 12.00h	Prof. Kang-Kuen Ni (Harvard)
	Fun with two atoms – a tale of collisions and reactions
12.00h – 12.40h	Prof. Ignacio Cirac (MPQ)
	Theoretical frontiers in quantum optics and quantum information
12.40h – 13.20h	Prof. Rainer Blatt (Scientific Advisory Board)
	Quantum Computations and Quantum Simulations with trapped ions
13.20h – 14.00h	Lunch
14.00h – 14.45h	Prof. Wolfgang Ketterle (Nobel laureate)
	New forms of matter with ultracold atoms: superfluids and supersolids
14.45h – 15.15h	Official MPHQ Opening Ceremony
	Prof. Gerhard Rempe (Director MPHQ)
	Prof. Martin Stratmann (President of the MPG)
	Prof. Jeremy Bloxham (Dean of Science Harvard)
15.15h – 16.00h	Prof. John Doyle (Harvard)
	Probing the frontiers of particle physics using quantum sensors
16.00h – 16.30h	Coffee break
16.30h – 16.45h	Dr. Johannes-Geert Hagmann (Deutsches Museum)
	Optics and Quantum Optics at the Deutsche Museum
16.45h – 17.45h	Experimental talk by Prof. Markus Greiner (Harvard)

Quantum Lego: from single atoms to quantum computing"

17.45h – 18.00h Closing remarks & Scientific wrap-up Prof. Gerhard Rempe

Abstracts

11th of January

Dr. Fabian Grusdt
Title: Meson theory of magnetic polarons in hole-doped anti-ferromagnets

Abstract:

By doping a fermionic Mott insulator at half filling, the anti-ferromagnetic (AFM) ground state is destroyed and a high temperature superconductor is obtained. To unravel the physics of the hole-doped regime of the Fermi Hubbard model, an important first step is to understand the behavior of a single hole inside an AFM. Here we describe this system by the formation of a meson: a confined pair of a spinon and a holon, connected by a geometric string of displaced spins. This is similar to mesons in high-energy physics which are understood quark antiquark pairs. We discuss direct signatures of meson formation in the Fermi Hubbard model, including the existence of rotationally excited states of mesons. It will be shown how recent breakthroughs in the study of the Fermi Hubbard model using ultracold atoms in a quantum gas microscope enable direct observations of mesons. Possible implications for the phase diagram of high-Tc cuprates are also discussed.

Dr. Johanne Zeiher
Title: Coherent dynamics in Rydberg-dressed spin systems“

Abstract:

Off-resonant optical coupling of an atomic ground state to a Rydberg state, so-called "Rydberg dressing", has been proposed as a versatile method to implement various long-range interacting spin models with ultracold atoms. In our experiment, we realize Rydberg-dressed Ising spin interactions in an atomic Mott insulator of Rubidium-87 by off-resonant optical coupling to a Rydberg p-state. First interferometric experiments in a two-dimensional sample demonstrated versatile control of the induced interactions, however collective loss processes reduced the lifetime of the system. Here, we present recent experimental results for a Rydberg-dressed 1d spin chain with long-range Ising interactions. Contrary to the 2d case, the collective loss can be avoided and lifetimes increase significantly. We substantiate the improved lifetimes by showing purely interaction driven coherent collapse and revival dynamics of the magnetization in a 1d spin chain.

Dr. Daniel Greif
Title: New frontiers in fermionic quantum gas microscopy

Abstract

Ultracold fermions in optical lattices are a powerful platform for addressing open questions on strongly correlated quantum phases. The approach of quantum simulation of the Hubbard model is hoped to give new insight into poorly understood phases, including pseudo-gap states and d-wave superfluids, as well as unusual dynamical phenomena, such as correlated hole dynamics in antiferromagnets or linear-T resistivity in strange metals. The site-resolved readout and control afforded by quantum gas microscopy offers a unique insight into such systems and a deep understanding of the microscopic mechanisms at play. An outstanding challenge is to reach the required low temperatures, where quantum effects become most relevant. Using conventional evaporative cooling combined with entropy redistribution in the lattice, we have recently been able to observe long-range antiferromagnetic order in our experiment with ultracold Li-6 atoms in a square lattice. In my talk, I will report on new frontiers we are currently exploring in experiments with fermionic quantum gas microscopy. I will demonstrate a new method for preparing quantum states close to the ground state, which we have recently developed and implemented. This approach is based on quantum state engineering and makes use of an ultra-low entropy band insulator of doublons as initial state. I will also discuss experimental possibilities on detecting correlated hole-dynamics in antiferromagnetically ordered states.

Dr. Erez Zohar
Title: Quantum Methods for Lattice Gauge Theories - Quantum Simulation and Gauge Invariant PEPS"

Abstract
Gauge symmetries are very central in physics: in high energy physics, gauge fields mediate the interactions among matter particles, and they also appear in various condensed matter physics contexts. As important as gauge theories are, they still involve non-perturbative puzzles which are not yet solved.

Quantum simulation and tensor networks are two many-body physics approaches which have been widely used recently, especially in condensed matter contexts, proving to be very useful. The first suggests to use controllable quantum systems as simulators of others, which might be otherwise inaccesible or hard to solve, while the latter allows one to efficiently construct and study physically relevant many body states with artbitrary symmetries. More recently, these methods have been generalized and applied also to high energy physics problems as well, and in particular to gauge theories.

In my talk I will discuss the application of those methods for the study of lattice gauge theories, focusing on the work carried out at the theory group at MPQ: first, quantum simulation of lattice gauge theories with ultracold atoms in optical lattices - suggesting to observe non-pertubative elementary particle physics in atomic simulators; and finally, gauged fermionic PEPS - a particular tensor network construction of gauge invariant states, involving dynamical gauge fields and fermionic matter, allowing one to use the efficient tensor network toolbox for the study of gauge theories.

Dr. Ephraim Shahmoon
Title: Optomechanical response of a two-dimensional atomic array

Abstract
We consider a two-dimensional (2D) atomic array as a novel platform for the study of quantum optomechanics. Such arrays can become both nearly perfectly-reflecting, and at the same time, very light, potentially leading to largely enhanced optomechanics. Considering the atomic motion under continuous laser illumination in free space, we find the formation of collective mechanical modes due to laser-induced dipole-dipole forces. In turn, this collective motion results in a multimode nonlinear optical response. Specifically, we find that the spectrum of the reflected light develops multiple sidebands, corresponding to the collective mechanical resonances, and exhibiting spatio-temporal quantum squeezing. These results demonstrate that a 2D array composed of dozens of atoms trapped in free space, may exhibit novel optomechanical responses comparable to those of macroscopic systems inside cavities. Implications on quantum nonlinear optomechanics and photonics are discussed.

Dr. Olivier Morin
Title: Coherence protection of a photonic-qubit memory

Abstract

The single photon is one of the most convenient qubit carriers. However, storing such a photonic qubit is a challenging task: not only the photon has to be stored but its quantum properties as well. After storage, any uncontrolled interaction with the outside world leads to the so-called “decoherence” effect and the loss of the qubit. Here, I will present our recent progress to counter act on the main sources of decoherences. By demonstrating an efficient storage and retrieval with a coherence time of more than 100ms, we have reached a time scale compatible with quantum communications at the global scale.

Dr. Lawrence Cheuk

Title: Laser Cooling and Optical Trapping of CaF Molecules

Abstract

In the past decades, advances in control of atoms have led to their use in many diverse areas, ranging from precision measurement and optical clocks to quantum information and simulation of strongly correlated systems. With their rich internal structure, molecules promise to offer much more. Nevertheless, control of molecules has proven to be much more challenging, precisely because of the many internal degrees of freedom. In this talk, I will report on recent progress in direct cooling and trapping CaF molecules. Starting from a buffer gas source, we have created cold, dense samples of CaF in a 3D magneto-optical trap. Further cooling using a gray molasses scheme brings these molecules well below the Doppler limit. This has allowed us to directly load molecules into an optical dipole trap, an ideal starting point for future experiments.

Dr. Renate Landig

Title: Time crystals in strongly interacting dipolar spin systems

Abstract

The interplay between periodic driving, disorder, and strong interactions has been predicted to result in exotic time- crystalline phases, which spontaneously break the discrete time--translation symmetry of the underlying drive. In this talk, I will present the experimental observation of such discrete time- crystalline order in a driven, disordered ensemble of about one million dipolar spin impurities in diamond at room temperature. We observe long-lived temporal correlations, experimentally identify the phase boundary and find that the temporal order is protected by strong interactions. We quantitatively explain these observations using resonance counting, which reveals critically slow thermalization dynamics as the origin of the observed long lived order.

12th of January

Prof. Mikhail Lukin
Title: Exploring new frontiers of quantum science with past, present and future Harvard-MPQ collaborations

Abstract

We will discuss recent developments at a new scientific interface between quantum optics, many-body physics and quantum information science. We focus on a specific example involving the use of quantum optical techniques for manipulating 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 phase transition in large arrays of atoms. We will discuss how these systems and techniques can be used for probing non-equilibrium quantum dynamics in complex systems, as well as for implementing and testing quantum algorithms.

Prof. Immanuel Bloch
Large Scale Quantum Simulations Using Ultracold Atomic Gases in Optical Lattices

Abstract

More than 30 years ago, Richard Feynman outlined the visionary concept of a quantum simulator for carrying out complex physics calculations. Today, his dream has become a reality in laboratories around the world. In my talk I will focus on the remarkable opportunities offered by ultracold quantum gases trapped in optical lattices to address fundamental physics questions ranging from condensed matter physics over statistical physics to high energy physics with table-top experiments. To date, ultracold atoms provide the only setting for quantum simulations in which `quantum supremacy', i.e. the ability to simulate settings beyond the ability of classic supercomputers, has been achieved. I will show how it has now become possible to image and control quantum matter with single atom sensitivity and single site resolution, thereby allowing one to directly image individual quantum fluctuations of a many-body system, to directly reveal antiferromagnetic order in the fermionic Hubbard model or hidden 'topological order' and exotic forms of incommensurate magnetic ordering that can now, for the first time, be directly detected in experiments. In addition, I will discuss our recent experiments on novel many-body localised states of matter that challenge our understanding of the connection between statistical physics and quantum mechanics at a fundamental level.

Prof. Kang-Kuen Ni
Title: Fun with two atoms – a tale of collisions and reactions

Abstract
What can we do with exactly two atoms? We tweezed and merged single cesium and sodium atoms into a single dipole trap. We study their collisions and reactions at the ultracold regime. We built a molecule out of two atoms by photoassociation. And currently, we are learning to create many single molecules coherently for quantum simulation and quantum information processing.

Prof. Ignacio Cirac
Title: Theoretical frontiers in quantum optics and quantum information

Abstract

In the last years, quantum optics and quantum information have merged with other areas of science, like condensed matter or high-energy physics. This opens various scientific questions and poses new theoretical challenges. In this talk I will give a brief overview of some of the areas of resarch that have emerged in that context, like the study and applications of emitters close to structured baths, and the development of theoretical tools to address many-body quantum problems.

Prof. Rainer Blatt
Quantum Computations and Quantum Simulations with Trapped Ions

Abstract

Rainer Blatt Institute for Experimental Physics, University of Innsbruck, Technikerstrasse 25, A-6020 Innsbruck, Austria Rainer.Blatt@uibk.ac.at, www.quantumoptics.at and Institute for Quantum Optics and Quantum Information, Austrian Academy of Sciences, Otto-Hittmair-Platz 1, A-6020 Innsbruck, Austria Rainer.Blatt@oeaw.ac.at, www.iqoqi.at

The quantum toolbox of the Innsbruck ion-trap quantum computer is applied to simulate the dynamics and to investigate the propagation of entanglement in a quantum many-body system represented by long chains of trapped-ion qubits [1]. With strings of up to 10 ions, a dynamical phase transition was recently observed [2] and an efficient procedure for the characterization of a quantum many-body system of up to 14 entangled ions has been implemented [3]. Moreover, using the quantum toolbox operations, universal (digital) quantum simulation was realized with a string of trapped ions [4]. Here we report the experimental demonstration of a digital quantum simulation of a lattice gauge theory, by realizing (1 + 1)-dimensional quantum electrodynamics (the Schwinger model) on a few-qubit trapped-ion quantum computer [3]. 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. To make efficient use of our quantum resources, we map the original problem to a spin model by eliminating the gauge fields in favor of exotic long-range interactions, which can be directly and efficiently implemented on an ion trap architecture.

[1] P. Jurcevic et al., Nature 511, 202 (2014) [2] P. Jurcevic et al., Phys. Rev. Lett. 111, 080501 (2017) [3] B. P. Lanyon et al., Nat. Phys. 13, 1158 (2017) [4] E. A. Martinez et al., Nature 534, 516 (2016)

Prof. Wolfgang Ketterle
New forms of matter with ultracold atoms: superfluids and supersolids

Abstract

Why do physicists freeze matter to extremely low temperatures? Why is it worthwhile to cool to temperatures which are a billion times lower than that of interstellar space? In this talk, I will discuss new forms of matter, which only exist at extremely low temperatures. Of special interest are superfluids which can flow without dissipation. Recently, we have observed a supersolid which is gaseous, liquid and solid at the same time.

Prof. John Doyle

Probing the frontiers of particle physics using quantum sensors

Abstract

The field of particle physics is in a peculiar state. The Standard Model (SM) of particle theory successfully describes every fundamental particle and force observed in laboratories, yet fails to explain basic properties of the universe such as the existence of dark matter, the amount of dark energy, and the preponderance of matter over antimatter. Huge experiments, of increasing scale (30-300,000 meters) and cost (0.1-10 billion USD), continue to search for new particles and forces that might explain these phenomena. To date, despite heroic efforts, no new particles beyond those in the SM have been detected. Given the cost and complexity of large-scale experiments, there is growing interest in different approaches to address these fundamental questions, which lie at the heart of modern particle physics and cosmology. Remarkably, it has become possible to meaningfully explore these questions with experiments small enough to fit in a single university laboratory room. These small-scale experiments rely on fundamentally different approaches compared to the more traditional large experiments. At their heart is the use of quantum-mechanical resonance behaviour, which enables exquisitely sensitive measurement of tiny energy shifts—shifts that can be caused by the existence of new quantum fields with exactly the properties needed to solve these known shortcomings of the SM. Breakthrough ideas, coupled with rapid advances in atomic/molecular/optical physics techniques and quantum-limited measurement devices, are leading to a surge in progress. Several new approaches are pushing the frontier of fundamental physics to a level that complements—and sometimes exceeds—the discovery potential of the traditional large-scale methods. As one example of the power of such “quantum sensing” experiments, is the EDM experiment called ACME, which is a collaboration between Yale and Harvard universities. Here the quantum sensor is given to us by Nature, a simple diatomic molecule. This cold molecule experiment takes place in a lab the size of a large living room. ACME made the most precise measurement of an electric dipole moment (EDM) ever [1], constraining the electron's EDM to be $d_e \leq 9.3 \times 10^{-29}$ e cm. At the same time, the Large Hadron Collider was setting records for ever-higher collision energies and luminosities. These two experiments have probed for new physics at similar, unprecedented levels of sensitivity – however ACME does so in a university laboratory environment and, in addition, is projected to greatly improve in sensitivity on the time scale of years, not decades. The Standard Model of physics is accepted to be incomplete, with no framework to explain fundamental observations such as dark matter and the matter-antimatter asymmetry. Many new theories aim to solve these problems, and the hierarchy problem, by introducing new particles and new sources of time-reversal (T) violation. The same theories often predict values for the electron EDM (an intrinsically T-violating observable) significantly higher than expected within the Standard Model. Our measurement of the electron EDM, together with results from the LHC and elsewhere, has severely constrained the viable parameter space for theories of new physics, such as supersymmetry. Under the typical assumption of order unity phases, EDM experiments are already able to place constraints on the mass of the stop (supersymmetric top) particle in the ~TeV range, similar to the results from the LHC. We also strongly constrain viable parameter space in the chargino sector at the TeV level – here in particular, the electron EDM presents a `uniquely powerful window' onto supersymmetry [2], probing regions of parameter space that are difficult for the LHC to access. New EDM experiments being planned can access physics in the 1000 TeV range, higher than any planned accelerator can reach [3].

[1] ACME Collaboration, Science 343, 269-272 (2014) [2] Nakai and Reece, arXiv 1612.08090 (2016)

[3] Hutzler and Hutzler, Phys. Rev. Lett. 119, 133002 (2018)

Posters (incomplete list)

Florentin Reiter

Hannes Pichler

Martin Schuetz

David Grimes

Andre Heinz: Towards Quantum Many-Body Physics with Strontium in Optical Lattices“

Thomas Kohlert: Exploring the Single-Particle Mobility Edge in a 1D Quasiperiodic Optical Lattice

Karen Wintersperger: Observation of parametric instabilities in 1D interacting shaken optical lattice systems

Christian Schweizer / Michael Lohse: Exploring 4D quantum Hall physics with a 2D topological charge pump"

Lab tours

Starting at 11am on Saturday

Tours:

Strontiumlab : Andre Heinz, Annie Park and Sebastian Blatt