

Humboldt Kolleg on Quantum Technologies

Jagiellonian University
in Kraków

6-8 July 2026



UNIwersYTET
JAGIELLOŃSKI
W KRAKOWIE

UNTERSTÜTZT VON / SUPPORTED BY



Alexander von
HUMBOLDT
STIFTUNG

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Local Organizing Committee

Chair: Krzysztof Sacha

Karthik Eswaran

Tanausú Hernández Yanes

Damian Włodzyński

Useful Information

Map and Locations

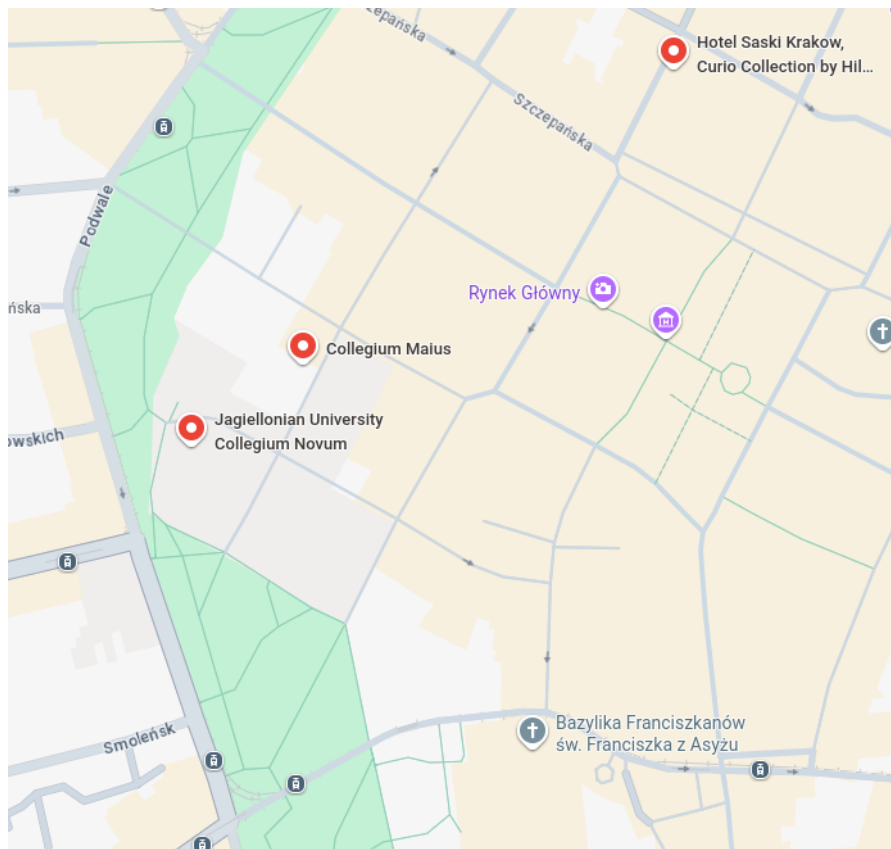


Figure 1: Map with the key locations for the conference. You may use the old town main square (*Rynek Główny*) as reference.

All sessions of the Kolleg will be held at *Collegium Novum* (Gołębia Street 24, 31-007 Kraków). The guided tour of Kraków will also start at this location. The welcome reception will also take place at Collegium Novum.

The conference dinner will take place at *Hotel Saski*, Sławkowska Street 3, 31-014



Figure 2: Photo of the Collegium Novum building.

Kraków.

The Jagiellonian University Museum is located in *Collegium Maius*, Jagiellońska Street 15, 31-010 Kraków

Wi-Fi

SSID: UJ_WiFi

- Login: wifiuj71@uj.edu.pl
- Password: #Kolleg#2026#

The eduroam network is also available.



Figure 3: Photo of the Hotel Saski entrance.



Figure 4: Photo of the Collegium Maius building.

Timetable

Sunday, July 5th

15:00–18:00	Guided Tour of Kraków
18:00–20:00	Welcome Reception and Registration

Monday, July 6th

08:00–09:00	Registration	
08:45–09:00	Opening of the Kolleg	
09:00–09:30	Henryk Figiel and Marian Jaskuła	Introduction to the Alexander von Humboldt Foundation
Chair: Krzysztof Sacha		
09:30–10:00	Marek Rams	Quantum and classical simulations of Ising model dynamics
10:00–10:30	Gediminas Juzeliūnas	Topological Sub-Wavelength Optical Lattices for Dark State Ultracold Atoms
10:30–11:00	Coffee break	
Chair: Frank Großmann		
11:00–11:30	Paweł Horodecki	Charging of quantum batteries via reservoir engineering
11:30–12:00	Iacopo Carusotto	How to prepare many-particle fractional quantum Hall fluids of synthetic quantum matter
12:00–12:30	Piotr Cyganik	SAMs for Organic Electronics -Stable Aromatic Monolayers on Metals with High or Low Conductivity
12:30–14:00	Lunch	
Chair: Szymon Pustelny		
14:00–14:30	Christof Weitenberg	Phase microscopes for quantum gases: from weakly to strongly correlated regimes

14:30–15:00	Krzysztof Jachymski	Dynamics of Bose polarons
15:00–15:30	André Eckardt	Open systems of neutral atoms: Floquet reservoir engineering integer and fractional Chern insulators
15:30–16:00	Coffee break	
Chair: Stefan Scheel		
16:00–16:30	Michael Fleis- chhauer	Many-body dynamics of interacting spin systems and the Truncated Wigner Approximation for Spins
16:30–17:00	Florian Mintert	Fast thermal state preparation beyond native interactions
17:00–17:30	Karol Życzkowski	Exploring Basic Quantum Structures: Contrasting the Typical and Atypical

Tuesday, July 7th

Chair: Marek Kuś		
09:00–09:30	Tilman Pfau	Novel qubits for the neutral atom platform
09:30–10:00	Natalia Korolkova	From Continuous Variable Quantum Secret Sharing to Quantum Microwave Networks
10:00–10:30	Luis Santos	Interplay between frustration and long-range interactions in dipolar triangular ladders
10:30–11:00	Coffee break	
Chair: Michael Fleischhauer		
11:00–11:30	Nigel Cooper	Phase-space microscopes for quantum gases
11:30–12:00	Szymon Pustelny	Quantum technologies to search for physics beyond the Standard Model
12:00–12:20	Mateusz Kędziora	Room-Temperature Exciton-Polariton Condensation and Guided Transport in Perovskite Monocrystals
12:20–12:40	Karthik Eswaran	Time quasicrystalline order from periodic driving
12:40–12:45	Conference Photo	
12:45–14:00	Lunch	
14:00–15:30	Poster Session	
15:30–16:00	Coffee break	
Chair: Christof Weitenberg		

16:00–16:30	Nikolay Vitanov	Quantum-enhanced localisation and imaging
16:30–17:00	Frank Großmann	Multi-configuration approaches to interacting many-body quantum dynamics: beyond mean field
17:00–17:30	Jens Biegert	Attosecond exploration of energy pathways in matter
18:30–21:30	Conference Dinner	

Wednesday, July 8th

Chair: Marek Rams		
09:00–09:30	Susanne Yelin	Unleashing Analog Quantum Computing
09:30–10:00	Stefan Scheel	Rydberg physics with excitons in cuprous oxide quantum wells
10:00–10:30	Jakub Zakrzewski	Dynamics in disordered Rydberg arrays
10:30–11:00	Coffee break	
Chair: Gediminas Juzeliūnas		
11:00–11:30	Kazimierz Rzążewski	Multicomponent quantum gases and spontaneous symmetry breaking
11:30–12:00	Radim Filip	Quantum Non-Gaussian Light and Matter
12:00–12:30	Peter Schlagheck	Creating highly entangled NOON states with ultracold bosonic atoms
12:30–14:00	Lunch	
Chair: Jens Biegert		
14:00–14:30	Robert Spreeuw	Optical tweezers for atom arrays and in ion traps
14:30–15:00	Martin Robert de Saint Vincent	Coherent control of large nuclear spins in a Fermi gas of strontium
15:00–15:30	Mariusz Gajda	Bose-Fermi mixtures of ultracold atoms
15:30–16:00	Coffee break	
Chair: Jakub Mielczarek		
16:00–16:30	Florian Schreck	Realization of continuous superradiant lasing on a narrow optical transition
16:30–17:00	Bogdan Damski	Expanding quantum magnetic field
17:00–17:30	Closing remarks	

Thursday, July 9th

09:00–10:30	Jagiellonian University Museum Tour
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Talks

Monday, July 6th

Marek Rams

Jagiellonian University in Kraków, Poland

Monday
09:30–10:00

Quantum and classical simulations of Ising model dynamics

Simulating dynamical processes in quantum many-body systems poses significant challenges. Much hope for advancing our understanding of such phenomena lies in the development of dedicated quantum simulators and quantum computers. In this context, we are currently witnessing a race for supremacy between advanced numerical algorithms and the current generation of quantum computers. In this presentation, I will explore aspects of this race through the lens of one of the simplest many-body models: the quantum Ising model on a square lattice, driven out of equilibrium by a time-dependent transverse field.

Gediminas Juzeliūnas*Vilnius University, Lithuania*Monday
10:00–10:30**Topological Sub-Wavelength Optical Lattices for Dark State Ultracold Atoms**

Ultracold atoms provide a versatile platform for simulating topological and many-body phenomena in condensed matter and high-energy systems [1-4]. The use of atomic dark states (long-lived superpositions of atomic internal ground states immune to atom-light coupling) offers new possibilities for such simulations. Making the dark states position-dependent allows for the generation of a synthetic magnetic field for ultracold atoms, as they adiabatically follow the dark states [4-9]. Here, we present a general description of two-dimensional (2D) topological dark-state lattices, elucidating their interplay with sub-wavelength lattices [7,9]. In particular, we demonstrate that one can create a periodic 2D array of narrow (subwavelength) peaks of a very strong effective magnetic field. Away from the narrow regions of strong magnetic field, there is a smooth background magnetic flux of the opposite sign, compensating for the magnetic flux from the former peaks. For sufficiently narrow peaks of the strong magnetic field, the smooth background magnetic field dominates, leading to the formation of narrow topological bands. This paves the way for experimental exploration of topological phases in dark-state optical lattices, offering new possibilities for simulating quantum Hall systems, fractional Chern insulators and related strongly correlated phases.

- [1] M. Lewenstein et al, Adv. Phys. 56, 243 (2007).
- [2] I. Bloch, J. Dalibard, and W. Zwerger, Rev. Mod. Phys. 80, 885 (2008).
- [3] C. Gross and I. Bloch, Science 357, 995 (2017).
- [4] N. Goldman, G. Juzeliūnas, P. Öhberg, and I. B. Spielman, Rep. Prog. Phys., 77, 126401 (2014).
- [5] E. Gvozdiavas, I. B. Spielman, and G. Juzeliūnas, Phys. Rev. A, 107, 033328 (2023).
- [6] S. Nascimbene and J. Dalibard, Phys. Rev. Lett. 135, 153402 (2025).
- [7] D. Burba and G. Juzeliūnas, Phys. Rev. Research 7, 043090 (2025).

- [8] O. E. Sommer and N. R. Cooper, arXiv:2509.01481.
- [9] D. Burba, D. Borodinas and G. Juzeliūnas arXiv:2606.00207.

Paweł Horodecki*University of Gdańsk , Poland*Monday
11:00–11:30**Charging of quantum batteries via reservoir engineering**

We shall present some results on charging quantum batteries the systems where the energy in the form of ergotropy is stored [1]. Typically the charger-battery system is coupled by a Hamiltonian term. It turns out that if, however, two oscillatory batteries have a qubit in between, than there is a catalysis effect – qubit does not store the energy, but helps in charging [2]. Using different technique, recently it has been shown that when interaction involves also the environment that acts collectively the charging can be improved [3,4]. We shall present those findings and also discuss preliminary results on some modification of the above paradigm.

[1] F. Campaioli, S. Gherardini, J. Q. Quach, M. Polini, G. M. Andolina, Colloquium: Quantum Batteries, Rev. Mod. Phys. 96, 031001 (2024).

[2] R. R. Rodríguez, B. Ahmadi, P. Mazurek, S. Barzanjeh, R. Alicki, and P. Horodecki, Catalysis in charging quantum batteries, Phys. Rev. A 107, 042419 (2023).

[3] B. Ahmadi, P. Mazurek, P. Horodecki, S. Barzanjeh, Nonreciprocal Quantum Batteries, Phys. Rev. Lett. 132, 210402 (2024).

[4] B. Ahmadi, P. Mazurek, S. Barzanjeh, and P. Horodecki, Superoptimal charging of quantum batteries via reservoir engineering: Arbitrary energy transfer unlocked, Phys. Rev. Applied 23, 024010 (2025).

Iacopo Carusotto

Pitaevskii BEC Center, INO-CNR, Italy

Monday
11:30–12:00

How to prepare many-particle fractional quantum Hall fluids of synthetic quantum matter

In this talk I will review and critically compare different strategies to generate FQH fluids of strongly interacting atoms or photons. After a summary of the experimental state-of-the-art and of the current challenges, I will present various schemes to scale up in particle number and realize macroscopic fluids. I will put a special focus on a recently proposed protocol based on the coherent Raman transfer of atoms from a large dilute BEC via an adiabatic path in the Fock space which avoids crossing topological phase transitions and thus maintains a sizable adiabatic gap open at all times. I will quantitatively assess the potential of this protocol and I will discuss its extension to photonic systems. I will conclude with a brief discussion on observable signatures of fractional statistics of quasi-holes in the bulk and on the nonlinear dynamics of the edge modes.

Piotr Cyganik*Jagiellonian University in Kraków, Poland*Monday
12:00–12:30**SAMs for Organic Electronics -Stable Aromatic Monolayers on Metals with High or Low Conductivity**

Self-assembled monolayers (SAMs) on metal substrates are a key component of modern interfacial physical chemistry and advanced nanotechnology. The robustness of SAMs strongly depends on their thermal stability, which, together with electrical conductivity, constitutes a critical parameter for applications in molecular and organic electronics as well as photovoltaics. In this work, we employ a multidisciplinary approach to investigate the structure, thermal stability, and conductivity of SAMs formed on metal substrates (Au or Ag) using various anchoring groups, including thiols, selenols, carboxylic acids, and carbenes. Our recent results [1–5] demonstrate the formation of thin, well-defined monolayers exhibiting exceptionally high thermal stability. Depending on the molecular system, these SAMs can be either highly insulating or highly conductive, making them promising nanomaterials for the modification of gate or drain/source electrodes in organic field-effect transistors (OFETs).

[1] Krzykawska, A.; Wróbel, M.; Kozieł, K.; and Cyganik, P. ACS Nano, 2020, 14, 6043.

[2] Wróbel, M.; Żaba T.; Sauter E.; Krawiec, M.; Sobczuk, J.; Terfort, A.; Zharnikov M.; and Cyganik, P. Adv. Electron. Mater., 2021, 7, 2000947.

[3] Wróbel, M.; Cegiełka, D.; Asyuda, A.; Kozieł, K.; Zharnikov, M.; and Cyganik, P. Nano Today, 2023, 53, 102024.

[4] Rojek, A.; Cegiełka, D.; Wróbel, M.; Stępień, M.; Shoji, Y.; Fukushima, T.; Zharnikov, M.; and Cyganik, P. ACS Appl. Mater. Interfaces, 2026, 18, 15665.

[5] Wróbel, M.; Ahmed, R.; Bro-Jørgensen, W.; Kozieł, K.; Nijhuis, C.A.; Solomon, G.C.; and Cyganik, P. Angew. Chem. Int. Ed. 2026 accepted

Christof Weitenberg

TU Dortmund University, Germany

Monday
14:00–14:30

Phase microscopes for quantum gases: from weakly to strongly correlated regimes

Quantum gas microscopes probe quantum many-body lattice states via projective measurements in the occupation basis, enabling access to various density and spin correlations. Phase information, however, cannot be directly obtained in these setups. Here I will describe our phase microscope for quantum gases, which measures the local phase profiles with single lattice-site resolution [1], based on Fourier-space manipulation in a matter-wave microscope [2]. We use the phase microscope to study the coherence properties of an ultracold Bose gas in a two-dimensional optical lattice across the thermal phase transition. Furthermore, I will present protocols for a many-body phase microscope, which will give access to various long-range off-diagonal correlators in experimentally realistic settings, which are highly relevant for characterizing many-body phases such as d-wave superconductors or fractional Chern insulators [3]. I will also discuss the idea of a phase-space microscope [4].

[1] J. C. Brüggengjürgen, M. S. Fischer, C. Weitenberg, arXiv:2410.10611 (2024)

[2] L. Asteria, H. P. Zahn, M. N. Kosch, K. Sengstock, C. Weitenberg, Nature 599, 571-575 (2021)

[3] C. Weitenberg, L. Asteria, O. Carlsson, A. Bohrdt, F. Grusdt, arXiv:2602.12142 (2026)

[4] N. R. Cooper, Y. Yang, C. Weitenberg, arXiv:2603.29568 (2026)

Krzysztof Jachymski*University of Warsaw, Poland*Monday
14:30–15:00**Dynamics of Bose polarons**

We study the Bose polaron problem including finite range interactions in the regime competing length scales, working in the reference frame of the impurity. We find that relaxation dynamics can occur via damped oscillations of the impurity velocity with simple dependence on the interaction strength. Furthermore, the equilibration process is sensitive to the type of the impurity-bath interaction. Specifically, interatomic forces describing ion-atom systems lead to much longer timescales and more pronounced oscillations in the strong coupling regime with respect to local interaction potentials.

André Eckardt*TU Berlin, Germany*Monday
15:00–15:30**Open systems of neutral atoms: Floquet-reservoir engineering integer and fractional Chern insulators**

Quantum simulators of ultracold atoms are famous for their high degree of isolation from the environment, making them ideal platforms for studying the coherent dynamics of quantum many-body dynamics. However, the approximate absence of uncontrolled coupling to the environment make them also interesting for the investigation of highly controlled open quantum systems, in which a highly controlled and well characterized environment, given for instance by a large cloud of atoms of another species, is engineered. This allows, on the one hand, to benchmark the validity of open-system theories based on various different master equations. On the other hand, it opens also a new route for robust dissipative state preparation, which circumvents the need of adiabatic state preparation and can be used to counteract Floquet heating. In my presentation, I will present our recent work on the dissipative stabilization of both inter and fractional Chern insulators in Floquet-engineered topological Chern bands. It relies on the combination of Floquet and reservoir engineering.

Michael Fleischhauer*RPTU University Kaiserslautern-Landau, Germany*Monday
16:00–16:30**Many-body dynamics of interacting spin systems and the Truncated Wigner Approximation for Spins**

The many-body dynamics of (dissipative) quantum spin systems is of key importance in many areas of physics and technology ranging from non-equilibrium phase transitions to solving optimization problems to collective radiative interactions. Its exact numerical treatment is however extremely challenging, being restricted either to small systems or to the classical limit of strong dephasing, which can be tackled by classical Monte Carlo methods. In this talk I discuss a semiclassical approach, termed truncated Wigner approximation (TWA) for spins, that allows to describe the coherent and dissipative many-body dynamics while taking into account lowest-order quantum effects. It is an extension of the discrete TWA (DTWA) [1], to include dissipative [2] and collective [3] spin processes. Based on continuous phase-space it allows to represent states with a positive quasi-probability distribution that do not have one in discrete space and thus can faithfully describe a broader class of processes even including the dynamical generation of entanglement. I discuss the application of this method to the superradiant decay of a spatially extended ensemble of atoms [4,5] including the simulation of multi- time correlations, the simulation of quantum annealing to the ground state of frustrated Ising models on large graphs, which is an NP-hard problem, and discuss the TWA in imaginary time [6].

[1] J. Schachenmayer, et al. Phys. Rev. X 5, 011022 (2015).

[2] C. D. Mink, et al. Phys. Rev. Res. 4, 043136 (2022)

[3] C. D. Mink and M. Fleischhauer, SciPost Physics 15, 233 (2023)

[4] F. Tebbenjohanns et al., Phys. Rev. A 110, 043713 (2024)

[5] Y. Spahn et al. arxiv:2603.03028

[6] T. Schlegel et al. arxiv:2603.03950

Florian Mintert*Imperial College, United Kingdom*Monday
16:30–17:00**Fast thermal state preparation beyond native interactions**

While questions on quantum simulation of ground state physics are mostly focussed on the realization of effective interactions, most work on quantum simulation of thermal physics explores the realization of dynamics towards a thermal mixed state under native interactions. Many open questions that could be answered with quantum simulations, however, involve thermal states with respect to synthetic interactions. We present a framework based solely on unitary dynamics to design quantum simulations for thermal states with respect to Hamiltonians that include non-native interactions, suitable for both presentday digital and analogue devices. By classical means, our method finds the control sequence to reach a target thermal state for system sizes well out of reach of state-vector or density-matrix control methods, even though quantum hardware is required to explicitly simulate the thermal state dynamics. With the illustrative example of the cluster Ising model that includes non-native threebody interactions, we find that required experimental resources, such as the total evolution time, are independent of temperature and criticality.

Karol Życzkowski

Jagiellonian University in Kraków and Polish Academy of Sciences, Monday
Poland 17:00–17:30

Exploring Basic Quantum Structures: Contrasting the Typical and Atypical

The theory of quantum technologies relies on three fundamental structures: the set Ω_N of mixed quantum states of order N , the discrete quantum operations acting on Ω_N , and the Lindblad operators generating continuous dynamics. On one hand, we investigate typical quantum states, operations, and Lindblad generators, using random matrix ensembles to establish their statistical properties as reference benchmarks. On the other hand, we identify atypical quantum objects with extremal properties, showcasing highly entangled multipartite states and strongly entangling quantum gates. Furthermore, we analyze discrete Hilbert space structures, focusing on quantum t -designs: collections of M objects, chosen in such a way that for all polynomial functions of a fixed degree t the average over them is equal to the average over the entire set with respect to the measure analyzed. A direct link between projective designs consisting of pure quantum states and classical simplex designs, mixed-state quantum designs, and quantum operation designs is demonstrated.

Tuesday, July 7th**Tilman Pfau***University of Stuttgart, Germany*Tuesday
09:00–09:30**Novel qubits for the neutral atom platform**

In the first part of the talk, I will discuss our endeavour to realize a gate-based quantum computer involving a novel fine-structure qubit encoded in the metastable $^3P^0$ and $^3P^2$ states of strontium [1]. We have recently implemented this qubit for the first time and measured its coherence in a magic optical tweezer, which is enabled by tuning the tensor polarizability of the $^3P^2$ via a control magnetic field. In the second part I will present work on a novel Rydberg qubit encoded in circular states of strontium atoms in optical tweezers. Circular Rydberg states promise orders-of-magnitude longer lifetimes compared to their low-L counterparts, which allows for overcoming fundamental limitations in the coherence properties of Rydberg atom based quantum simulators [2,3]. These results open exciting prospects for exploiting the unique properties of two-valence electron atoms for quantum computation and simulation. References: [1] G. Unnikrishnan et al., Phys. Rev. Lett. 132, 150606 (2024) [2] C. Hölzl et al., Phys. Rev. X 14, 021024 (2024) [3] E. Pultinevicius et al., arXiv:2510.27471

Natalia Korolkova

University of St. Andrews, United Kingdom

Tuesday
09:30–10:00

From Continuous Variable Quantum Secret Sharing to Quantum Microwave Networks

In this work, we experimentally demonstrate a $((2, 3))$ threshold Quantum Secret Sharing (QSS) protocol in a local tripartite superconducting network at microwave frequencies [1]. This is a continuously-variable (CV) quantum communication protocol, exploiting superconducting JPAs for both the generation and manipulation of microwave entangled signals, which enables the reconstruction of secret quantum coherent states with fidelities beyond the no-cloning threshold. Furthermore, we investigate inherent connections between the QSS protocol and other quantum information processing protocols, which are fundamental to a future quantum internet, such as quantum dense coding and quantum erasure correction. In a more general sense, the $((k, n))$ threshold QSS protocol is an extremely powerful and versatile building block for genuinely multipartite networks. This protocol provides unconditional security for communications, resilience against localized errors, and high-fidelity transmission of quantum states. These properties are especially relevant for applications such as conference key agreement, distributed quantum sensing, and blind quantum computing. Blind quantum computing represents a particularly interesting and important direction for developing superconducting quantum networks due to their affinity with scalable superconducting quantum computers.

[1] W. K. Yam, C. Wilkinson, S. Gandorfer, F. Fesquet, M. Handschuh, A. Marx, R. Gross, N. Korolkova, and K. G. Fedorov, Quantum secret sharing in tripartite superconducting network, arXiv:2604.13643 (2026).

Luis Santos

Institute of Theoretical Physics, Leibniz University of Hannover, Germany

Tuesday
10:00–10:30

Interplay between frustration and long-range interactions in dipolar triangular ladders

Dipoles in optical ladders provide a simple platform for the study of the interplay between frustration and long-range interactions. In this talk, I will focus on dipoles in triangular ladders. I will discuss how this system allows for the realization of intriguing phases and phase transitions, such as a dipole-induced transition between a chiral superfluid and a non-chiral two-component superfluid, or the realization of chiral and nematic spin phases. Interestingly, dipolar bosons in triangular ladders may realize an intriguing state, the so-called anyon condensate. I will comment on what is meant here by anyons, and discuss how properly tuned dipoles can be employed to realize this peculiar state. Finally, I will comment on how frustration may induce liquefaction, i.e., the formation of self-bound lattice droplets with a filling fraction lower than one.

Nigel Cooper

University of Cambridge, United Kingdom

Tuesday
11:00–11:30

Phase-space microscopes for quantum gases

Quantum gas microscopes offer unprecedented insights into quantum many-body states of cold atomic gases. Here we introduce concrete protocols for extending quantum gas microscopes to measure in phase space, by mapping momentum onto auxiliary degrees of freedom and using positive operator-valued measures. We distinguish between two distinct operational modes. In the Husimi-Q phase space microscope, position and momentum are jointly measured; in this mode the fundamental quantum noise appears in the position measurement. Conversely, the averaged-mode phase space microscope extracts the spatial dependence of averages of the momentum density (and its moments); these averages can be retrieved with arbitrary spatial resolution. We illustrate the utility of these techniques in diverse physical settings.

Szymon Pustelny*Jagiellonian University in Kraków, Poland*Tuesday
11:30–12:00**Quantum technologies to search for physics beyond the Standard Model**

Dark matter remains one of the most profound unresolved mysteries in contemporary physics. While compelling astrophysical observations provide a broad consensus for its existence, direct detection continues to elude the scientific community. This ongoing challenge drives the development of novel theoretical models and innovative detection strategies. One particularly promising scenario posits that dark matter consists of ultralight bosons. Due to their exceptionally low mass, these particles are expected to behave not as individual microscopic objects, but rather as a coherently oscillating classical field. Crucially, theoretical models predict that this background field couples directly to the intrinsic spin of Standard Model particles, exerting a tiny, oscillating or transient torque—an effect that acts as a "pseudo-magnetic" field.

To probe these subtle, non-magnetic spin interactions, we have developed an advanced optical sensor. This device is engineered to detect extremely weak spin interactions while actively suppressing its sensitivity to ordinary magnetic fields. This critical noise reduction significantly enhances the sensor's performance, enabling it to probe physics beyond the Standard Model. In this presentation, I will describe how arranging these sensors into a synchronized global network further amplifies our search capabilities. Such a network provides unprecedented capabilities for detecting astrophysical-scale dark-matter structures. To provide concrete perspective, I will conclude by discussing a representative application of this sensor network in the search for specific ultralight dark-matter particles.

Mateusz Kędziora

Institute of Experimental Physics, Faculty of Physics, University of Warsaw, Poland Tuesday
12:00–12:20

Room-Temperature Exciton-Polariton Condensation and Guided Transport in Perovskite Monocrystals

Exciton-polaritons provide a unique opportunity to study macroscopic quantum phenomena, such as Bose-Einstein condensation, echoing effects typically observed in ultra-cold atomic gases but at drastically higher temperatures due to their extremely low effective mass. As a driven-dissipative system, polaritonic condensates inherently balance continuous decay and external pumping, presenting both challenges in maintaining coherence and advantages for exploring rich, non-equilibrium physics. This presentation discusses room-temperature exciton-polariton condensation and guided transport within perovskite monocrystalline waveguides which support nonlinear polariton phenomena even without additional Bragg mirrors. Driven by exciton-mediated interactions and strong optical nonlinearities, this robust guided transport - combined with the condensate's chiral properties and susceptibility to optical trapping - highlights the potential of this system for probing the dynamics of quantum fluids of light. Thanks to the partially photonic nature of these quasiparticles, the generated condensate exhibits excellent long-range propagation along the crystal structures and demonstrates efficient coupling across air-gaps, offering integration into existing photonic architectures and neuromorphic computing.

Karthik Eswaran

Jagiellonian University in Kraków, Poland

Tuesday
12:20–12:40

Time quasicrystalline order from periodic driving

In analogy to solid state systems, time quasicrystals are many-body systems which exhibit a subharmonic response at a pair of incommensurate frequencies, owing to the breaking of a time translation symmetry. Here, we consider a sequence of periodically driven quantum clock ladder which display time translation symmetry breaking in the limit of large clock dimension. By selecting the clock dimensions such that their ratio is a rational approximant to an irrational number, time quasicrystalline order emerges in this limit, and can shown to exhibit prethermal stability. This showcases a scenario where aperiodic order in the time domain can emerge from an incommensurate response dictated by Hilbert space structure, rather than by active imposition via quasiperiodic driving.

Nikolay Vitanov*Sofia University, Bulgaria*Tuesday
16:00–16:30**Quantum-enhanced localisation and imaging**

Quantum technologies offer new routes to localisation and imaging beyond conventional limits of resolution, contrast, and parameter estimation. In this talk I will present recent results from the Center for Quantum Technologies, Sofia University, on using coherent quantum control for spatial selectivity. The central idea is to replace broad excitation profiles by sharply structured transition probabilities, engineered through pulse shaping, composite sequences, and interference.

A particular emphasis will be placed on narrowband excitation and power narrowing, where increasing the pulse area, or using designed sequences, produces spectral and spatial features that become narrower rather than broader. This counterintuitive regime can be used for localisation: when the Rabi frequency, detuning, or light shift varies across space, the transition probability maps these variations into confined patterns. Thus, coherent control converts the internal-state response into a high-resolution position marker.

I will connect these ideas to earlier work on subwavelength localisation and imaging with Thomas Halfmann's group in Darmstadt, where spatially dependent excitation generated narrow localisation regions. Building on this direction, CQT's expertise in designed pulses, composite-pulse engineering, robust gates, and power-narrowed line profiles provides a toolbox for enhancing contrast, suppressing side lobes, and improving robustness.

The broader message is that quantum-enhanced imaging does not require entanglement or many-body resources. Significant enhancement can already arise from interference, phase control, and designed single-particle dynamics. These methods are relevant for atomic and molecular imaging, trapped-ion and neutral-atom platforms, spectroscopy, sensing, and calibration of inhomogeneous fields. The talk will outline mechanisms and implementations, showing how quantum control can manipulate states and extract spatial information with enhanced precision.

Frank Großmann*TU Dresden, Germany*Tuesday
16:30–17:00**Multi-configuration approaches to interacting many-body quantum dynamics: beyond mean field**

We give a brief review of generalized coherent states [1], which may serve as time-evolving basis functions to variationally solve the time-dependent Schrödinger equation for Bose-Hubbard (BH) models using a multi-configuration Ansatz [2].

We then discuss the results of benchmark calculations for the bosonic Josephson junction model and highlight the fact that the multi-configuration method is well suited to reveal genuine quantum effects beyond mean field with surprisingly small multiplicity [3]. Furthermore, for larger BH systems with double digit well numbers, in the Mott insulator regime, a quantum enhancement of thermalization is found [4].

[1] W. M. Zhang, D. H. Feng, and R. Gilmore, RMP 62, 867 (1990)

[2] Y. Qiao and F. Grossmann, Phys. Rev. A 103, 042209 (2021)

[3] Y. Qiao and F. Grossmann, Front. Phys. 11, 1221614 (2023)

[4] Y. Qiao et al., Phys. Rev. Lett. 135, 060404 (2025)

Jens Biegert

ICFO, Spain

Tuesday
17:00–17:30

Attosecond exploration of energy pathways in matter

The properties of materials and devices are governed by the microscopic interplay among light, charge carriers, and the crystal lattice. Under intense, ultrashort light pulses, this interplay can depart strongly from the weak-excitation regime, giving rise to nonequilibrium states and light–matter hybrids with properties absent in equilibrium. Understanding how such states emerge requires resolving the many-body dynamics linking electronic excitation, carrier scattering, lattice motion, and coherence across their natural timescales. I will show how attosecond soft X-ray spectroscopy offers a powerful route to this goal by combining core-level sensitivity with attosecond temporal resolution. Recent advances, including the generation of the shortest isolated soft X-ray pulses reported to date, now enable time-resolved core-level absorption measurements that disentangle electronic and structural dynamics, tracking coherent and incoherent processes from the initial excitation through femtosecond and picosecond relaxation. As a prototypical condensed-matter system, I will focus on graphite driven into the strong light–matter coupling regime by intense ultrashort excitation. Graphite provides an ideal platform for exploring how collective electronic dynamics, carrier–phonon coupling, and lattice motion combine to form transient light-dressed states. Probing its response with attosecond soft X-ray absorption reveals the buildup and relaxation of the coupled light–matter system, showing how nonequilibrium populations, coherent lattice motion, and many-body interactions shape transient material states and light-induced phases.

Wednesday, July 8th**Susanne Yelin***Harvard University, USA*Wednesday
09:00–09:30**Unleashing Analog Quantum Computing**

Recent advances are expanding the power and flexibility of analog quantum platforms, opening new routes for both quantum simulation and quantum information science. In this talk, I will discuss how modest levels of control can be used to access key observables and dynamical regimes in strongly correlated fermionic systems, including settings with pairing, long-range interactions, and cooling. I will also describe how globally controlled analog platforms can nevertheless achieve universal quantum computation, and how optimal-control techniques can be used to engineer complex effective interactions and topological dynamics. Finally, I will outline recent progress toward approximate error correction tailored to analog quantum systems. Together, these developments point toward a broader view of analog quantum computing, in which large-scale quantum devices are not only simulators of specific models, but flexible computational resources whose capabilities can be systematically unlocked.

Stefan Scheel

University of Rostock, Germany

Wednesday
09:30–10:00

Rydberg physics with excitons in cuprous oxide quantum wells

Excitons in semiconductors are bound states formed by the Coulomb interaction between an electron in the conduction band and a hole in the valence band. In bulk crystals such as cuprous oxide, excitonic bound states have been shown to follow a Rydberg series similar to those known from atomic systems, thereby making Rydberg physics possible in solid-state systems. In this talk, I will first briefly review the physics of Rydberg excitons in bulk cuprous oxide, before elaborating on the effects on their confinement in quantum well structures. In particular, I will focus on the possibility to observe bound states in the continuum in excitonic spectra in cuprous oxide quantum wells that arise because of destructive interference between adjacent exciton resonances.

Jakub Zakrzewski*Jagiellonian University in Kraków, Poland*Wednesday
10:00–10:30**Dynamics in disordered Rydberg arrays**

The nonergodic dynamics in models with a positional disorder is discussed. Such a disorder may be easily realized in Rydberg atom arrays. We discuss peculiarities of localization in that case as well as a possibility to create a subset of excited states with apparently nontrivial topological character. Talk based on PRL 133, 196302 (2024); PRB 113, 064205 (2026).

Kazimierz Rzażewski*Center for Theoretical Physics, Polish Academy of Sciences, Poland*Wednesday
11:00–11:30**Multicomponent quantum gases and spontaneous symmetry breaking**

Strongly repelling two-component ultracold gases confined in a spherically symmetric trap undergo a quantum phase transition breaking the symmetry of the trap. The effect holds both for fermions and bosons. The phase separation emerges naturally in the mean-field description. I will explain how to reconcile this fact with the symmetry of the exact ground state of the corresponding Schrödinger equation.

Radim Filip*Palacky University, Czechia*Wednesday
11:30–12:00**Quantum Non-Gaussian Light and Matter**

Quantum non-Gaussian states are crucial for quantum technology involving bosonic systems, with applications already investigated in sensing and error correction. The talk will present recent theoretical techniques suitable for experiments that have enhanced our understanding, control, and use of quantum non-Gaussian coherences across optical, microwave, and mechanical platforms. This field remains challenging, both theoretically and experimentally. Therefore, we will highlight recent achievements in contrast to ongoing experiment-related problems. The talk will end with a focus on necessary quantum nonlinearities involving light, atoms, mechanical oscillators, and superconducting circuits, to promote discussion of the further development of this promising area.

Peter Schlagheck*University of Liège, Belgium*Wednesday
12:00–12:30**Creating highly entangled NOON states with ultracold bosonic atoms**

NOON states, given by coherent superpositions of the form $|N,0\rangle + |0,N\rangle$ (possibly amended by relative phase factors), are highly entangled quantum states that involve N bosonic quanta on two modes. They can be seen as manifestations of Schrödinger cat states and are of great potential interest for quantum metrology, especially when being realized with matter. Here we discuss viable proposals for the creation of such NOON states using ultracold bosonic atoms that are located on two symmetric sites of a lattice. The protocols that we focus on are based on collective tunneling, taking place in the self-trapping regime where on-site interaction is dominant with respect to inter-site hopping. While the associated collective tunneling rate is prohibitively low for realistic lattice parameters, we show that it can be drastically enhanced via a periodic driving of the configuration, giving rise to chaos-assisted tunneling [1]. Further reductions of the NOON state creation time are possible through adiabatic transitions into the NOON superposition, whose efficiency can be substantially enhanced via the technique of counterdiabatic driving [2]. NOON states with $N=5$ particles can then be created on time scales significantly below a second, which is in reach within ultracold atomic setups.

[1] G. Vanhaele and P. Schlagheck, PRA 103, 013315 (2021); G. Vanhaele et al., PRA 106, L011301 (2022).

[2] S. Dengis, S. Wimberger, and P. Schlagheck, PRA 111, L031301 (2025).

Robert Spreeuw*University of Amsterdam, the Netherlands*Wednesday
14:00–14:30**Optical tweezers for atom arrays and in ion traps**

We perform quantum simulation experiments in arrays of strontium atoms, which interact via Rydberg excitation. As a part of this project we developed a fast parallel rearrangement technique utilizing a fast (kHz rate) spatial light modulator (SLM). This method achieves, with a single SLM, what would otherwise require many pairs of acousto-optic deflectors, each driven with multiple RF tones. Parallel rearrangement is useful for the initialization of arrays as well as in mid-circuit rearrangements in quantum processors. We investigated the transverse field Ising model with atoms arranged in a fractal geometry of a Sierpinsky gasket. We find that in the quantum regime, the phase diagram exhibits phases in which the spins flip one-by-one, and Rydberg excitations are delocalized over multiple sites of a sublattice. We also investigate the use of optical tweezers as a tool to induce spin-dependent forces on trapped ions. The spin dependence arises from non-paraxial effects in strongly focused tweezers, leading to longitudinal field components and polarization gradients in the focal plane. This results in spatial shifts of the atom-light interaction strength which was measured quantitatively for the case of an electric quadrupole transition. These non-paraxial spin-dependent forces can be used for novel quantum gate schemes as recently demonstrated. At the same time, non-paraxial effects may pose limitations on the fidelities for existing gates. Finally we look into the possibility of utilizing non-paraxial effects to create novel, spin-textured tweezer traps for neutral atoms.

Martin Robert de Saint Vincent

Laboratoire de Physique des Lasers, CNRS, Univ Sorbonne Paris Nord, France Wednesday
14:30–15:00

Coherent control of large nuclear spins in a Fermi gas of strontium

H. Ahmed, A. Litvinov, P. Guesdon, E. Maréchal, J. H. Huckans, B. Pasquiou, B. Laburthe-Tolra, M. Robert-de-Saint-Vincent Laboratoire de Physique des Lasers, CNRS, Université Sorbonne Paris Nord

Ultracold alkaline-earth atoms are used on a variety of platforms: quantum simulators e.g. of generalised Fermi Hubbard models; neutral atom quantum computers; and high precision sensors such as optical clocks. The spin degree of freedom of these atoms could be a powerful resource in the above applications. In this talk, I will discuss coherent manipulation schemes that enable harnessing it, i.e., provide the capability to prepare or measure any state.

The spin of a ground-state strontium-87 atom has two key characteristics: it has a large quantum number $F = 9/2$, and it is entirely contained within the nucleus. This quantum number means that one atom could be in any of 10 states, or any quantum superposition of those. Consequently, one atom contains a lot of stored information, more than e.g. “qubits” that are in a superposition of two states. Furthermore, the nuclear nature of the spin gives these states strong robustness against environmental perturbations such that quantum superpositions can survive over many seconds.

To manipulate or extract all that quantum information, one needs to be able to perform a set of several control operations. Spin precession around a magnetic field is one such operation, but is not sufficient. Here, we exploit a property of the atom called tensor polarisability to implement a sufficient set of distinct manipulations. We then realise proof-of-principle experiments to illustrate opportunities offered by objects with large spin. Multiple fields can be measured in parallel, e.g. for noise cancellation in sensors; and a subset of states can serve as a primary resource (an effectively smaller spin), while the other states are used to perform seemingly incompatible quantum measurements in parallel.

H. Ahmed et al, PRX Quantum 6, 020352 (2025)

Mariusz Gajda

Institute of Physics, Polish Academy of Sciences, Poland

Wednesday
15:00–15:30

Bose-Fermi mixtures of ultracold atoms

Ultracold Bose–Fermi mixtures provide a unique platform for exploring many-body quantum phenomena arising from the interplay between bosonic and fermionic quantum statistics. The combination of Bose–Einstein condensates and degenerate Fermi gases enables the realization of novel self-organized states of matter, including bright solitons, quantum droplets, supersolids, and droplet crystals. Owing to the high degree of experimental control over interactions and trapping geometries, these systems offer exceptional opportunities to investigate nonlinear dynamics, self-binding mechanisms, and collective excitations in quantum gases. One of the most remarkable consequences of attractive Bose–Fermi interactions is the formation of bright solitons in mixtures where bosons are intrinsically repulsive. A sufficiently strong attraction between bosonic and fermionic atoms can effectively reverse the sign of the boson–boson interaction, leading to the emergence of self-trapped wave packets that propagate without dispersion. Beyond solitons, attractive Bose–Fermi mixtures can form self-bound quantum droplets stabilized by beyond-mean-field effects and quantum fluctuations. Finite-temperature studies reveal a rich dynamical behavior governed by the interplay between thermal excitations, particle evaporation, and interaction strength. The inclusion of long-range dipolar interactions further enriches the physics of Bose–Fermi mixtures. In quasi-one-dimensional geometries, the attraction between fermions and a dipolar Bose condensate can drive a sequence of quantum phase transitions from self-bound droplets to supersolid states and, ultimately, to crystals of isolated droplets. The emergence of roton excitations in the collective spectrum signals the onset of density modulation and supersolidity. Together, these phenomena establish ultracold Bose–Fermi mixtures as a versatile laboratory for studying nonlinear quantum matter and emergent many-body phases.

Florian Schreck*University of Amsterdam, Netherlands*Wednesday
16:00–16:30**Realization of continuous superradiant lasing on a narrow optical transition**

Superradiance allows lasing directly from narrow optical transitions, making it a promising approach for realizing ultra-stable optical frequency references. Coherence is stored predominantly in the collective atomic emission amplitudes rather than in coherent intracavity photons, enabling a lasing frequency that is robust against cavity length fluctuations and lasing linewidths even narrower than the natural linewidth of the transition. To explore the full potential and overcome the Fourier limit, steady-state superradiant lasers have been proposed as candidates to realize a new generation of frequency references: active optical clocks [1,2,3]. We demonstrate continuous superradiant lasing on the 7.5 kHz-wide $1S_0 \rightarrow 3P_1$ transition of strontium using a hot atomic beam. The broadening mechanisms of the transition linewidth in this kind of system are dominated by atomic Doppler and cavity transit time broadening. To enter a regime in which the collective atomic linewidth dominates and other broadening effects are overcome, we implement a swept velocity shelving scheme [4], which collimates the atomic beam and reduces the velocity distribution in the direction of emission. We achieve collective strong coupling in the bad-cavity regime in an optical single-mode cavity with a linewidth of 6.8 MHz. With this scheme, we realize continuous emission with a linewidth more than an order of magnitude lower than the natural linewidth of the transition. We investigate lasing properties such as cavity pulling suppression and scaling laws of the lasing linewidth characteristic of continuous operation and superradiance. Finally, we observe a phase transition to a multicomponent superradiant regime, as predicted by theory [5].

- [1] J.B. Chen, Chin. Sci. Bull. 54, 348 (2009).
- [2] D. Meiser et al., Phys. Rev. Lett. 102, 163601 (2009).
- [3] L. Haon et al., Phys. Rev. Lett. 125, 253602 (2020).
- [4] F. Famà et al., in preparation.
- [5] S.B. Jäger et al., Phys. Rev. A 104, 033711 (2021).

Bogdan Damski

Jagiellonian University in Kraków, Poland

Wednesday
16:30–17:00

Expanding quantum magnetic field

We discuss the quantum theory of the causal formation of a long-range magnetic field generated by an external current that is instantaneously switched on and subsequently kept constant in time. The resulting non-equilibrium quantum state, describing the expanding magnetic field, is obtained exactly and compared with the corresponding quantum magnetostatic state. In contrast to the magnetostatic case, the expanding solution exhibits a propagating shockwave-like front separating regions where the magnetic field has already been formed from those that remain causally disconnected from the source. We show that although the expanding field locally approaches the magnetostatic field behind the shockwave-like front, the associated quantum systems remain distinct at all times. In particular, we obtain manifestly different results for the energy, photon number, and their fluctuations in expanding and magnetostatic field configurations. Our results are first derived for a general external current and then illustrated with a specific example.

Posters

Poster session: Tuesday, July 7th, from 14:00 to 15:30.

Pavel Belov

Universität Rostock, Germany

Bound states in the continuum in cuprous oxide quantum wells

Bound states in the continuum (BICs) are remarkable quantum states characterised by the absence of linewidth broadening, resulting in giant non-radiative lifetimes. The existence of bound states embedded in the continuum was first suggested by von Neumann and Wigner in the context of an open quantum system formed by a rapidly oscillating potential. Nowadays, BICs became of practical relevance in photonics as particular solutions of the wave equation. They are the subject of extensive study in quantum optics due to their unique properties, including the ability to enhance light-matter interactions, produce sharp Fano resonances and generate extremely long-lived, confined single-photon excitations. However, the proposed quantum-mechanical systems incorporating BICs still fall into the category of speculative theoretical work, rather than practical realization. The already designed theoretical setups are difficult to implement in atomic systems as they require rather challenging conditions. In this report, we propose a realistic semiconductor system containing BICs which allows for a practical realization. By varying the confinement strength of excitons in cuprous oxide quantum wells, we show that the long-lived Rydberg states of the confined electron-hole pairs appear in the continuum background. The trivial symmetry-protected BICs in this system are formed due to a different parity of the quantum-confinement subbands, while the proper nontrivial BICs appear as a result of the Friedrich-Wintgen destructive interference between adjacent exciton resonances. Based on our quantum-defect-theory and complex-coordinate-rotation calculations, we argue that finite-sized cuprous oxide crystals, due to their large exciton binding energies, are a convenient platform for experimental identification of BICs. The report is based on the publication: A. Aslanidis et al., Phys. Rev. B 111, L121103 (2025).

Raphael Benz

University of Stuttgart, 5th Institute of Physics, Germany

Experimental setup for quantum network experiments based on neutral atoms in an optical cavity

The practical implementation of a quantum coherent network remains a pursued challenge across various hardware platforms. Cold neutral atoms trapped in a high-finesse optical cavity have proven to be a promising platform due to the efficient light-matter coupling and precise controllability of the system. Using optical tweezers to address individual atoms opens the possibility of extending this platform to versatile multi-qubit quantum network nodes. I present the progress and current status of our experimental setup with an emphasis on the vacuum system and the cavity design. With our system, a wide range of experiments becomes feasible, including photon-mediated quantum information processing between intra-cavity atoms, the generation of highly entangled photonic cluster states, and the creation of optical GKP states.

Yakov Braver

Vilnius University, Lithuania

Optical creation of soliton lattices and localised vortices in multicomponent BEC

We present a widely accessible and experimentally realisable technique for the controlled creation of dark-bright solitons and soliton lattices in atomic Bose-Einstein condensates (BECs). The method is based on preparing the condensate in a dark state of a Λ -coupled three-level system. Numerical simulations reveal that individual dark-bright solitons created through this scheme can survive over experimentally accessible timescales, even when the coupling laser fields are switched off. Meanwhile, the fate of soliton lattices upon the quench of the fields depends on the scattering lengths: the lattice is found to persist on timescales comparable to the condensate lifetime only when the scattering lengths are all equal. The present dark-state-based technique also opens up new avenues for exploring unconventional vortices in two-component BECs. Using light beams with orbital angular momentum, we theoretically show how to create a stable, pinned vortex configuration, where the rotating component is confined to the region surrounded by the second, non-rotating component. The atoms constituting this vortex can be localised in volumes much smaller than the volume occupied by the second component. We also show that the vortex position can be changed dynamically by moving the laser beams, provided the beams' movement speed remains below the speed of sound. This allows us to use the localised vortex to stir the second component, and to determine the superfluid flow's critical velocity.

Domantas Burba

Vilnius University, Lithuania

Extending the cold atom hubbard toolbox with state-dependent sub-wavelength lattices

In 1998, D. Jaksch et al. proposed using ultracold atoms in optical lattices as quantum simulators of strongly correlated lattice models, a vision realized experimentally by M. Greiner et al. four years later. Since then, the available quantum-simulation toolbox has expanded substantially, including the engineering of synthetic gauge fields through laser-assisted tunneling and the realization of long-range interactions with dipolar atoms and molecules. Here, I present two theoretical works showing how state-dependent subwavelength lattices provide further routes for extending Bose–Hubbard physics.

In the first work, we analyze a recently realized subwavelength lattice formed by counter-propagating lasers driving two-photon Raman transitions in ultracold atoms. In this setup, the tunneling amplitude, range, and phase can be controlled by tuning the detunings, while the reduced lattice spacing enhances interaction effects. We show that this enables regimes supporting density-wave and chiral-superfluid behavior, with distinct scenarios governed by the lattice depth and detunings.

In the second work, we demonstrate that a suitable tripod scheme realizes a frustrated, non-standard Bose–Hubbard model characterized by strong pair hopping and density-induced tunneling. Combining density matrix renormalization group calculations with analytical mappings, we show that interaction-driven pair tunneling stabilizes a robust pair superfluid, characterized by algebraic pair correlations and gapped single-particle excitations. We further identify a chiral superfluid resulting from frustration induced by competing nearest- and next-nearest-neighbour tunnelings.

These results demonstrate that state-dependent subwavelength lattices form a flexible platform for engineering strong interactions, geometrical frustration, and correlated hopping beyond conventional Bose–Hubbard models.

Grzegorz Czelusta

Jagiellonian University in Kraków, Poland

Quantum technologies for satellite earth observation

Earth observation satellites generate tens of terabytes of multi- and hyperspectral imagery daily, straining the transfer, storage, and analysis pipeline. We present two complementary quantum approaches targeting different stages of this chain, together with a compiler that lets photonic algorithms run on gate-based hardware. First, we extend support vector machines with quantum kernels for cloud detection in Landsat-8 imagery. Pixels are embedded into a Hilbert space by parameterised feature maps, and the kernel is estimated as a state fidelity via a circuit-inversion scheme, with feature-map parameters tuned by kernel-target alignment. On the 38-Cloud benchmark the hybrid classifiers reach 91%. Second, we use Gaussian Boson Sampling (GBS) for spectral data reduction. Since GBS output probabilities are governed by matrix hafnians, it natively samples dense subgraphs. Recasting redundant spectral bands as a similarity graph, GBS clusters them and one representative band is retained per cluster, yielding a compact, non-redundant feature set. To run photonic algorithms on accessible gate-based devices, we introduce an optical-to-qubit compiler based on a controlled, unitarity-preserving truncation of Fock space. Explicit circuits for phase rotation, displacement, squeezing, and the symmetric beam splitter are built for $N=2$ and $N=4$ truncations and benchmarked. Together, these results outline a practical route to quantum-enhanced Earth observation, bridging continuous-variable quantum optics and discrete-variable quantum computing.

Celia Delaive

ULiège, Belgium

Creating noon states with ultracold bosonic atoms using time crystals

NOON states are highly entangled states involving N bosons distributed over two modes. They are of great interest for quantum metrology, especially when realized with massive bosons, as these are sensitive to external forces and light fields. However, their realization remains challenging due to the slowness of the collective tunneling process underlying their formation, and due to the requirement of perfect symmetry between the two modes. Here, we propose to overcome both these problems by adding a periodic driving to our system of ultracold bosonic atoms. This driving gives rise to a perfectly symmetric lattice in time domain via a nonlinear resonance with an unperturbed motional mode of the atoms. The resulting NOON state therefore constitutes a discrete time crystal. Furthermore, the periodic driving induces chaotic dynamics in the system, and this chaos assists and can significantly accelerates the tunneling process.

Ali Emami Kopaei

Warsaw university, Poland

Time dynamic of altermagnetism

Distinguishing altermagnetism from traditional ferromagnetism and antiferromagnetism typically relies on bulk momentum-space probes. Here, we show that the non-equilibrium real-space spreading of a localized spin wave packet provides an unambiguous, direct fingerprint of altermagnetic symmetry. Using linear spin-wave theory on a 2D checkerboard lattice with couplings J_1 and J_2 , we demonstrate that altermagnetic band splitting induces a pronounced directional anisotropy in the magnon group velocity. This anisotropy manifests in real time as a structured, internal cross-like interference pattern within a circular expansion profile for the frustrated regime ($J_2 > 0$). We further show that switching to the unfrustrated regime ($J_2 < 0$) stiffens the lattice, increasing transport velocities and rotating the internal high-velocity hotspots by $\pi/2$. These insights establish real-space, time-resolved imaging as a powerful paradigm for diagnosing unconventional magnetic order in both solid-state systems and synthetic quantum architectures.

Bartosz Grygielski

Jagiellonian University in Kraków, Poland

Mikok - trapped ion quantum computer unit

MIKOK is a National Centre for Research and Development (NCBR)-funded project focused on the development of a trapped-ion quantum computing unit from foundational hardware components. The realization of such a system requires extensive hardware calibration procedures as well as dedicated software support for control and optimization. This poster presents an overview of the current status of the physical and engineering work conducted within the project, highlighting key challenges encountered in the implementation of a scalable quantum computing unit and outlining both near-term and long-term milestones. The project is carried out by a consortium led by Warsaw University of Technology, in collaboration with Silesian University of Technology, Military University of Technology, Military Institute of Armament Technology, and SONOVERO R&D Ltd.

Tanausú Hernández Yanes

Jagiellonian University in Kraków, Poland

Nonstabilizerness in quantum-enhanced metrological protocols

Nonstabilizerness (colloquially “magic”) characterizes genuinely quantum (beyond-Clifford) operations necessary for preparation of quantum states and can be measured by stabilizer Rényi entropy (SRE). For permutationally symmetric states, we show that the SRE depends, for sufficiently large systems, only on a constant number of expectation values of collective spin operators. This compact description is leveraged for analysis of spin-squeezing protocols, which inherently generate nonstabilizerness. Under one-axis twisting (OAT), the generation of optimal squeezing is accompanied by a logarithmic divergence of SRE with system size. Continued time evolution under OAT produces metrologically useful so-called kitten states, that is, superpositions of rotated Greenberger-Horne-Zeilinger states, that feature many-body Bell correlations but exhibit a smaller, system-size-independent SRE that decreases with increasing Bell-correlation strength. Our results reveal connections between nonstabilizerness, multipartite correlations, and quantum metrology and provide a practical route to quantify nonstabilizerness in experiments for precision sensing.

[1] T. Hernández-Yanes P. Sierant, J. Zakrzewski, and M. Plodzień, Phys. Rev. A 113, 012416 (2026).

Navid Kazemiseresht

Institute of Physics, Polish Academy of Sciences, Poland

Universal spin-squeezing dynamics in spinor condensates

The production of large-scale entangled states is one of the main goals of next-generation quantum technologies, with an immediate potential for applications in the context of entanglement-assisted quantum sensing. A very promising platform to achieve this goal is offered by ultracold spinor gases, made of atoms with a large internal spin sensitive to magnetic fields. Here we show that the native spin-changing collisions in a spinor Bose-Einstein condensate, combined with an arbitrary quadratic Zeeman shift, can generate scalable spin squeezing in the collective spin of the ensemble, following the universal paradigm of the celebrated one-axis-twisting model. Squeezing dynamics is driven by the quadratic Zeeman shift when this shift is small; and by the spin-changing collisions for large shifts, in the form of stroboscopic squeezing. Turning off the Zeeman shift freezes out the collective-spin dynamics, so that the ensuing collective spin dynamics can be uniquely governed by an external field to be sensed. Our theoretical results pave the way for the use of spinor Bose gases with a large spin in fundamental studies of entanglement, as well as in advanced metrological applications.

Maximilian Kieler

University of Liège, Belgium

Semiclassical foundation of universality in chaotic quantum circuits

The fundamental correspondence between quantum chaotic single-particle systems and random matrix theory is well understood in terms of periodic orbit theory. In contrast, we show that many-body systems with explicit subsystem structure exhibit characteristics that are not captured by the single-particle framework. Therefore, we present a periodic orbit theory for many-body systems with well-defined semiclassical limit. We identify periodic orbit families arising exclusively in the many-body setting and implement a central limit theorem characterizing their correlations. Using this, we explicitly demonstrate that spectral correlations in chaotic quantum circuits coincide with their random matrix counterparts.

Tanoy Kanti Konar

Jagiellonian University in Kraków, Poland

Interplay of nonstabilizerness and ergotropy in quantum batteries

Nonstabilizerness plays an essential role in an efficient simulation of quantum systems on quantum computers. In this work, we investigate its role in the context of quantum batteries (QBs). To this end, we consider a system of N spin- $\frac{1}{2}$ particles, where the left half serves as the charger and the right half acts as the battery. By studying different classes of interactions between the charger and the battery, we quantify the amount of nonstabilizerness required to store work in the QB. Our results reveal that a one-to-one correspondence between the ergotropy stored in the battery and the total nonstabilizerness of the composite system emerges whenever the interaction Hamiltonian preserves a $\mathbb{U}(1)$ symmetry. In contrast, this correspondence is generally lost for more generic interactions that do not respect this symmetry. Finally, we examine the complementary scenario in which the battery is initialized in a nonstabilizer state and subsequently charged through Clifford evolution. In this case, we find that the maximum average charging power exhibits a non-monotonic dependence on the initial nonstabilizerness. Remarkably, the highest average power can be achieved even when the initial state carries no magic (nonstabilizerness), demonstrating that the initial magic is not a necessary resource for generating an optimal charging power in this protocol.

Maciej Bartłomiej Kruk

Institute of Physics, Polish Academy of Sciences, Poland

Geometry and fluctuations: exploring 3d bose-einstein condensates in anisotropic traps

This study investigates the interplay between confinement geometry and the thermal fluctuations of a Bose-Einstein condensate (BEC). Utilizing Hybrid Sampling - a novel Monte Carlo-based simulation method developed by the authors - we analyze interacting Bose gases within both canonical and microcanonical frameworks in a 3D anisotropic harmonic potential. We demonstrate that the trap's aspect ratio serves as a critical tuning parameter for particle number ensemble fluctuations. Notably, our results reveal a geometric transition in fluctuation behavior: while interactions typically suppress fluctuations in isotropic systems, high levels of anisotropy lead to a significant enhancement of maximal fluctuations.

Piotr Kulik*University of Warsaw, Poland***Quantum engineering with ultracold polar molecules using trap-induced resonances**

Polar molecules present a promising platform for quantum technologies. Their long-lived states and tunable anisotropic interactions with highly controllable arrays of optical tweezers place them alongside other promising platforms, such as Rydberg atoms. One of the key challenges in experimental realizations is motional dephasing, which arises from the coupling between internal qubit states and external motional degrees of freedom within the trap. In this work, we reframe this coupling as a resource rather than a limitation. By numerically solving the two-body problem of dipolar molecules confined in separate optical tweezers using a coupled-channel renormalized Numerov method, we identify trap-induced resonances-avoided crossings between molecular bound states and trap vibrational states-that naturally arise for experimentally relevant parameters in NaCs molecules. We demonstrate that the internal state dependence of dipole-dipole interactions leads to rotational-state-selective resonances, which we exploit to design an adiabatic controlled-phase gate with achievable gate times in the sub-millisecond regime. Beyond quantum gates, we further outline how the sensitivity of trap-induced resonance positions to external fields enables two complementary quantum sensing protocols for weak electric field detection.

Mateusz Kędziora

Institute of Experimental Physics, Faculty of Physics, University of Warsaw, Poland

A versatile perovskite platform for non-equilibrium exciton-polariton condensation and circuitry

Exciton-polaritons provide an excellent platform for studying non-equilibrium Bose-Einstein condensation, the creation of advanced states of light, and quantum effects. Due to their exceptional non-linear optical properties, lasing, and waveguiding capabilities, perovskites offer a promising platform for studying the strong coupling regime at room temperature. We demonstrate a versatile, template-assisted method to efficiently fabricate large-scale waveguiding perovskite crystals of arbitrarily predefined geometries such as microwires, couplers, and splitters. We nonresonantly stimulate a condensate of waveguided exciton-polaritons, resulting in polariton lasing from the transverse interfaces and corners of our perovskite microstructures, even without external resonators. The condensate polaritons are found to propagate over long distances in the wires and can couple to neighboring wires through large air-gaps, making our platform promising for integrated polaritonic circuitry and on-chip optical devices with strong nonlinearities. Furthermore, this condensate exhibits chiral spin properties and can also be used for optical trapping. Further manipulation of the crystals, such as confining them in an optical microcavity, adding polymer gratings, or structuring them allows them to be used in nonlinear polaritronics and for neuromorphic computing.

Joseph Lamarre

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Probing non-classicality in high-harmonic spectroscopy of VO_2 via photon-correlation metrology

Vanadium dioxide undergoes a prototypical, strongly correlated insulator–metal transition with rich electron–lattice dynamics. We interrogate this transition with a quantum-sensitive variant of high-harmonic spectroscopy: solid-state HHG combined with single-photon correlation metrology on selected harmonics in the visible/near-visible. The goal is to move beyond mean-intensity observables and access the quantum fluctuations and inter-harmonic correlations imprinted by the non-perturbative light–matter interaction in the solid. Indeed, high-harmonic spectroscopy becomes markedly more informative when we read out the photon statistics of selected harmonics, not just their average spectra. By tracking photon-statistical indicators, here the second-order intensity correlation, and inter-harmonic correlations, we access fluctuation-level observables which are witness to nonclassical behavior (e.g., antibunching or sub-Poissonian statistics). These include the optical spatio-temporal mode structure and inter-harmonic nonclassicality via the Cauchy–Schwarz inequality. This correlation-based metrology is mostly agnostic to the specific driver details and works in the visible/near-visible where efficient single-photon detection is practical, enabling fast, non-destructive measurements with high dynamic range. As a materials probe, it offers three advantages: sensitivity to precursors of phase changes through changes in bunching and effective optical spatio-temporal mode number; pathway selectivity via inter-harmonic correlations that reveal shared or competing channels; and robustness against slow drifts, since normalized coincidence statistics suppress common-mode noise. We demonstrate these capabilities on tungsten-doped VO_2 , whose insulator–metal transition provides a tunable platform, to link photon-correlation fingerprints to evolving electronic and structural order, establishing photon-correlated HHG as a general route to fluctuation-level materials spectroscopy.

João Pedro Mendonça

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Role of matter interactions in superradiant phenomena

The superradiant phenomenon, usually described by the Dicke model, is a hallmark of strong light-matter interaction. We explore how matter-matter interactions influence this phenomenon by performing ground-state simulations of Dicke-like models with both isotropic and anisotropic interactions. We find that Ising-type interactions produce two qualitatively distinct phase boundaries, one of which gives rise to an antiferromagnetic-normal phase connected to the superradiant regime via a first-order phase transition. Under anisotropic couplings, we uncover a strongly correlated phase where in-plane spin order coexists with superradiance, exhibiting sublinear scaling of the photon occupation per site and power-law decay of spin correlations. Furthermore, superradiance is strengthened by tuning either isotropic or anisotropic interactions, highlighting the role of intrinsic many-body correlations in shaping light-matter quantum phases.

Juan Ramón Muñoz de Nova

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Hawking time crystals

We propose a time crystal based on a quantum black-hole laser, where the genuinely spontaneous character of the symmetry breaking stems from the self-amplification of spontaneous Hawking radiation. The resulting Hawking time crystal (HTC) is characterized by the periodic dependence of the out-of-time density-density correlation function, while equal-time observables are time independent because they embody averages over different realizations with a random oscillation phase. The HTC provides a nonlinear periodic analog of the Andreev-Hawking effect, exhibiting anticorrelation bands resulting from the spontaneous, quantum emission of pairs of dispersive waves and solitons into the upstream and downstream regions. Remarkably, we prove that any parametric amplifier has associated a time operator, which leads to a unique characterization of the time-crystal formation in terms of two time operators: one associated with the initial black-hole laser and another associated with the final spontaneous Floquet state.

Michele Notarnicola

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Nonlocal continuous-variable quantum nondemolition gates by optical connections

Nonlocal quantum gates, coupling quantum systems located at a distance, are crucial for distributed quantum computing. To this aim, high-capacity optical noiseless connections between different processing units are essential for transmitting large amounts of information per mode. Simultaneously, optical quantum computing offers future high-speed multimode quantum processors. We propose a library of feasible protocols to implement a necessary nonlocal continuous-variable (CV) quantum nondemolition (QND) gate between two distant users sharing a quantum channel and exploiting classical communication. The users are endowed with a newly achieved high-fidelity and large-bandwidth element - single-pass phase-sensitive optical parametric amplifier (OPA), that allows for both online squeezing and channel-loss compensation. The use of OPAs enhances quality of the resulting gate in terms of both excess noise and entangling capability. The proposed schemes are also applicable to CV cluster state fusion, providing a first step towards development of distributed CV measurement-based quantum computation.

Viktor Noviĉenko

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Floquet treatment of polar quantum system ultrastrongly coupled with light

We consider a two-level polar quantum system subjected to a classical plane-wave laser drive with a frequency that is near-resonant with the system transition frequency. The system is described by a time-dependent Hamiltonian with the driving frequency that is assumed to be high in comparison with the detuning frequency and the transverse coupling strength. In contrast, the longitudinal coupling strength is assumed to be of the order of the driving frequency. Such an arrangement corresponds to the longitudinal ultrastrong coupling regime, which can be implemented, e.g., in atomic lattices. To treat this problem analytically, we first eliminate divergent terms using prescribed unitary transformations, then obtain a Floquet effective Hamiltonian and a micromotion operator up to first order in the inverse-frequency expansion. Additionally, we obtain an exact effective Hamiltonian by numerically integrating the flow equations with the Toda generator.

Maksym Prodius

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Spinor lattice bosons coupled to the optical cavity

The plethora of possible ground states of spinor bosons placed in an external lattice and a cavity is revisited. We discuss the simplest case when the external lattice nodes coincide with the antinodes of the cavity field. We analyze the problem within the grand-canonical mean-field approach, considering both the homogeneous system and the nonhomogeneous case with a harmonic trapping potential. Due to the spin degree of freedom, in the homogeneous case, we treat the system in a twofold manner: we impose the physically relevant total-magnetization constraint, while also discussing the minimization landscape for the full unconstrained problem. In the latter, by combining analytical arguments with numerical calculations based on the Gutzwiller ansatz, we show that the system exhibits two types of magnetic phases: an antiferromagnetic Mott insulator (AFM) and a ferromagnetic density wave (FDW). In addition, three distinct supersolid phases emerge, characterized by different patterns of spin and density imbalances. In the case of the zero total magnetization, the FDW phases are replaced by NOON density waves (NDW). These new ground states present density-modulated quantum superpositions of the underlying spin components of the bosons. Finally, we present the phase diagram of the trapped system, which is directly relevant for future experiments.

G. P. Teja

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Fock-state superpositions and efficient entanglement sharing with in atom-cavity systems.

Deterministic generation of Fock-state superpositions in optical pulses remains a long-standing challenge. Atom-cavity systems under the Jaynes–Cummings interaction can in principle produce such states, but adiabatic elimination introduces dispersive shifts that must be carefully accounted for, and cavity leakage into multiple temporal modes causes decoherence. We overcome these issues with a memory resonator and further upgrade the DCLZ entanglement-sharing protocol, suppressing unwanted high-Fock contributions and making performance limited only by photon-number-resolving detector efficiencies. We propose single-atom and Rydberg-atom platforms as a promising test-bed for these protocols.

Gabriela Wójtowicz

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Robustness of spin states for quantum metrology

Quantum metrology encounters significant difficulties in noisy settings, where decoherence quickly diminishes valuable quantum resources. We analyze the fundamental precision bounds of large-spin systems exposed to spatially correlated dephasing. In the regime of weak noise, we derive a perturbative expression for the QFI. This short-time/weak-noise result provides analytical insight into how collective spin moments determine both the achievable sensitivity and its deterioration in the presence of noise. A complete characterization of the QFI can be supplemented with a numerical toolbox. Since exact diagonalization techniques are practically intractable, we propose a tensor-network-based method to compute the QFI and identify the optimal measurement via numerical integration of the Lyapunov equation and characterize the method. Importantly, the numerical implementation requires only the time-evolution algorithm.

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