DesOEQ 2023 Booklet

3rd – 7th of July 2023

TIC Building, University of Strathclyde, Glasgow

Image: commons.wikimedia.org/wiki/File:Strathclyde_University,_Glasgow.jpg

List of Talks

Invited talks will be 35 minutes with 10 minutes for questions. Hot topic talks will be 15 minutes with 5 minutes for questions.

Invited Talks

Hans Peter Büchler *Topological phases with Rydberg atoms*
Callum Duncan *Diabatic protocols for complex systems*
Francesca Ferlaino
Thierry Giamarchi *Hall effect, interactions and cold atomic gases*
Andrew Green *Phase transitions in the classical describability of open quantum systems*
Lucia Hackermuller *Nonequilibrium molecule association - shortcuts to adiabaticity*
Zoran Hadzibabic
Dieter Jaksch *Quantum Physics in Connected Worlds*
Elham Kashefi
Alicia Kollar *spatial and temporal lattices in circuit QED*
Stefan Kuhr Commensurate and incommensurate 1D interacting quantum systems
Achilleas Lazarides
Tom Manovitz
Hannes Pichler
Jonathan Pritchard Scalable Qubit Arrays for Quantum Computation and Optimisation
Ulrich Schneider *Ultracold bosons in unconventional lattices*
Robert Smith
Peter Zoller *Exploring Large-Scale Entanglement in Quantum Simulation*

Hot Topic Talks

Aidan Arnold *Enhanced optical geometries for atoms*
Salvatore Butera *Analogue model of cosmological pre-heating and the back-reaction effect*
Sonja Franke-Arnold *Designing atomic spin structures*
Alex Guttridge *Observation of Rydberg blockade due to the charge-dipole interaction between an atom and a polar molecule*
Mehedi Hasan *Frustration with Negative Absolute Temperature*
Timon Hilker *Hole pairing mediated by magnetism in mixed-dimensional Hubbard models*
Viv Kendon *Multistage quantum walks vs QAOA for optimisation problems*
Sridevi Kuriyattil
Georgia Nixon *Local Floquet Hamiltonian Engineering in Optical Lattices*
Pablo Poggi *Measurement-induced multipartite-entanglement regimes in collective spin systems*
Lorenzo Rosso *Non-Hermitian and Zeno Physics in fermionic lossy correlated gases*
Orazio Scarlatella *Steady-states of laser-driven subwavelength atomic arrays: a dynamical mean-field theory study*

List of Posters

Please place your poster on the board corresponding to your allocated number

Odd numbers will present their poster in Poster Session I on Tuesday and even numbers will present their poster in Poster Session II on Thursday.

Please find poster abstracts at the end of this document.

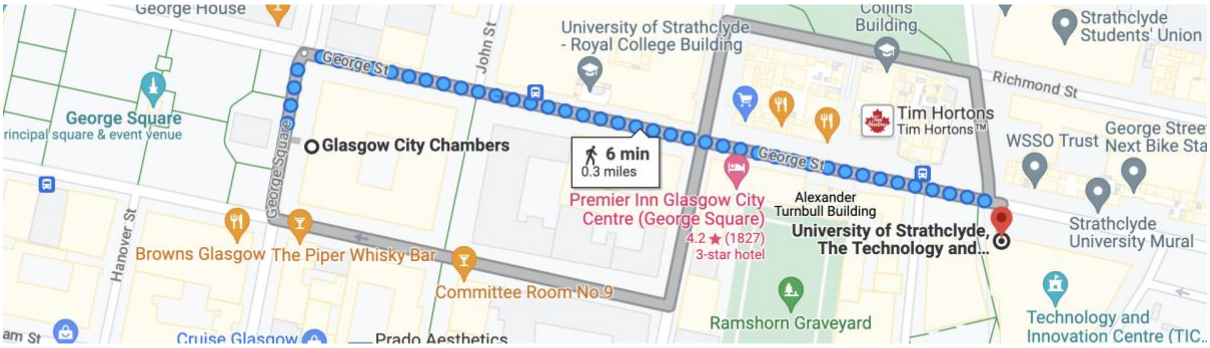
1. **Ryan Connor** *Quantum Inspired Variational Algorithms for Non-Linear PDEs*
2. Robbie Cruickshank *Instabilities of interacting matter waves in optical lattices with Floquet driving*
3. Moritz Cygorek *Divide-and-conquer for numerically exact long-time simulations of driven open quantum systems*
4. Andre de Oliveira *Rydberg Atom Trapping and Quantum Analogue Computing with Blue Bottle Trap Arrays*
5. Elliot Diamond-Hitchcock *Defect Free Atomic Array Assembly With Cesium-133*
6. Moritz Wilhelm Epping and Tim Rien *Machine Learning methods in ultra-cold atoms*
7. Jiri Etrych *Bose Polarons in a Homogenous Bose-Einstein Condensate*
8. Steph Foulds *Determining the Concentratable Entanglement of multipartite quantum states with projective measurements on an ensemble*
9. Emmanuel Gottlob *Bose Hubbard Models for Optical Quasicrystals*
10. Lee Reeve *Dynamics in an Optical Quasicrystal*
12. *Entanglement Spreading in Densely Connected Systems*
11. Zhuoxian Ou *Cold Atoms in an Optical Quasicrystal*
12. Tomohiro Hashizume *Entanglement Spreading in Densely Connected Systems*
13. Thomas Hamlyn *An extended quantum Rabi model with two interacting qubits*
14. Benjamin Hopton *Proposal for multi-frequency light generation to be used for enhanced atom capture experiments*
15. Asa Hopkins *Introducing Trophic Incoherence to Traditional Neural Network Architectures*
16. Lara Janiurek *Nine dimensional quantum walks for solving differential equations*
17. Paul Ireland *Dual-Species Neutral Atomic Qubit Arrays for Fault Tolerant Quantum Computing*
18. Lennart Koehn and Arthur La Rooij *Commensurate and incommensurate 1D interacting quantum systems*
19. Johannes Kombe *Electron transport in engineered one-dimensional nanowires*
20. Arthur La Rooij and Paul Schroff *Accurate holographic light potentials using pixel crosstalk modelling*
21. Milan Krstajic *Measuring the dipolar interaction shift of the BEC critical temperature*
22. Konstantinos Konstantinou *Degenerate 39K Bose gases in dynamic size-tuneable box traps*

23. Gavin Lamb *Characterisation of three-body loss in ultracold 166Er and the production of large dipolar Bose-Einstein condensates*
24. Ewen Lawrence *Numerical approaches for non-adiabatic terms in quantum annealing*
25. Anton Lauenborg Andersen *Quantum Nondemolition Measurements of Moving Target States*
26. Mads Middelhede Lund *Photon subtraction and addition by two-level emitters*
27. Oliver Lunt *Capturing hydrodynamic transport through coarse-grained measurements*
28. Elliott Mansfield *Quantum Transport of Electron Pairs in Helical Nanowires*
29. Gevorg Martirosyan *Far-from-equilibrium Bose gases*
30. Omar Moutamani *Vortex Dynamics in Ultracold Quantum Mixtures*
31. N. S. Srivatsa *Breakdown of operator growth hypothesis in open quantum systems*
32. Oscar Negrete *Solving nonlinear PDEs using qubits*
33. Gerard Pelegrí *High-fidelity multiqubit Rydberg gates via two-photon adiabatic rapid passage*
34. Boyko Nikolov *Randomized Benchmarking Using Non-Destructive Readout*
35. David Reid *Theoretical investigation of topologically robust edge-states physics in a harmonic synthetic dimension and bridging with experiment*
36. Jens Havgaard Nyhegn *Magnetic polaron in a bilayer antiferromagnet*
37. Shinichi Sunami *Probing non-equilibrium dynamics across the BKT critical point by dynamical control of bilayer 2D Bose gases*
38. Matt Overton *Photon Storage in an Interrupted Waveguide*
39. Thomas Young *Coarse-Grained measurements on Gaussian States*
40. Tanish Satoor and Christoph Eigen *Far-from-equilibrium dynamics with two-dimensional Bose gases*
41. Timon Hilker *Hole pairing mediated by magnetism in mixed-dimensional Hubbard models*
42. Paul Wong *d-wave scattering resonances in a 39K Bose gas*
43. Viv Kendon *QEVEC and CCP-QC - developing quantum algorithms for scientific applications*
44. Muhammad Zia *Modelling Charge Transport in Molecular Junctions*
45. Callum Duncan *Counterdiabatic optimised local driving*
46. Sonja Franke-Arnold *Designing atomic spin structures*
47. Callum Duncan *Anomalous Mobility Edges and Critical States in the 2D Generalised Aubry-André Model*
48. Georgia Nixon *Local Floquet Hamiltonian Engineering in Optical Lattices*
49. Alex Guttridge *Observation of Rydberg blockade due to the charge-dipole interaction between an atom and a polar molecule*
50. Lorenzo Rosso *Non-Hermitian and Zeno Physics in fermionic lossy correlated gases*

Civic Reception Information

We will be hosted at Glasgow City Chambers on Tuesday 4th of July at 6:30 pm

Please enter through the main entrance which is located at George Square



Workshop Dinner Information

The conference dinner will be at The Trades Hall of Glasgow, 85 Glassford Street on Wednesday 5th of July beginning with arrival drinks at 6:30 pm.

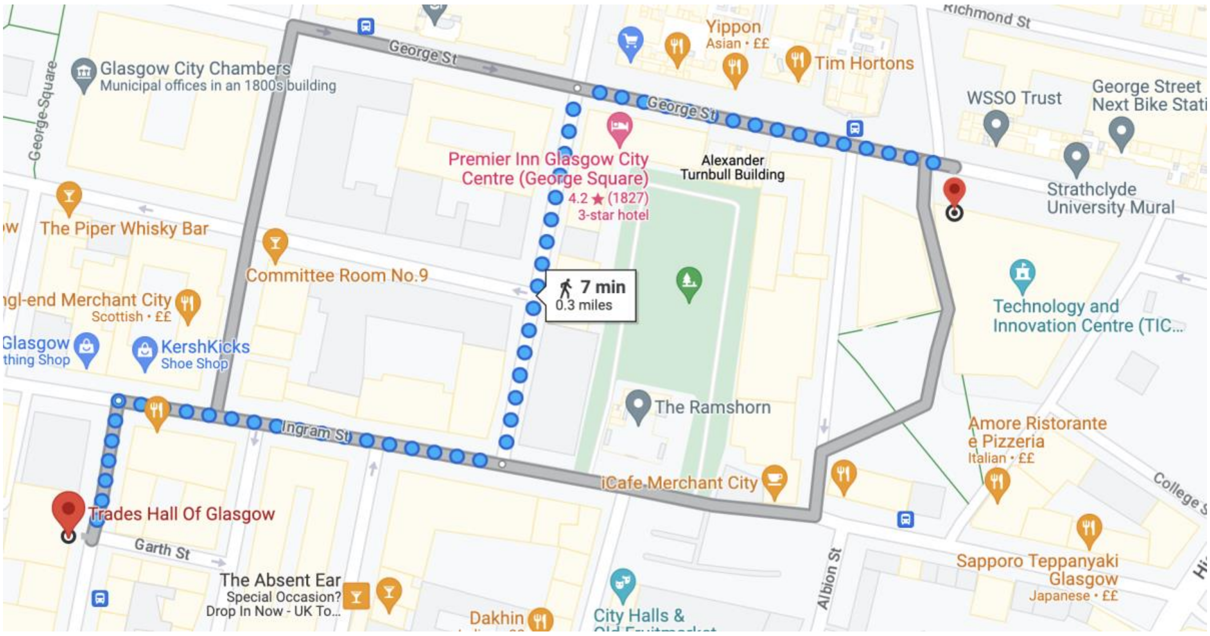


Image: commons.wikimedia.org/wiki/File:Trades_Hall.jp

Poster Session I Abstracts

Tuesday 04th July – 1 pm to 3 pm
(Numbers refer to assigned poster boards)

1. *Quantum Inspired Variational Algorithms for Non-Linear PDEs*
Ryan Connor
Simulating fluid and plasma dynamics remains an important but challenging task in modern physics, with huge memory and CPU requirements to model turbulent flow. Instead of thinking about this problem classically, we utilise techniques developed initially for quantum many-body physics, in the form of Tensor Networks (TNs), to create a physical motivated way to represent the solutions to these non-linear problems more efficiently on classical hardware.

3. *Divide-and-conquer for numerically exact long-time simulations of driven open quantum systems*
Moritz Cygorek
Process Tensor Matrix Product Operators (PT-MPOs) [1] provide an efficient and general [2] framework for numerically exact simulation of open quantum systems strongly coupled to non-Markovian environments. To obtain stationary states and to extract spectral information, simulations over very many time steps are required. Here, we demonstrate a novel PT-MPO algorithm [3] with a scaling advantage over established methods: Our divide-and-conquer strategy realises log-linear scaling with the number of time steps, which becomes constant-in-time if the environment has a finite memory. This makes our algorithm extremely useful for long-time simulations, e.g., to obtain stationary states under non-equilibrium conditions of strong driving and strong coupling to the environment, or to extract spectral information via Fourier transforms. Concretely, we demonstrate million-time-step simulations of spectra of quantum dots coupled to phonons in the strongly driven Mollow regime, reducing the numerical demands from weeks or month to minutes, as well as studies of superradiant emission from several quantum emitters in a Rabi model beyond the rotating-wave approximation. As such, our algorithm provides a significant step forward in modelling open quantum systems, which, in conjunction with scalable PT-MPO approaches to many-body quantum systems [4], paves the way for efficient numerically exact simulations of complex out-of-equilibrium many-body quantum systems.
[1] M.R. Jørgensen, F.A. Pollock, Phys. Rev. Lett. 123, 240602 (2019)
[2] M. Cygorek, M. Cosacchi, A. Vagov, V. M. Axt, B. W. Lovett, J. Keeling, E. M. Gauger, Nature Physics 18, 662 (2022)
[3] M. Cygorek, J. Keeling, B. W. Lovett, E. M. Gauger, arXiv:2304.05291 [quant-ph] (2023)
[4] G.E. Fux, D. Kilda, B. W. Lovett, J. Keeling, arXiv:2201.05529 [quant-ph] (2023)

5. *Defect Free Atomic Array Assembly With Cesium-133*
Elliot Diamond-Hitchcock
Neutral atom systems provide a promising route for quantum computing and quantum simulation. By using the strong dipole-dipole interactions between nearby Rydberg atoms, along with a range of cold-atom techniques, the Scalable Qubit ARays (SQuARe) project at the University of Strathclyde aims to create an effective and scalable quantum information platform.

The first step to realising this neutral atom platform is generating an array of atoms in the desired configuration. We present development on previous work in the field by demonstrating the efficient generation of defect free arrays of neutral Cesium-133 atoms using movable optical tweezers. This includes a novel and scalable algorithm for generating the moves required for rearrangement of atoms.

7*. Bose Polarons in a Homogenous Bose-Einstein Condensate*
Jiri Etrych

9*. Bose Hubbard Models for Optical Quasicrystals*
Emmanuel Gottlob
We developed a method to construct the Hubbard Hamiltonian of non-periodic potentials and illustrate it in the case of the 2D 8-fold optical quasicrystal . To this end, we construct Wannier Functions without resorting to Bloch's theorem and use them to extract the on-site energies, tunneling amplitudes and on-site interaction energies. We then compute the ground state many-body phase diagram of the optical quasicrystal using quantum Monte-Carlo methods to reveal the existence of superfluid, Bose glass and Mott Insulating ground states.

11. *Cold Atoms in an Optical Quasicrystal*
Zhuoxian Ou

13. An extended quantum Rabi model with two interacting qubits
Thomas Hamlyn
We study a modified quantum Rabi model with a monochromatic bosonic mode and two qubits coupled via a spin-spin interaction. We focus on eigenstates of the model in two different regimes. Without qubit mixing, the Hilbert space can be divided into two symmetry sectors. It is found that the model can be reduced to the standard Rabi model, and therefore the eigenenergy can be obtained systematically through solving the so-called G-function. With the addition of the mixing term the nature of the symmetry sectors changes and an analytic spectrum can still be obtained. We study the super-radiant phase transition with the mean field and direct diagonalization method, both giving consistent results. It is found that the addition of the mixing terms breaks the spatial mirror symmetry of the ground state wavefunction.

15. Introducing Trophic Incoherence to Traditional Neural Network Architectures
Asa Hopkins
Artificial neural networks (NNs) at their core are an attempt to emulate the biological NNs found in the brains of animals, and can accomplish certain tasks more efficiently than more traditional computing methods. However, there are still ways that artificial NNs fall short of their biological counterparts. Most artificial NNs are made up of layers of nodes, with edges only being formed between adjacent layers. This kind of strict ordering is not seen in nature and the existence of edges connecting non-adjacent layers is important to the stability of larger natural systems, such as food chains and metabolic pathways. The extent to which this strict layering is broken is known as the trophic incoherence. This work investigates methods of adding trophic incoherence to artificial NNs, and the effects doing so has on the convergence speed

during training (fast convergence is more energy efficient) and the accuracy after training is completed.

17. *Dual-Species Neutral Atomic Qubit Arrays for Fault Tolerant Quantum Computing*

Paul Ireland

Over the last decade, Neutral atom arrays have become a prominent contender as a platform for quantum computation owing to the scalability of optical tweezers allowing for up to 1000 identical qubits in two or three-dimensional arrays [1]. Ultracold atomic qubits benefit from long hyperfine ground state coherent times and the Rydberg blockade mechanism, allowing for high fidelity inter-qubit interaction via the long-ranged dipole-diploe interaction. As with all quantum systems, atomic qubits are susceptible to noise and with this in mind, the next generation of neutral atom arrays will aim to overcome this hurdle through error detection and correction [2]. We present progress toward new experimental apparatus utilising dual-species tweezer arrays of Rb and Cs atomic qubits in a cryogenic system, which allows for longer trap lifetimes. Building on recent demonstrations of high-fidelity operations on arrays of up to 225 atoms in a room temperature system [3], we aim to demonstrate error correction through crosstalk-free readout of ancilla and data qubits as a route towards fault-tolerant, scalable quantum computation. We present a comprehensive overview of the experimental hardware to create our atomic qubits, the underlying methods for creating interspecies gates, and an overview of error detection and correction protocols which will be tested on this system.

This project is supported by the Royal Academy of Engineering, EPSRC and M Squared Lasers Ltd.

[1] M. Morgado and S. Whitlock, AVS Quantum Sci. 3, 023501 (2021)
[2] I. Cong et al., Phys. Rev. X 12, 021049 (2022)
[3] B. Nikolov et al., arXiv:2301.10510 (2023)

19. *Electron transport in engineered one-dimensional nanowires*

Johannes Kombe

Chiral structures are found ubiquitously in nature, and the observation of spin-selective transport suggests that the chirality directly impacts the electron transmission. The role of coherence in the electron transport within chiral systems is believed to be important, but presents a challenge experimentally and theoretically. Here, quantum transport measurements on reconfigurable chiral nanowires at the LaAlO3/SrTiO3 interface reveal oscillatory transmission resonances as a function of both magnetic field, and chemical potential. We interpret these resonances as arising from an engineered axial spin-orbit interaction within the spiral-shaped electron waveguide. From a mean-field Hartree-Fock-Bogoliubov theory we show enhanced electron pairing due to an engineered spin-orbit coupling, reveal the structure of the system's underlying helical eigenstates, and propose an effective scattering model to account for the observed transmission resonances.

21. *Measuring the dipolar interaction shift of the BEC critical temperature*

Milan Krstajic

The effect of dipolar interactions on harmonically trapped BECs has been the subject of intense and fruitful research over recent years, but despite being theoretically calculated over 15 years ago [1] the modification of the BEC transition temperature due to dipole-dipole interactions has, up to now, not been experimentally observed.

We will present our experimental findings on this topic; using an ultracold erbium gas confined in a highly prolate trap we directly observe the dependence of the critical temperature on the orientation of the dipoles relative to the trap.
[1] Phys. Rev. Lett. 98, 080407 (2007)

23. *Characterisation of three-body loss in ultracold 166Er and the production of large dipolar Bose-Einstein condensates*
Gavin Lamb
Dipolar quantum droplets and supersolids are subject to intense research. However, studies are often limited by the achievable atom numbers and hindered by high three-body loss rates. We present our study of density-dependent atom loss in an ultracold gas of 166Er, identifying several previously unknown features which display a strong temperature dependence. We use the detailed knowledge of the loss landscape to produce dipolar Bose-Einstein condensates with more than 2√ó10^5 atoms, pointing towards optimal strategies for the study of large-atom-number dipolar gases in the droplet and supersolid regimes.

25. *Quantum Nondemolition Measurements of Moving Target States*
Anton Lauenborg Andersen
We present a protocol for probing the state of a quantum system by its resonant coupling and entanglement with a meter system. By continuous measurement of a time evolving meter observable, we infer the evolution of the entangled systems and, ultimately, the state and dynamics of the system of interest. The photon number in a cavity field is thus resolved by simulated monitoring of the Rabi oscillations of a resonantly coupled two-level system, and we propose to regard this as a practical extension of quantum nondemolition measurements with applications in quantum metrology and quantum computing.

27. *Capturing hydrodynamic transport through coarse-grained measurements*
Oliver Lunt
Real-time dynamics present a challenge for tensor-network methods, due to the rapid growth of entanglement. However, in thermal equilibrium we need only a few parameters, such as temperature or chemical potential, to fully describe the state. This observation has motivated several approaches which apply ‘artificial dissipation’ (AD) to remove entanglement, while ostensibly preserving the relevant information to describe local observables as they equilibrate. Using insights from recent studies of entanglement phase transitions in monitored systems, we propose an AD method which employs coarse-grained measurements of the local charge density. This scheme is tailored to have small ‘backflow' errors on charge correlators, yet can prove effective at removing entanglement, thereby enabling real-time simulation of hydrodynamics to long times with modest bond dimension. It is simple to implement, requiring only the application of a bond dimension 3 MPO, and has the memory advantage of working on quantum states rather than operators, unlike alternative AD schemes.

29. *Far-from-equilibrium Bose gases*
Gevorg Martirosyan

31. *Breakdown of operator growth hypothesis in open quantum systems*
N. S. Srivatsa

The operator growth hypothesis (OGH) is a technical conjecture about the behaviour of operators, specifically, the asymptotic growth of their Lanczos coefficients, under repeated action by a Liouvillian. It is expected to hold for a sufficiently generic many-body system. When it does hold it yield bounds on the high frequency behavior of local correlation functions and measures of chaos (like OTOCs), as well as a route to numerically estimating response functions. Here we investigate how OGH generalises to open quantum systems where the Liouvillian is replaced by a Lindbladian. For a quantum system with local Hermitian jump operators, we show that the OGH somewhat breaks down: we define a generalisation of the Lanczos coefficient and show that it initially grows linearly as in the original OGH, but experiences exponentially growing oscillations on scales determined by the dissipation strength (which we can analytically control). We see this behavior manifested in a semi-analytically solvable model (large-q SYK with dissipation) and numerically for an ergodic spin chain. We show that the breakdown of OGH arises because the dissipative part of the Lindbladian eventually wins over the the unitary part under repeated application of the Lindbladian. We construct a simple toy model with hopping and dissipation that captures this behavior together with the correct scaling (of the point of breakdown with dissipation strength) observed in the dissipative SYK and the ergodic spin chain models.

33. *High-fidelity multiqubit Rydberg gates via two-photon adiabatic rapid passage*
Gerard Pelegrí
We present a robust protocol for implementing high-fidelity multiqubit controlled phase gates (CkZ) on neutral atom qubits coupled to highly excited Rydberg states. Our approach is based on extending adiabatic rapid passage to two-photon excitation via a short-lived intermediate excited state common to alkali-atom Rydberg experiments, accounting for the full impact of spontaneous decay and differential AC Stark shifts from the complete manifold of hyperfine excited states. We evaluate and optimise gate performance, concluding that for Cs and currently available laser frequencies and powers, a CCZ gate with fidelity F > 0.995 for three qubits and CCCZ with F > 0.99 for four qubits is attainable in 1.8s via this protocol. Higher fidelities are accessible with future technologies, and our results highlight the utility of neutral atom arrays for the native implementation of multiqubit unitaries.

35. *Theoretical investigation of topologically robust edge-states physics in a harmonic synthetic dimension and bridging with experiment*
David Reid
Since the emergence of topological physics, there has been a fascination with investigating robust phenomena, such as topologically-protected edge states. Within the field of analogue quantum simulation, considerable effort has been devoted to realising such topological effects in various platforms, including cold atoms. Unlike solid-state materials, where topological edge states were initially discovered for electrons under the influence of magnetic fields, cold atoms are charge neutral and so this physics has been simulated by other means. In this poster, we will discuss theoretical progress at the University of Birmingham towards experimentally investigating an implementation of topological edge states based on a synthetic dimension of harmonic trap states. Building on our recent 1D experiment, we combine the synthetic dimension of harmonic trap states with a second real spatial dimension in order to simulate a 2D topological system. We discuss how effective

edges can be created along the synthetic dimension of harmonic trap states and present numerical simulations for realistic experimental parameters.

37. *Probing non-equilibrium dynamics across the BKT critical point by dynamical control of bilayer 2D Bose gases*

Shinichi Sunami

We report on the observation of non-equilibrium dynamics across the Berezinskii-Kosterlitz-Thouless (BKT) critical point by dynamical control of bilayer 2D Bose gases. We quench the system by coherently splitting a single 2D Bose gas into two, resulting in a sudden crossing from the superfluid to the normal phase, and we monitor the relaxation dynamics using the matter-wave interferometry technique. From the interference patterns, we obtain the time evolution of the phase correlation function and vortex density and compare with the real-time renormalization group theory. We further report on the observation of the BKT transition in a bilayer 2D Bose gas with controllable coherent coupling between the two layers, which shows a coupling-dependent critical point. Our multiple-RF dressing technique for trapping ultracold atoms allows precise and dynamical control of the coupling strengths between the two layers, which can be used to probe further non-equilibrium phenomena in 2D systems.

39. *Coarse-Grained measurements on Gaussian States*

Thomas Young

Unitary dynamics generated by a Hamiltonian generally leads to the growth of entanglement between regions of a system which are initially not entangled with one another. Meanwhile measurements of observables with support on a subsystem reduces the entanglement between the subsystem and the rest of the system. The interplay between unitary dynamics and measurements gives rise to complex entanglement dynamics which in general is not solvable and often does not exhibit relaxation to a steady state. In some systems such as random unitary circuits and free fermions it has been shown that such a steady state can exist and that there is even a phase transition, between phases characterised by entanglement scaling with system size, as the relative strength of the measurements compared with the unitary dynamics is varied. Here we are not focused on the phase transition but rather the dynamics that lead to different entanglement structures in the steady state, particularly how the dynamics change when the measurements do not reveal complete information about the state of the system. We focus on the particular example of coarse-grained observables, measured using the continuous weak monitoring protocol.

We study entanglement growth in an oscillator chain subjected to Gaussian unitary dynamics and the weak measurement of commuting coarse-grained observables (e.g., total oscillator displacement in contiguous regions of various sizes). We derive expressions for the steady state correlation functions and entanglement entropy for a large class of initial Gaussian states. We find that entanglement is fragile: regardless of the scale of coarse-graining of our measurement variables, as soon as the measurements occur with finite rate and density, entanglement saturates to an area law at long times. These exact results for the steady states are compared with real-time numerical simulations for finite systems, finding excellent agreement in the long-time limit. Interestingly, the time taken for the system to relax to the steady state scales with system size as O(L log L) meaning that in the thermodynamic limit we predict that the entanglement grows linearly in time leading to volume law entanglement. We do not currently have a simple explanation as to why the entanglement saturates to area-law at long times in a finite system and the origin of the O(L log L) relaxation time.

We contrast this with a different setup, where we take volume-law Gaussian states and subject them to coarse-grained measurements and no unitary dynamics. In the strong measurement limit, the post-measurement entropy corresponds roughly to the number of degrees of freedom left undetermined by the outcomes of all the measurements applied. Volume-law entanglement survives when the operators being measured do not overlap in support. Whilst when they overlap substantially the resulting state has area-law entanglement with cat-state-like correlations.

We argue that the measurement of coarse-grained observables might arise in a non-idealised experiment where the ancillary system, used to induce weak measurements on the system of interest, is coupled to it with finite spatial extent (e.g. photons coupled to the total dipole moment for each unit cell in a lattice system).

41. *Hole pairing mediated by magnetism in mixed-dimensional Hubbard models*
Timon Hilker
Unravelling the origin of unconventional superconductivity is one of the driving forces behind quantum simulations with Fermions in optical lattices. In these strongly correlated materials, the necessary pairing of charge carriers is often assumed to be related to the interplay of antiferromagnetic correlations and dopant motion. In antiferromagnets with weak doping, individual holes form magnetic polarons whose motion is strongly reduced due to the magnetic background.
With our quantum microscope, we investigate if pairs of dopants can overcome the frustrating effect and find strong competition between this magnetically mediated hole-hole attraction and repulsion due to Pauli blocking [1]. However, in a mixed-dimensional system [2], where we restrict the hole motion to one dimension while keeping the spin order two-dimensional, we directly image tightly bound pairs of holes[1]. Upon increased doping, we currently investigate the formation of stripes [3], which form the ground state of the standard Hubbard model [4] and support the emergence of d-wave superconductivity [5].
[1] S. Hirthe, T. Chalein, A. Behret, D. Boursund P. Boioxic, F. Grusdt, E. Demler I. Bloch, and T. A. Hilker, Magnetically mediated hole pairing in fermionic ladders of ultracold atoms. Nature 613 462-467 (2023).
[2] Bohrdt, A., Homeier, L., Bloch, I., Demler, E., and Grusdt, F. Strong pairing in mixed dimensional bilayer antiferromagnetic Mott insulators. Nat. Phys. 18, 651-656 (2021).
[3] Schlömer, H., Bobrot, A., Pollet, L., Schollwöck, U., and Grusdt, F. Robust stripes in the mixed-dimensional t-J model. Phys. Rev. Res., 5(2), L022027 (2023).
[4] Qin, M., Chung, C. M., Shi, H., Vitali, E., Hubig, C., Schollwöck, U., White, S. R., and Zhang, S. Absence of Superconductivity in the Pure Two-Dimensional Hubbard Model. Physical Review X, 10(3), 31016 (2020)
[5] Xu, H., Chung, C.-M., Qin, M., Schollwöck, U., White, S. R., and Zhang, S. (2023). Coexistence of superconductivity with partially filled stripes in the Hubbard model arXiv 2303.08376

43. *QEVEC and CCP-QC - developing quantum algorithms for scientific applications*

Viv Kendon
Collaborative Computational Project on Quantum Computing (CCP-QC) is a UKRI EPSRC-funded network linking computational scientists with quantum computing scientists and engineers, to develop some of the first useful applications of quantum computers. Quantum Enhanced and Verified Exascale Computing (QEVEC) is a UKRI EPSRC/STFC ExCALIBUR cross-cutting project funded as part of the development of the next generation of HPC in the UK. The poster will provide an overview of both projects, and how to get involved in the associated knowledge exchange activities.

45. *Counterdiabatic optimised local driving*
Callum Duncan
Adiabatic protocols are employed across a variety of quantum technologies, from implementing state preparation and individual operations that are building blocks of larger devices, to higher-level protocols in quantum annealing and adiabatic quantum computation. The problem of speeding up these processes has garnered a large amount of interest, resulting in a menagerie of approaches, most notably quantum optimal control and shortcuts to adiabaticity. The two approaches are complementary: optimal control manipulates control fields to steer the dynamics in the minimum allowed time, while shortcuts to adiabaticity aims to retain the adiabatic condition upon speed-up. We outline a new method that combines the two methodologies and takes advantage of the strengths of each. The new technique improves upon approximate local counterdiabatic driving with the addition of time-dependent control fields. We refer to this new method as counterdiabatic optimized local driving (COLD) and we show that it can result in a substantial improvement when applied to annealing protocols, state preparation schemes, entanglement generation, and population transfer on a lattice. We also demonstrate a new approach to the optimization of control fields that does not require access to the wave function or the computation of system dynamics. COLD can be enhanced with existing advanced optimal control methods and we explore this using the chopped randomized basis method and gradient ascent pulse engineering.

47. *Anomalous Mobility Edges and Critical States in the 2D Generalised Aubry-André Model*
Callum Duncan
We study the single-particle properties of two-dimensional quasicrystals where the underlying geometry of the tight-binding lattice is crystalline but the on-site potential is quasicrystalline. We will focus on the 2D generalised Aubry-André model which has a varying form to its quasiperiodic potential, through a deformation parameter and varied irrational periods of cosine terms, which allows a continuous family of on-site quasicrystalline models to be studied. We show that the 2D generalised Aubry-André model exhibits single-particle mobility edges between extended and localised states and a localisation transition in a similar manner to the prior studied one-dimensional limit. However, we find that such models in two dimensions are dominated across large parameter regions by critical states. The presence of critical states results in anomalous mobility edges between both extended and critical and localised and critical states in the single-particle spectrum, even when there is no mobility edge between extended and localised states present. Due to this, these

models exhibit anomalous diffusion of initially localised states across the majority of parameter regions, including in both the extended and localised regimes.

49. *Observation of Rydberg blockade due to the charge-dipole interaction between an atom and a polar molecule*

Alex Guttridge

Ultracold dipolar systems, including atoms excited to Rydberg states and polar molecules, hold great potential for quantum simulation and computation. Rydberg atoms offer strong, long-range interactions, which enable the engineering of quantum entanglement and multi-qubit gates through the Rydberg blockade mechanism. Polar molecules also exhibit long-range interactions and possess multiple long-lived rotational states that can be coupled using microwave fields to achieve high-fidelity quantum operations. Optical tweezer arrays have enabled the trapping of both these systems, creating the possibility of a hybrid system that combines the advantages of both platforms. This hybrid system offers new capabilities, including non-destructive readout of the molecular state [1], cooling of molecules using Rydberg atoms [2], and photoassociation of giant polyatomic Rydberg molecules [3].

I will describe the first observation of Rydberg blockade due to the charge-dipole interaction between an atom and a polar molecule. Our experiment involves the creation of a hybrid system consisting of ultracold RbCs molecules and Rb atoms trapped in species-specific optical tweezers. We form weakly bound RbCs molecules by merging together optical tweezers containing Rb and Cs atoms and transfer the weakly bound RbCs molecules to the rovibrational ground state using stimulated Raman adiabatic passage. Finally, we observe blockade of the transition to the Rb(52s) Rydberg state due to the charge-dipole interaction with a RbCs molecule in the rovibrational ground state. The blockade we have observed provides a mechanism for conditional and non-destructive state readout of the molecule and opens up new research directions which I will briefly discuss.

[1] S. Patsch et al., J. Phys. Chem. Lett. 13, 10728 (2022).
[2] B. Zhao et al., Phys. Rev. Lett. 108, 193007 (2012).
[3] S. T. Rittenhouse and H. R. Sadeghpour, Phys. Rev. Lett. 104, 243002 (2010).

Poster Session II Abstracts

Thursday 06th July – 1 pm to 3 pm

(Numbers refer to assigned poster boards)

2. *Instabilities of interacting matter waves in optical lattices with Floquet driving*
Robbie Cruickshank
Superfluids with periodic driving forces can usually be described by the Floquet formalism which provides a time-independent Hamiltonian for the system [1]. Floquet engineering offers a powerful toolbox for quantum simulation in condensates, with precise control over parameters such as hopping and the band structure [1, 2]. Such systems can experience instabilities due to atomic interactions, whereby excitation modes grow exponentially in time, limiting the coherence time of the experiment [3]. We experimentally investigate [3] the stability of a caesium quantum gas with repulsive interactions in a driven optical lattice, creating a stability diagram from slow to fast driving frequencies and from weak to strong driving strengths. We expand analysis of different types of instabilities from static to periodic systems to offer a convenient mapping for the stability between static and driven systems. The results allow for one to avoid unstable parameter regimes in future experiments.
[1]: A. Eckardt, Colloquium: Atomic quantum gases in periodically driven optical lattices, Rev. Mod. Phys. 89, 011004 (2017).
[2]: H. Lignier, C. Sias, D. Ciampini, Y. Singh, A. Zenesini, O. Morsch, and E. Arimondo, Dynamical Control of MatterWave Tunneling in Periodic Potentials, Phys. Rev. Lett. 99, 220403 (2007).
[3]: A. Di Carli, R. Cruickshank, M. Mitchell, A. La Rooij, S. Kuhr, C. E. Creffield, and E. Haller, Instabilities of interacting matter waves in optical lattices with Floquet driving (2023), arxiv:2303.06092.

4. *Rydberg Atom Trapping and Quantum Analogue Computing with Blue Bottle Trap Arrays*
Andre de Oliveira
Red-detuned optical traps are an effective and reliable approach to scalable trapping of single atoms, whilst excitation to Rydberg states enables tuneable interactions necessary for implementing various quantum computation protocols using neutral atom arrays. However, these traps require high intensities that induce AC Stark shifts on atomic optical transitions and are repulsive to atoms excited to Rydberg states. While these challenges can be overcome by performing Rydberg excitation ‘in the dark’ (with traps turned off), this results in increased atom loss and limited operation time.

Alternatively, blue-detuned bottle traps offer a solution to these limitations by trapping both ground and Rydberg state atoms in the same optical potential, but with reduced confinement and Rydberg detection fidelity. We overcome this limitation by implementing bichromatic trap arrays, enabling efficient loading and state detection in deep red traps whilst transferring atoms into arrays of blue-detuned optical traps to demonstrate simultaneous trapping of caesium atoms in both ground and Rydberg states, achieving coherent Rabi oscillations between the two states within the blue trapping potential. Due to the reconfigurable nature of blue trap arrays, atoms can be brought within the Rydberg blockade radius, allowing for strong many-body interactions. Combined with adiabatic frequency-shaped Rydberg pulses, this approach can be used to perform quantum analogue computing and simulation to solve relevant real-world quantum optimization problems in both one and two-dimensional scalable arrays. We provide experimental evidence of the feasibility of this approach and its potential for practical applications.

6. *Machine Learning methods in ultra-cold atoms*
Moritz Wilhelm Epping and Tim Rien

8. *Determining the Concentratable Entanglement of multipartite quantum states with projective measurements on an ensemble*
Steph Foulds
Entanglement is a vital resource in quantum computation and information. In general, the amount of entanglement in a state determines its usefulness. The standard methods for detecting and characterising quantum entanglement are either resource intensive or require prior knowledge of the state in question. We extend the two-qubit pure state entanglement measure concurrence to the multipartite entanglement measure Concentratable Entanglement (CE) and provide a more efficient method of experimentally estimating it, the Bell-basis test for entanglement, the output probabilities of which are related to the CE and purity of the input ensemble state. We show these results are robust to small variations in the input states and are therefore suitable for experimental estimation. The Bell-basis test can be achieved experimentally with current hardware and is particularly suited to larger ($n > 3$) multipartite states. Unlike many other multipartite measures, Concentratable Entanglement (CE) has a simple form, can be directly estimated from experiment, and can be used for mixed states; therefore, we present CE as a standard entanglement measure for multipartite states.

10. *Dynamics in an Optical Quasicrystal*
Lee Reeve

12. *Entanglement Spreading in Densely Connected Systems*
Tomohiro Hashizume
The speed of entanglement spreading in a system is determined by the underlying geometry of a system. When a system is only interacting locally, then it is known that the speed is bounded by a constant value, the Lieb-Robinson bound. When the interactions a non-local, however, the bound breaks down and gives rise to an exotic dynamics such as fast-scrambling dynamics, where the information gets spread exponentially fast across a system. Here we present early time dynamics of entanglement spreading in the models on dense and sparsely coupled graphs; and discuss the emergence of chaotic dynamics when those systems are coupled.

14. *Proposal for multi-frequency light generation to be used for enhanced atom capture experiments*
Benjamin Hopton
We propose an experimental set up for the generation of multi-frequency light, which can be used in place of single-frequency detuned laser light for an increase in atom capture, for example in magneto-optical traps (MOTs), using rubidium atoms. Multi-frequency light generation should enable more than just the low-velocity end of the thermal distribution of rubidium atoms to be captured; the use of multiple frequencies, separated from each other on the order of the natural linewidth of the atomic transition in question, allows a larger class of Doppler shifts to be available

for excitation from the laser. This increases the capture velocity for a MOT, resulting in an increased MOT loading rate and thus atom capture number. Ongoing analysis suggests an increase in the atomic capture rate approximately three to six orders of magnitude greater, although the accuracy still requires some fine-tuning in the simulations. Enhancing the atom capture number in a MOT and producing larger ultracold ensembles of atoms can also be shown to have much more widespread applications for probing currently unobserved and highly debated theories such as the quantisation of gravity and dark matter detection.

16. *Nine dimensional quantum walks for solving differential equations*
Lara Janiurek
Discrete time quantum walks (DTQW) are analogous to classical random walks, however the randomness is introduced via the quantum superposition of states. The wavefunction of the system evolves with discrete time steps. The evolution of the DTQW is governed by two unitary operators, the shift and coin operators. The shift operator allows the quantum walker to move in each direction while the coin operator, that dictates how the walk is performed, can be designed to give the desired dynamics. Here, a nine-dimensional quantum walk is constructed to give the dynamics of a Lattice Boltzmann particle flow on a D2Q9 lattice grid. When the continuum limit of this walk is taken, whereby the lattice spacing and time steps are no longer discrete but instead continuous, it is hoped that the system will produce the Navier Stokes equation. If so, a new way at implementing a quantum Lattice Boltzmann scheme is achieved. This walk might not give the exact form of the Navier Stokes equation, but will still produce some form of differential equation that may be useful.

18. *Commensurate and incommensurate 1D interacting quantum systems*
Lennart Koehn and Arthur La Rooij
Quantum-gas microscopes using ultra-cold atoms in optical lattices offer a powerful platform for quantum simulation with single-atom manipulation and detection capabilities. The key to single-site control is programmable light patterns from a digital micromirror device (DMD) that can create arbitrary potential landscapes. In our most recent study, we apply dynamically varying repulsive DMD potentials to deterministically prepare incommensurate 1D systems of interacting bosonic atoms with controllable particle densities.

Starting from a commensurate state with unit filling, the confining potential is dynamically changed to reduce the available sites while retaining the atom number. We study the spatial distribution of the (in)commensurate gases from the weakly interacting to the strongly interacting regime, as well as the atom number variance to characterise our 1D systems. Finally, we probe their response to an external bias field to measure particle mobility.

20. *Accurate holographic light potentials using pixel crosstalk modelling*
Arthur La Rooij and Paul Schroff
Arbitrary light potentials have proven to be a valuable and versatile tool in many quantum information and quantum simulation experiments with ultracold atoms. Using a phase-modulating spatial light modulator (SLM), we generate arbitrary light potentials holographically with measured efficiencies between 15 and 40% and an accuracy of <2% root-mean-squared error. Key to the high accuracy is the modelling of pixel crosstalk of the SLM on a sub-pixel scale which is relevant especially for

large light potentials. We employ conjugate gradient minimisation to calculate the SLM phase pattern for a given target light potential after measuring the intensity and wavefront at the SLM. Further, we use camera feedback to reduce experimental errors and remove optical vortices. Using a combination of all these techniques, we achieved more accurate and efficient light potentials compared to previous studies.

22. *Degenerate 39K Bose gases in dynamic size-tuneable box traps*
Konstantinos Konstantinou
Homogeneous atomic clouds in optical box potentials have allowed novel experiments on phenomena such as the second sound, critical dynamics and turbulence, which are much harder, or in some cases impossible, to study in the more common harmonic traps, where the atomic density is inhomogeneous [1]. However, the production of box-trapped atomic gases has so far relied on an intermediate cooling step in harmonic traps. Extending the capabilities of box traps, we use electrically controlled focus-tuneable lenses to create optical boxes (for 39K atoms) whose size can be changed in real time. This allows for direct transfer of laser-cooled clouds into a box trap and runaway evaporation via independent control of the trap depth and the collision rate; moreover the initial conditions for evaporation can be improved by performing laser cooling on clouds already trapped in the dark box [2]. Beyond improving the production of homogeneous gases, the dynamically tuneable boxes open further possibilities for many-body experiments with degenerate gases, including studies of thermodynamics in dynamical containers and the attainment of high-density homogeneous gases that are favourable for experiments on collective light scattering [3]. We will give an overview of our first experiments with these novel traps.
[1] Navon, N., Smith, R.P. & Hadzibabic, Z. Quantum gases in optical boxes. Nat. Phys. 17, 1334-1341 (2021)
[2] Yukai Lu, Connor M. Holland & Lawrence W. Cheu, Molecular Laser Cooling in a Dynamically Tunable Repulsive Optical Trap, Phys. Rev. Lett. 128, 213201 (2022)
[3] Lu, Y.-K., Margalit, Y. & Ketterle, W., Bosonic stimulation of atom-light scattering in an ultracold gas, Nat. Phys. 19, 210–214 (2023)

24. *Numerical approaches for non-adiabatic terms in quantum annealing*
Ewen Lawrence
Adiabaticity can be used to improve accuracy and precision of many quantum control procedures such as quantum annealing, adiabatic quantum computing and ground state preparation. However, processes need to be implemented very slowly to achieve the adiabatic limit, lengthening control sequences and increasing the susceptibility of the system to decoherence. One approach to overcoming this problem is to apply counterdiabatic driving, which can be defined via a quantity known as the Adiabatic Gauge Potential (AGP). The AGP characterises the adiabaticity of a system, and in general is a difficult quantity to compute. We present a new approach to symbolically computing the AGP using commutation relations, which we apply to the Ising graph Hamiltonian class as an example. This new approach allows efficient computation of the AGP on larger graphs than were previously possible with other methods.

26. *Photon subtraction and addition by two-level emitters*
Mads Middelhede Lund

We employ a cascaded system approach to numerically simulate the interaction of photon pulses with a two-level scatterer in a chiral waveguide QED setup. We show that the scattering of a two-photon pulse may lead to the predominant population of only two output wave packet modes in an entangled state. In a complementary wave packet basis, this is a product state of two orthogonal single-photon wave packets. Operating this process in reverse allows a perfect merging of distinguishable single-photon wave packets into a single-mode pulse carrying two identical photons. Furthermore, we extend our findings to n-photon pulses, resulting in single-photon subtracted and added states. Utilizing the process with multiple emitters, we propose a scheme for multiphoton addition and subtraction.

28. *Quantum Transport of Electron Pairs in Helical Nanowires*
Elliott Mansfield
We consider an electron waveguide model with a periodically modulated potential along the directions transverse to motion to describe conductance features displayed in recent solid state experiments. By including periodic effects and electron-electron interactions in the mean field, we construct a set of Bogoliubov-de Gennes equations with a Brillouin zone structure. Then by studying the pairing energy around the chemical potential, we can determine whether electrons are transported as pairs or as single electrons. We find that the helical modulation leads to an increase in the critical magnetic field at which electron pairs are broken by the Zeeman splitting. Additionally, the modulation engineers a spin-orbit coupling, which results in triplet pairs in the nanowire region. Then we utilise a scattering model to describe oscillations in the conductance as a result of triplet pairs being interfered out as they backscatter off the interface between helical and unmodulated regions, which is also consistent with experimental results. These results allow us to guide future experiments in these systems in order to understand more about the material, whose highly controllable behaviour would be an excellent prospect for solid state quantum simulation.

30. *Vortex Dynamics in Ultracold Quantum Mixtures*
Omar Moutamani
The study of vortex dynamics can give key insight into the inner workings of superfluid or superconducting systems [1,2]. We report progress towards the construction of an ultracold rubidium-potassium experimental apparatus designed to study the dynamics of vortices in a binary superfluid. The use of a mixture of atoms enables us to fine-tune the interactions between particles, in the vicinity of a Feshbach resonance. In particular, control over interspecies interactions may allow us to reach regimes where quantum fluctuations are dominant [3]. In this experimental apparatus, a dynamically configurable optical potential will be used to attain precise control of vortex nucleation, in different condensate geometries. We expect that this apparatus will allow us to study the interaction of two single-vortices with the same or different circulation, the vortex drag of one superfluid on the other, and the behavior of many vortices in this mixture of atoms.
[1] F. Barenghi et al., Proc. Natl. Acad. Sci. U.S.A. 111, 4647 (2014)
[2] L. P. Pitaevskii and S. Stringari, Vol. 164 (Oxford University Press, 2016)
[3] C. Fort et al., Phys Rev Research 1, 033155 (2019)

32. *Solving nonlinear PDEs using qubits*
Oscar Negrete

This work presents our current progress in the implementation of methods based on Variational Quantum Algorithms (VQAs) that can be implemented in near-term quantum simulators and Noisy Intermediate-Scale Qubit (NISQ) devices for solving the nonlinear Partial Differential Equations (PDEs) that model the complex many-body dynamics of both quantum and classical systems. To illustrate our approach, we demonstrate the first results of solving a simple linear PDE, a quantum harmonic oscillator. We also discuss different classes of Ansatz that yield a well-behaved landscape for parameter optimizations which the VQAs can utilize. With one of the aims being benchmarking these quantum algorithms, we also explore quantum-inspired classical algorithms that use Matrix Product States (MPS) as a framework to encode the values of the solution over exponentially many spatial grid points, while keeping the required computational resources increasing only polynomially.

34. *Randomized Benchmarking Using Non-Destructive Readout*
Boyko Nikolov
Holographically generated arrays of Rydberg atoms have emerged as a competitive, highly scalable platform for quantum computing and simulation. While gate operation fidelities have improved significantly in recent years, state detection methods require further attention. Current experiments typically read out the state of the qubits by inducing state-selective atom loss and are therefore unable to distinguish different loss mechanisms. Furthermore, this destructive detection method is incompatible with repetitive error correction algorithms and necessitates re-loading of atoms on every experimental cycle.

We present the first practical application of a non-destructive readout (NDRO) procedure in the context of randomized benchmarking of microwave single qubit gates. Results on an array of 225 stochastically-loaded Cs atoms using conventional readout demonstrate that our system is capable of performing below the error threshold for fault tolerance. By increasing trap depth and reducing array size to 49, we perform NDRO by scattering light on a cycling transition for 10 ms to achieve a 99% detection fidelity and a 90% survival probability. This allows us to use post-selection methods and reduce our state preparation and measurement error.

36. *Magnetic polaron in a bilayer antiferromagnet*
Jens Havgaard Nyhegn
Adding a dopant to an antiferromagnetic spin background disturbs the spins and leads to the formation of a quasiparticle coined the magnetic polaron, which is theorised to be the charge carriers in the superconducting phase in cuprates. The dynamics of these charge carriers is a long-standing and fundamental problem. Recently, a new generation of quantum simulation experiments based on atoms in optical lattices has emerged that gives unprecedented insights into the detailed spatial and temporal dynamics of this problem, which compliments earlier results from condensed matter experiments. Focusing on observables accessible in these new experiments, we explore here the equilibrium as well as non-equilibrium dynamics of a mobile hole in two coupled antiferromagnetic spin lattices.

38. *Photon Storage in an Interrupted Waveguide*
Matt Overton
Cold atoms are useful for many quantum information applications. Their strong interactions with light give them many uses in atom-photon junctions. However, one difficulty with cold atoms is integrating them with waveguides and other photonic

devices. Here we demonstrate a method that involves trapping the atoms inside a micromachined hole through an optical fibre. By carefully selecting the geometry of the cavity, one can tune the transmission of light through it, with convex parabolic surfaces having the greatest transmission [1].
Here we use caesium atoms to demonstrate electromagnetically induced transparency (EIT) within the waveguide hole. EIT allows the transparency of a medium to be controlled using a laser field. The effects this has on the complex susceptibility leads to slow light and (if the control laser power is reduced to zero) can also lead to photon storage. Integrating cold atoms into an optical waveguide for storage like this has obvious applications in quantum computing and quantum communication.

[1] Cooper, N., Da Ros, E., Briddon, C. et al. Prospects for strongly coupled atom-photon quantum nodes. Sci Rep 9, 7798 (2019)

40. *Far-from-equilibrium dynamics with two-dimensional Bose gases*
Tanish Satoor and Christoph Eigen
In this poster, I will present three sets of recent experiments on far-from-equilibrium two-dimensional Bose gases in uniform potentials.

Firstly, we study wave collapse induced by attractive interparticle interactions, as described by the nonlinear Schrödinger equation. The stability depends on competition between the kinetic and interaction energies, and on the system's dimensionality. Here, we study the collapse behaviour in the critical two-dimensional case, and also contrast it directly with 3D. We observe collapse if the atom number is larger than the critical value, which, due to scale invariance of the 2D Bose gas, is independent of the system size. Furthermore, we study the atom loss dynamics of the collapse event, providing benchmarks for theories of nonlinear wave phenomena.

Secondly, we study self-similar spatiotemporal scaling, as expected near a non-thermal fixed point, during relaxation dynamics from a far-from-equilibrium state. We initiate relaxation from a highly non-thermal state by suddenly turning on the interactions. We observe bidirectional particle and energy conserving dynamics with self-similar spatiotemporal scaling, revealed in the cloud's momentum distribution.

Thirdly, we use a time-varying optical potential to drive the system at a high wavenumber and study the subsequent formation of an inverse wave-turbulent cascade down to low wavenumbers. Using matter-wave focussing to probe the momentum distribution, we are able to resolve a the cascade propagating from the forcing scale to the dissipation (condensate) scale.

42. *d-wave scattering resonances in a 39K Bose gas*
Paul Wong
The tunability of interactions in cold atom systems has proven to be one of the most powerful tools in the field. Most success stories on exploring different interaction regimes, including that of unitarity, so far relied on utilising s-wave Feshbach resonances. Exploitation of higher-partial-wave scattering resonances can open even more possibilities, such as studies of exotic superfluids, but these (generally narrower) resonances remain far less explored. We perform a systematic experimental study of d-wave scattering resonances in the F=1 hyperfine manifold of 39K using atom-loss spectroscopy. Our measurements of resonances in different spin states, and at different gas densities and temperatures, will help identify most promising routes for future many-body experiments.

44. *Modelling Charge Transport in Molecular Junctions*
Muhammad Zia
We present a study of applying the automated compression of arbitrary environments (ACE) [1] method to model charge transport in molecular junctions. ACE is a powerful technique that can simulate the dynamics of open quantum systems, even when the environment is complex. We have applied ACE to model the transport of electrons through a molecular junction. We discuss the implications of our results and the potential of ACE for studying charge transport in molecular junctions.
[1] Cygorek, M., et al., Simulation of open quantum systems by automated compression of arbitrary environments. Nature Physics, 18(3), 273-279 (2022)

46. *Designing atomic spin structures*
Sonja Franke-Arnold
We investigate the transmission of vector beams, correlated in their polarization and spatial degrees of freedom, through cold atoms in the presence of a transverse magnetic coupling field. This creates an atom-state interferometer, whose phase-dependent dynamics allow us to imprint the spatially varying polarization of a vector beam onto atomic spin polarizations. This provides a tool for analysing either the external magnetic field or the vector beam itself: By analysing the absorption profile of a given vector beam we can deduce the alignment of the external magnetic field, demonstrating an atomic compass. Moreover we find that the absorption profiles contain interference fringes whose modulation strength is given by the spatial polarisation correlation of the vector beam, allowing us to identify optical concurrence from a single absorption image.

48. *Local Floquet Hamiltonian Engineering in Optical Lattices*
Georgia Nixon
Ultracold atoms in optical lattices have widely demonstrated success as quantum simulators of translationally-invariant systems. However, the ability to locally tune the parameters of a tight-binding model is a highly sought-after goal which would allow for the simulation of a wider range of quantum phenomena. Motivated by recent advances in realising quantum gas microscopes as well as highly versatile optical tweezers, here we theoretically demonstrate that local control over individual tunnelling links in an optical lattice can be achieved by incorporating a local, time-periodic potential. We employ Floquet theory to capture the dynamics of locally driven optical lattices and investigate applications of this technique in one dimension to engineer various different configurations. Extending to two dimensions, we show that local periodic driving in a three-site plaquette allows for full control of Hamiltonian parameters including tunnelling amplitudes and flux values piercing the plaquette. Our results are applicable to different lattice geometries and demonstrate the vast array of phenomena that can be accessed by periodically driving a system locally.

50. *Non-Hermitian and Zeno Physics in fermionic lossy correlated gases*
Lorenzo Rosso
Several experiments have studied the dynamics of correlated one-dimensional quantum gases in the presence of two-body losses, both for bosons and for fermions. The theoretical characterisation of the interplay between the unitary and

lossy dynamics has thus emerged as an important challenge and it has recently attracted attention. We consider an interacting one-dimensional gas of spin-1/2 fermions with two-body losses. Firstly, we investigate the dynamical phase diagram of the model. The latter characterises the approach to the stationary state and displays a wide quantum-Zeno (QZ) region, identified by a peculiar behaviour of the lowest eigenvalues of the associated non-Hermitian Hamiltonian.

In a second part, we developed a dynamical theory for the QZ regime using an approximation scheme based on an effective decoupling of charge and spin degrees of freedom, where the latter effectively evolve according to a non-Hermitian Heisenberg Hamiltonian. Moreover, by considering different initial states, we present how different spin orders develop peculiar charge properties, witnessed by the momentum distribution function.