Northern Quantum Meeting VI - Newcastle University (13th January 2020)

10:00 - 10:45 *Arrival + coffee*

10:45 - 11:30 **Erik Gauger** - Heriot-Watt University
Harnessing non-equilibrium effects in bio-inspired and engineered quantum networks
This talk will explore the interplay between coherent quantum and dissipative processes that is typical of condensed matter nano-structures embedded in real-world environments. My theoretical approach combines inspiration from the processes and molecular structures that underlie natural photosynthesis with the development of sophisticated open quantum systems approaches. Based on this framework, I will demonstrate the emergence of complex dynamics and non-equilibrium effects. I will argue that some of these effects could become beneficial and unlock non-classical performance for a host of practical applications ranging from improved photodetectors to solar light-harvesting and molecular electronics.

11:30 - 11:50 **Luke Anastassiou** - University of Liverpool
Simulating a quantum spin gyroscope based on projective measurements
Quantum sensors are thought to provide a route to improving the quality of on-board navigation systems in vehicles to reduce the reliance on external references such as GPS and other GNSS systems. We simulate the fundamental principles of a quantum spin gyroscope which relies on projective measurements and we examine the results in the context of quantum information theory.

11:50 - 12:10 **Keaghan Krog** - Newcastle University
Dynamic Simulations of Hot-Electron Quantum-Optic Devices
The advent of single-electron sources and the development of using chiral edge states as ballistic channels for electron transport has allowed for electronic analogues of quantum optic experiments. These open up new ways to experiment and understand the wave properties of electrons as well as find applications to quantum technology e.g. flying qubits. The electrons used are emitted into the edge states with an energy 100meV above the Fermi sea, reducing decoherence. In this talk I will focus on how to model these electrons as Gaussian waves and numerically simulate an electronic Mach-Zehnder interferometer.

12:10 - 12:30 **Adam Stokes** - University of Manchester
Uniqueness of the phase transition in many-dipole systems
The superradiant phase transition in many-dipole systems is debated, because of numerous apparently conflicting no-go and counter no-go theorems which are proven in different gauges. We show that a unique phase transition occurs, and that it manifests unambiguously via a macroscopic gauge-invariant polarisation. We show further that the gauge choice controls the extent to which this polarisation is included as part of the radiative quantum subsystem and thereby determines the degree to which the abnormal phase is classed as superradiant. No-go and counter no-go theorems refer to different definitions of radiation and are therefore not contradictory, but actually equivalent

12:30 - 12:50 **Stefan Spence** - Durham University
Merging optical microtraps containing single atoms
On the route towards assembling defect-free arrays ultracold molecules our experiment has accomplished single atom trapping of 87Rb and 133Cs in optical tweezers. The trap depth and frequency are characterised by spectroscopy and release and recapture experiments. Species-selective loading of the tweezers requires consideration of the atomic polarisability. We will merge adjacent traps using acousto-optic deflectors to combine Rb and Cs atoms.

12:50 - 13:40 *Lunch*

13:40 - 14:00 **Clarissa Barratt** - Newcastle University
Incoherent effects in hot-electron quantum optics
Using dynamical quantum dot single-electron pumps, high-energy single-electrons may be injected into semiconductor systems, reliably and at a high rate. These electrons provide us with a new platform to probe fundamental semiconductor physics in unprecedented detail. We discuss coupling single-electron sources into interferometer geometries, and investigate the effect of the uncertainty in injection energy on the phase contributions of the interferometer's physical parameters. We also present calculations of the decay rate of a hot electron subject to phonon scattering, and determine how the electron injection energy and the magnetic field affect these rates.

14:00 - 14:20 **Laurentiu Constantin Nita** - Durham University
Quantum reasoning
I will present a visual method for performing quantum compilation on small size quantum gate model circuits. This is the process by a quantum program is transformed to a form compatible with a given quantum processor. The search for optimal solutions is extremely important in the current era of quantum computing, where device constraints mean that non-optimal solutions output little more than nonsense. Developing compilation is therefore almost as important as developing hardware in order to deliver useful quantum computation. I will present a method that will allow others not trained in quantum computing to solve quantum compilation problems.

14:20 - 14:40 **Harry Miller** - University of Manchester
Quantum work statistics close to equilibrium
I study the statistics of dissipated quantum work along quasi-isothermal processes, and present a general analytic expression for the resulting work distribution. All work cumulants split into classical (non-coherent) and quantum (coherent) terms, implying that close to equilibrium there are two independent channels of dissipation at all levels of the statistics. For non-coherent or commuting protocols, the work distribution is a Gaussian. On the other hand, quantum coherence leads to positive skewness and excess kurtosis in the distribution, and this non-Gaussianity provides a direct witness of non-classicality. These quantum signatures are illustrated using a quenched Ising chain.

14:40 - 15:00 **Ryan Doran** - Newcastle University
Numerical method for simulating an infinite rotating 2D Bose gas
We present a method for evolving the projected Gross-Pitaevskii equation in an infinite rotating Bose–Einstein condensate, the ground state of which is a vortex lattice. We use quasi-periodic boundary conditions to investigate the behaviour of the bulk superfluid in this system, in the absence of boundaries and edge effects. Our spectral representation uses the eigenfunctions of the one-body Hamiltonian as basis functions. We show how the convergence of this model is affected by simulation parameters. We investigate the quenched evolution of this system from non-equilibrium initial conditions, the evolution to a lattice groundstate, and the melting of this lattice.

15:00 - 15:20 **Amjad Aljaloud** - University of Leeds
A quantum heat exchanger for nanotechnology
Heat exchangers convert heat into other, more easily disposable forms of energy. Here we design a quantum heat exchanger which converts heat into light on relatively short, quantum optical time scales. Our scheme is based on collective cavity-mediated laser cooling of an atomic gas inside a cavitating bubble, which is variation of standard laser cooling techniques. Laser cooling routinely transfers individually trapped ions to nano-Kelvin temperatures for applications in quantum technology. The quantum heat exchanger which we propose here is expected to provide cooling rates of the order of Kelvin temperatures per millisecond for applications in micro and nanotechnology.

15:20 - 15:50 *Coffee*

15:50 - 16:10 **Jasminder Sidhu** - University of Strathclyde
Tight bounds on the simultaneous estimation of incompatible parameters
Estimating multiple parameters is important for many applications in quantum information processing. However, the unattainability of fundamental precision bounds for incompatible observables provides diminished returns for many practical implementations. The Holevo Cramer-Rao bound (HCRB) has instead been proposed as a fundamental attainable bound for multi-parameter estimation problems. A general closed form for the HCRB is not known given that it requires a complex optimisation over multiple variables. In this talk, I show how the HCRB can be analytically solved for two parameters and demonstrate how it can be used to gain deeper insight into magnetic field sensing.

16:10 - 16:30 **Thomas Bland** - Newcastle University
Persistent current formation in double-ring geometries
Quenching an ultracold bosonic gas in a ring across the Bose-Einstein condensation phase transition is known to lead to the spontaneous emergence of persistent currents. We present work examining how these phenomena generalize to a system of two experimentally accessible co-planar rings with a common interface, or to the figure-of-eight geometry, and demonstrate an emerging independence of winding numbers across the rings (Bland *et al.*, arXiv:1911.12802). The persistence of such findings in the presence of dissipative coupled evolution is attributed to the local character of domain formation across a phase transition and topological protection of the randomly emerging winding numbers.

16:30 - 16:50 **Daniel Hodgson** - University of Leeds
A physically motivated quantisation of the free electromagnetic field in Rindler space
As an alternative to canonical quantisation, Bennett *et al.* developed a more intuitive scheme for the quantisation of the electromagnetic field relying on a few experimentally verified assumptions. Here we generalise the scheme to static spacetimes, thus providing a more direct quantisation method in these circumstances. In the Rindler spacetime the scheme reproduces the Unruh effect. It is shown that a quantisation describing locally defined wave-packets may also be constructed using similar assumptions. These wave-packets necessarily contain negative frequency excitations. Here we are especially interested in their consequences for vacuum transformations in the Rindler frame.

16:50 - 17:10 **Jie Chen** - Durham University
Energy Efficient Traffic Routing in Wireless Mesh Network using a Quantum Annealer
Low power network routing design is imperative in future portable device to device communication as these devices are usually facilitated by batteries with limited amount of power supply. Apart from the energy concern, a customer friendly communication will also require timeliness and accuracy. In this work, we formulate this multi-objective optimisation problem as a quadratic binary unconstraint optimisation problem, encode it using a newly devised scheme and solve it using the solver API that is linked to the quantum processor devised by D-Wave, Inc. Results show the feasibility of this pioneering approach in the telecom engineering field.

17:10 - 17:30 **Zach Blunden-Codd** - University of Manchester
Quantum toolbox for strongly coupled open quantum systems
In the weak coupling regime a variety of methods can be used to study open quantum systems. However, as couplings become stronger a naive application of weak coupling techniques can lead to quantitative and qualitative errors. We provide a unified framework for investigating strong coupling techniques, such as chain, reaction-coordinate, and fictitious mode mappings, by way of a “quantum toolbox” of Hamiltonian transformations. This allows us to precisely determine the approximations required for the various strong coupling approaches to be valid, so that we can apply existing methods appropriately and develop new techniques for reaching heretofore unexplored parameter regimes.

17:30 *Pub*

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