Physics Post Graduate Conference

Wednesday 19th August 2020

Room 1

Zoom link : https://strath.zoom.us/j/95971352997 (passcode : 087432)

Time	Student	Primary Supervisor
09:30-09:45	**Rachel Dawson**	**Riis**
	Optically Pumped Magnetometry for Medical Imaging Optically Pumped Magnetometers (OPMs) with ultrahigh-sensitivity are able to detect ultra-low magnetic fields for a range of applications including medical imaging. Magnetoencephalography (MEG) is a type of medical imaging that detects biomagnetic fields caused by electric currents in brain signals and analyses these fields to generate 3D images of real time brain networks. Here we present a type of OPM with significant advantages in cost, operational temperature, and size as an alternative to traditional detection methods for MEG whilst aiming to achieve fT to pT level sensitivity. We discuss an approach to reach this sensitivity by operating in the Spin Exchange Relaxation Free (SERF) regime to null the effects of spin exchange on spin relaxation through a combination of high atomic density and operation within a zero-field environment. To achieve these conditions our experiment uses a caesium vapour cell heated to 120°C encased within a 5-layer mumetal shielding. Once constructed we will test the validity of caesium within a SERF regime OPM for use in MEG based on sensitivity and accuracy.	
09:45 – 10:00	**Matt Mitchell**	**Haller**
	Complex Periodic Potentials formed by Time-Averaged Accordion Lattices Optical lattices, periodic potentials formed by interfering laser beams, are frequently used to simulate condensed matter physics with ultracold quantum gases. Especially within the study of transport phenomena across boundaries and interfaces, the creation of complex optical potentials with barriers, variable lattice spacing, and position-dependent interactions is required. We experimentally demonstrate the time-averaged potentials of accordion lattices with variable lattice spacing to produce rich local structures to mimic non-sinusoidal lattices and boundaries. Our experiment uses BECs of caesium atoms which are trapped in a blue-detuned optical lattice with tuneable lattice spacing, phase, and lattice depth. We form the lattice by focusing two interfering laser beams onto our BEC at variable angles. The phase of the lattice and the intensity of our laser beams are controlled by a piezo mounted mirror and by an acousto-optic modulator. Our setup allows us to quickly tune the lattice spacing from 1.5-20um at frequencies of up to 2kHz. Our first experiments with the lattices will be studying the heating of the atoms, production of complex interference patterns, and band structure measurements of our BEC. Our results will be compared to theoretical simulations of the lattice potentials.	

10:00– 10:15	**Andrew Robertson**	**Henrich**
	Coarse-Grained Simulation of DNA My PhD focuses on the study of DNA through its mechanical and thermodynamic properties. By using a coarse-grained model, the degrees of freedom are dramatically reduced compared to atomic or continuum models while still retaining an accurate thermodynamic representation of the structure. This type of model is very well suited to the study of the mechanical behaviour of longer chains (>1000 base pairs) over longer periods of time, as well as the study of different topologies and their behaviour. This presentation describes my study of these coarse-grained simulation methods, and my research into triplet repeat structures using these methods this year.	
10:15 – 10:30	**Ieva Cepaite**	**Daley**
	Variational Quantum Algorithms for Solving Partial Differential Equations A growing area of research in the field of Quantum Information is that of Variational Quantum Algorithms (VQA) - ways of exploiting quantum technologies and machine learning in tandem in order to minimize resources in solving a much wider range of problems. One particular area of interest in which quantum computers could offer a boost in efficiency is that of large-scale Partial Differential Equations (PDEs) which are often solved numerically while requiring intensive amounts of memory and time on even the best classical computers. Based on recent work, we hope to apply a VQA approach to solving PDEs in order to achieve some form of advantage over current classical methods as well as developing novel ways to exploit the native physics of some quantum technologies in order to implement the protocol more efficiently.	
10.30 – 10.45	**Marcin Mrozowski**	**Griffin**
	Systems Engineering for Atomic Magnetometry Atomic magnetometry presents a new outlook into ultra-high sensitivity magnetic field measurements. With an advent of portable, low power devices which are capable of operation at room temperature and sensitivities approaching these of SQUIDs (Superconducting QUantum Interference Device). Offering access to application such as magnetocardiography and detection of underwater vessels, which was previously reserved for bulkier systems. We present work on systems engineering for alkali atom optical magnetometry, with an overall aim of design and development of a full system control for autonomous operation of an OPM (optically pumped magnetometer) based system. Enabling creation of portable sensors with performance similar to laboratory-based setups.	
	Break 10:45-11:15	

11:15-11:30	**Alan Bregazzi**	**Riis**
	Developing a chip scale laser cooling platform for atomic clocks Through the invention of the grating magneto-optical trap (GMOT) the footprint of the optical set-up required for the trapping process has been reduced dramatically from three counter-propagating orthogonal laser pairs down to just one input beam, incident on a diffraction grating. One of the main factors now limiting a truly miniaturised magneto-optical trap is the vacuum package; that must be capable of maintaining UHV for extended periods of operation. Work towards GMOT imaging in a future microfabricated vacuum cell for use in compact atomic sensors such as atomic clocks is presented here. An additional study has also been undertaken investigating the effect the trap beam profile has on trapped atom number, allowing the maximum possible atom number in any compact device.	
11:30-11:45	**Brendan Keliehor**	**Riis**
	Portable 2-Photon Optical Atomic Clock There is an increasing demand for high accuracy portable atomic clocks in applications like data transmission, remote navigation, and geological meteorology. The ^{87}Rb two-photon transition (TPT), $5S_{1/2} \rightarrow 5D_{5/2}$ is an ideal clock transition candidate for a compact optical atomic clock which could bridge the gap between portable microwave frequency references and state of the art optical frequency references. This research aims to follow in the footsteps of recent work toward a portable optical frequency reference by using a frequency-doubled, narrow-linewidth 1556 nm telecoms fiber laser. This laser will be used to probe the 778 nm ^{87}Rb TPT, using Doppler-free spectroscopy. It has been demonstrated that such a clock is capable of offering excellent short-term fractional frequency stability at the level of $\sigma_y \approx 10^{-13}$ as well as long-term stability of $\sigma_y < 10^{-14}$. With the implementation of a frequency comb, this system can simultaneously provide an electronic frequency reference and an optical frequency reference. Therefore providing direct stabilisation for 778 nm lasers, and for 1556 nm C-band lasers used in long-distance fiber-optic communication as well as for Doppler radar systems.	
11:45-12:00	**Mateusz Mrozowski**	**Pritchar**
	Practical high-brightness quantum illumination for unspoofable LIDAR We present the design of a high brightness heralded photon source for quantum LIDAR. Exploiting the strong correlations from generation of photon pairs offers the advantages of quantum illumination to achieve an enhanced signal-to-noise ratio in presence of strong background noise relative to classical illumination, as well as, developing protocols robust to jamming. Photon pairs at 660 nm & 960 nm will be created using four-wave mixing in a birefringent optical fiber, pumped using transform limited picosecond pulses with GHz repetition rates derived from 785 nm CW laser diode using a cavity-enhanced optical frequency comb. Our simulations predict pulses to have average power of 285 mW, a peak power of 40 W and an expected pair generation rate of 2000 pairs/s.	

12:00-12:15	**Madjid Hadjal**	**McKee**
	Automated classification of ocean colour remote sensing for environmental monitoring and legislative compliance Since 1970, a correlation between the colour of the ocean observed from aircrafts and the algae concentration at the ocean surface has been studied. With the launch of satellites equiped with spectroradiometers during the last forty years, it became possible to access light information in the visible and near infrared from space for the whole Earth everydays. Ocean colour algorithms using band ratio between the blue and green bands has been developped and used to assess the concentration of chlorophyll a, a green pigment used by phytoplancton to convert light into chemical energy. These algorithms are sensitive to multiple factors, such as the aerosols composition of the atmosphere, or the constitutents of the water. They will fail and give an overestimated concentration in coastal and turbid waters by up to several orders of magnitude due to failure of the atmospheric correction, a process trying to measure the signal coming from the water only. Classification of the waters could be a good opportunity to improve the results in turbid areas. We studied the performance of the most recent products in ocean color and started to use machine learning techniques to see if the limitations from the atmospheric correction failure could be avoided by using top-of-atmosphere measures directly.	
12:15-12:30	**Richard Murchie**	**Jeffers**
	Modelling a classical illumination based LIDAR protocol LIDAR (Light Detection and Ranging) is a versatile technology, its advancement is of interest to many fields of science and industry. Modelling classical illumination using quantum mechanics to investigate the physical limits of a LIDAR protocol will then allow a quantum illumination based protocol to be compared, and hence a quantum advantage to be proven.	
Lunch 12:30-13:30		
13:30-13:45	**Anthony Pike**	**Griffin**
	Rotation Sensing with Atom Interferometry Platforms such as GPS provide geolocation data to users under a wide range of circumstances, preventing the runaway accumulation of error that otherwise occurs in dead reckoning systems which attempt to infer their position from internal sensors e.g. 3-axis accelerometers and inertial measurement units (IMUs). Such satellite-systems however are vulnerable to jamming and spoofing by malicious actors and may be unusable under certain weather conditions or subject to outages due to ground station technical issues. Atom based gyroscopes could offer increased sensitivity to rotation, with less drift, than optical gyroscopes and are of interest in inertial sensing applications, providing a potential pathway to reducing or eliminating reliance on these external systems or serving as a reliable alternative when they are not available. Our experiment aims to demonstrate rotation sensing with an atomic Mach-Zehnder interferometer using Bose-Einstein condensates (BECs) of ^{87}Rb as a coherent matter wave source.	

13:45 – 14:00	**Edward Irwin**	**Griffin**
	Cesium SERF Magnetometry for MEG Optically Pumped Magnetometers (OPMs) have become the leading devices for magnetic field detection with their sensitivities now reaching in to the aT/Hz^(1/2) region with the realisation of Spin Exchange Relaxation Free (SERF) magnetometry in 2002. With these extremely sensitive devices access into the world of detecting magnetic fields produced by the body is opened up, most notably magnetoencephalography (MEG) which is the detection of magnetic fields produced by the brain. How this technique works, along with an introduction to magnetometry as a whole, why this area of MEG is of interest to us will be covered as well as how the experiment is designed to achieve this.	
14:00 - 14:15	**Grant Henderson**	**Yao**
	Propagation of structured light through a Bose-Einstein Condensate The ability to structure the intensity, phase and polarization of light opens new possibilities in engineering light distributions for interaction with various types of media, with applications in high-resolution imaging, nanoparticle manipulation, surface plasmon excitation, sensing, and laser machining [1]. In self-focusing (Kerr) nonlinear media uniformly polarized light with a helical phase structure, which carries orbital angular momentum (OAM), is known to fragment while propagating [2, 3]. However, by structuring the transverse polarization distribution, the resultant "fully-structured light" can propagate more stably and take longer to fragment [4]. OAM beams in nonlinear cavities have been shown to form rotating Turing patterns, the velocity of which may be controlled by the phase and polarization structure [5]. Here we investigate the propagation of structured light through ultracold atoms [6]. We demonstrate the formation of interleaved and coincident filamentation patterns appearing in both atomic and optical fields. Using the Non-Polynomial Schrödinger equation to include an alternative two-dimensional description of the evolution of the atomic wavefunction [7], we show that this filamentation process can be enhanced and, in select cases, stabilized if additional non-linear terms describing optical saturation and three-body loss are included. **References** [1] Halina Rubinsztein-Dunlop et al., J. Opt. **19**, 013001 (2017). [2] W. J. Firth and D. V. Skryabin, Phys. Rev. Lett. **79**, 2450 (1997). [3] A. S. Desyatnikov and Y. S. Kivshar, Phys. Rev. Lett. **87**, 033901 (2001). [4] F. Bouchard et al., Phys. Rev. Lett. **117**, 233903 (2016). [5] A. M. Yao, C. J. Gibson, and G.-L. Oppo, Opt. Express **27**, 31273 (2019). [6] M. Saffman and D. V. Skryabin, *Spatial Solitons* (Springer, 2001) pp. 433–447. [7] L. Salasnich, A. Parola, and L. Reatto, Phys. Rev. A **65**, 043614 (2002).	

14:15 - 14:30	**Alan McWilliam**	**Riis**
	Hardware Development for Atomic Magnetometry Optically pumped magnetometers (OPMs) provide remarkably sensitive routes for magnetic field measurements by exploiting the optical transitions occurring in magnetically sensitive alkali metal vapour cells through their interaction with resonant laser light. Microfabrication of these vapour cells at scale using silicon wafer technology serves as a reliable, high throughput method of magnetic sensor production. Currently, analysis of buffer gas pressures and absorption linewidths for caesium filled cells is carried out using machinery available at a cell probing station. Plans for extracting further information about the relaxation rates and atomic coherence lifetimes which will provide an excellent indication of each cell performance involve utilising the Free-Induction-Decay (FID) technique. However, being of a metallic nature the probing station is an inherently magnetically noisy device meaning many modifications are crucial in order to effectively implement this approach. The progress made so far in characterising the magnetic field around the cell measurement region and the next plans for implementing three sets of independent coils to provide the alterations needed for sufficient field control is discussed.	
14:30 - 14:45	**Stacey Connan**	**McKee**
	Optimised modelling of underwater light fields in the Arctic Ocean. Surface Average Temperatures in the Arctic region are increasing at twice the rate of the global average. With this has come a reduction in sea ice cover, snow cover and melting of permafrost. Changes in environmental conditions will mean a shift in Arctic ecosystem dynamics, potentially impacting the global carbon pump and marine food chain. Light plays a crucial in marine ecosystems, but how much detail and complexity do we need to make accurate predictions about primary production? How will increased light entering the water affect phytoplankton populations? This session will explore the possibility of constructing a cost-efficient underwater light model to be used in primary production modelling in the Barents Sea. We hope to determine which optical properties are crucial and which approximations are necessary to provide sufficient accuracy of primary production modelling whilst minimising computational time and cost.	
	Break 14:45-15:15	
15:15-15:30	**Josh Walker**	**Robb**
	Spontaneous magnetic ordering mediated by light We examine the behaviour of a gas of cold atoms which are optically pumped in a single mirror feedback configuration using numerical simulations. We show that pumping with linearly polarised light generates transitions involving Zeeman sublevels and conseqently fluctuations in the magnetic properties of the atoms. This results in a polarisation instability which drives changes in optical phase. Due to the Talbot effect and the single mirror feedback, a feedback cycle results in self-structuring of the atoms into spatially ordered magnetic states. We investigate the spontaneous magnetic ordering present in the system, the effect of external magnetic fields and the resulting rich variety of observed phases. We also look at the association between the atomic populations & coherences and the polarisation properties of the returning reflected light. Results from the simulations are compared with those from recent experiments.	

15:30-15:45	**Beatrice Bottura**	**McConnell**
	Studying Escherichia coli biofilm morphology using the Mesolens Biofilms are biological structures formed by bacterial cells embedded in an extracellular matrix. This conformation protects bacteria from external stress, and can lead to chronic infections and antibiotic resistance. In order to study biofilm morphology, we use the Mesolens, a custom-built microscope with 4x magnification and numerical aperture of 0.47, allowing to image a field of view of 6 mm x 6 mm with sub-cellular resolution along a 3 mm depth. We use fluorescence microscopy to investigate *Escherichia coli* biofilm morphology for cells growing in different media. In particular, we focus on recently-discovered intra-colony channel structures, which are thought to participate in nutrient transport from the periphery to the centre of the biofilm. In the future, we will also study biofilms formed by shape mutants of *E. coli* (from rod-shaped to spherical), as well as by non-motile mutant strains, and investigate the presence of channel structures in those.	
15:45-16:00	**Simon Armstrong**	**Griffin**
	Integrated grating chip for use in ultracold atom experiments Compact cold atom devices are of increasing interest for application in the field of sensors and metrology. A newly designed grating chip featuring reflective diffraction grating and embedded microscopic wires has been realised which should enable the production of ultracold Rb87 atoms by first loading a grating magneto-optical trap (GMOT) before transporting atoms into a Ioffe-Pritchard (IP) magnetic trap wherein evaporative cooling will be employed. This project aims to further develop robust, compact and portable cold atom systems with a novel design.	