CENTRE FOR DOCTORAL TRAINING IN
APPLIED PHOTONICS
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SUSSP 79

International Summer School in Photonic Sensing & Spectroscopy

2 – 11th July 2023

Welcome

Welcome to the programme of the SUSSP79 International Summer School in Photonic Sensing and Spectroscopy. The CDT in Applied Photonics is delighted to be hosting our first in-person summer school since 2018, in the seaside town of St Andrews.

The format of our summer school will involve talks given by our eight fantastic speakers, each of whom will be giving 2 - 3 lectures spread across the programme. There will also be lots of opportunity for discussions at our panel sessions, at social events and excursions.

Posters from delegates will be displayed throughout the week, alongside dedicated sessions for each group and elevator pitches for each poster. We have several prizes available for attendees and we will share details of these in this programme.

A new addition to our summer school this year is our Hackathon. This full-day event will be a chance for delegates to showcase skills in a guided group challenge we think will be lots of fun.

We hope SUSSP79 will be an enjoyable and memorable experience for everyone, and we look forward to welcoming you to St Andrews this July.

Colette Bush
Director, SUSSP79

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Timetable

Sunday 2nd - Thursday 6th July 2023

	Sunday	Monday	Tuesday	Wednesday	Thursday
	2nd July	**3rd July**	**4th July**	**5th July**	**6th July**
9:00 - 9:30		Prof. Anita Mahadevan-Jansen	Dr Harry Milton	Dr Geoffrey Cranch	Hackathon (8:00 -21:00)
9:30 - 10:00					
10:00 - 10:30		Prof. Piotr Maslowski	Dr Hanieh Fattahi	Dr Harry Milton	
10:30-11:00					
11:00 - 11:30		Break	Break	Break	
11:30-12:00		Posters & Pitches	Public Engagement Talk	Posters & Pitches	
12:00-12:30					
12:30-1:00			Prof. Anita Mahadevan-Jansen		
1:00-1:30					
1:30-2:30		Lunch	Lunch	Lunch	
2:30-3:00		Dr Hanieh Fattahi	Dr Harry Milton	Prof. Piotr Maslowski	
3:00-3:30					
3:30-4:00		Break	Break	Break	
4:00-4:30		Panel	Prof. Anita Mahadevan-Jansen	Prof. Martin Lavery	
4:30-5:00	Welcome Reception				
		Observatory Tour	Ceilidh	Formal Dinner	Pizza

Friday 7th - Tuesday 11th July 2023

	Friday	Saturday	Sunday	Monday	Tuesday
	7th July	**8th July**	**9th July**	**10th July**	**11th July**
9:00 - 9:30			Beach Activities	Prof. Anita Mahadevan-Jansen	Prof. Frank Vollmer
9:30 - 10:00					
10:00 - 10:30		Dr Lucile Rutkowski		Prof. Frank Vollmer	Prof. Malte Gather
10:30-11:00					
11:00 - 11:30		Break		Break	Break
11:30-12:00	Prof. Piotr Maslowski	Posters & Pitches		Dr Lucile Rutkowski	Dr Lucile Rutkowski
12:00-12:30					
12:30-1:00	Dr Geoffrey Cranch			Prof. Malte Gather	Prize giving
1:00-1:30					
1:30-2:30	Lunch	Lunch	Lunch	Lunch	Lunch
2:30-3:00	Dr Geoffrey Cranch	Prof. Malte Gather	Craigtoun Park	Promoting Your Research	
3:00-3:30					
3:30-4:00	Break	Break		Break	
4:00-4:30	Panel	Group Work		Panel	
4:30-5:00					
	Board Games Evening			Pub Quiz	

Sunday 2nd July

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9:00 – 17:00	Accommodation Check-in You are welcome to check-in to your accommodation at any point throughout the day
17:00 – 18:00	Welcome Event A brief welcome talk and introduction to the SUSSP79 Photonics Sensing & Spectroscopy. Nisbet Room beside the main reception of David Russell Apartments.
18:00 – 19:00	Evening Meal Served in the dining room of David Russell Apartments
19:00 – 21:00	Welcome Drinks Reception Join us for a drink, some nibbles and an ice-breaker to start the summer school!

Monday 3rd July

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9:00 – 10:00	Prof. Anita Mahadevan-Jansen Biography & Abstract
10:00 – 11:00	Prof. Piotr Masłowski Title: *Optical cavities for absorption spectroscopy and frequency metrology* Biography & Abstract
11:00 – 11:30	Morning Tea Break
11:30 – 13:30	Posters Abstracts
13:30 – 14:30	Lunch Break
14:30 – 15:30	Dr Hanieh Fattahi Title: *Attosecond and femtosecond spectroscopy at extreme limits* Biography & Abstract
15:30 – 16:00	Afternoon Tea Break
16:00 – 16:30	Panel: *How will emerging photonic science technology impact us in the next twenty years?* The iPhone has only existed for 15 years, but already we take for granted the powerful photonic technologies in the palm of our hand like LiDAR, facial recognition and fingerprint sensing. Fast-forwarding twenty years, what will be the impact of emerging technologies like quantum optics, integrated photonics and smart sensors in the domains of healthcare, communication, security and transport?

Tuesday 4th July

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9:00 – 10:00	Dr Harry Milton Title: *Electro-active adjustable Lenses* Biography & Abstract
10:00 – 11:00	Dr Hanieh Fattahi Title: *Attosecond and femtosecond spectroscopy at extreme limits* Biography & Abstract
11:00 – 11:30	Morning Tea Break
11:30-12:30	Camilla Irvine-Fortescue Title: *Public Engagement*
12:30 – 13:30	Prof. Anita Mahadevan-Jansen Biography & Abstract
13:30 – 14:30	Lunch Break
14:30 – 15:30	Dr Harry Milton Title: *Applications of Electro-active Lenses* Biography & Abstract
15:30 – 16:00	Afternoon Tea Break
16:00 – 16:30	Prof. Anita Mahadevan-Jansen Title: Navigating your PhD/EngD & Early Career
20:00- 22:00	Ceilidh *Upper College Hall*

Wednesday 5th July

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9:00 – 10:00	Dr Geoffrey Cranch Title: *Optical fibre sensor technology 1* Biography & Abstract
10:00 – 11:00	Dr Harry Milton Title: *Experiments and Analysis of Electro-active lenses* Biography & Abstract
11:00 – 11:30	Morning Tea Break
11:30 – 13:30	Posters Abstracts
13:30 – 14:30	Lunch Break
14:30 – 15:30	Prof. Piotr Masłowski Title: *Optical cavities for absorption spectroscopy and frequency metrology* Biography & Abstract
15:30 – 16:00	Afternoon Tea Break
16:00 – 17:00	Martin Lavery *Creativity in Engineering*
19:00 - 22:00	Formal Dinner *Lower College Hall*

Thursday 6th July

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8:00- 20:00	Hackathon School of Physics and Astronomy Lunch, refreshments and an evening meal will be delivered to the foyer of the School of Physics and Astronomy
20:00-22:00	Presentations Physics Lecture Theatre B

Friday 7th July

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9:00 – 11:30 Late start

11:30 – 12:30 Prof. Piotr Masłowski
Title: *Optical cavities for absorption spectroscopy and frequency metrology*
Biography & Abstract

12:30 – 13:30 Dr Geoffrey Cranch
Title: *Optical fibre sensor technology 2*
Biography & Abstract

13:30 – 14:30 Lunch Break

14:30 – 15:30 Dr Geoffrey Cranch
Title: *Optical fibre sensor technology 3*
Biography & Abstract

15:30 – 16:00 Afternoon Tea Break

16:00 - 16:30 Panel: *What role will photonics play in the quest for sustainable development and net-zero?*
At its heart of the United Nations' 2030 Agenda for Sustainable Development are its 17 Sustainable Development Goals, which are an urgent call for action by all countries - developed and developing - in a global partnership. Can photonics make an impact in realizing these goals, and if so, what will this look like?

19:00 - 21:00 Board Games
Nisbet Room, David Russell Apartments

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10:00 – 11:00	Dr Lucile Rutkowski Title: *Molecular spectroscopy based on optical frequency comb sources* Biography & Abstract
11:00 – 11:30	Morning Tea Break
11:30 – 13:30	Posters Abstracts
13:30 – 14:30	Lunch Break
14:30 – 15:30	Prof. Malte Gather Biography & Abstract
15:30 - 16:00	Afternoon Tea Break
16:00 - 17:00	Group Work

Sunday 9th July

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10:00 – 13:00	Beach Activities Choice of Kayaking, Surfing, paddleboarding and games on the beach. *Wetsuits are provided but please bring a bathing suit.*
13:00 – 14:00	Lunch
14:00+	Walk to Craigtoun Park

Monday 10th July

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9:00 – 10:00	Prof. Anita Mahadevan-Jansen Biography & Abstract
10:00 – 11:00	Prof. Frank Vollmer Title: *Single-Molecule Sensing with Optoplasmonic Microcavities: i) fundamentals* Biography & Abstract
11:00 – 11:30	Morning Tea Break
11:30 – 12:30	Dr Lucile Rutkowski Title: *Molecular spectroscopy based on optical frequency comb sources* Biography & Abstract
12:30 – 13:30	Prof. Malte Gather Biography & Abstract
13:30 – 14:30	Lunch Break
14:30 - 15:30	Christine Tudhope - Promoting Your Research
15:30 - 16:00	Afternoon Tea Break
16:00 - 16:30	Panel: *ChatGPT and AI—a threat or opportunity for scientific research?* In a world of predatory journals, publish-or-perish culture and deep fakes, can the conventional model of scientific research and dissemination survive, and will we be able to trust the results we read? How do we protect against this, and will AI be a tool to enhance research, or a Pandora's box we will regret ever opening?
20:00-22:00	Pub Quiz *Nisbet Room, David Russell Apartments*

Tuesday 11th July

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9:00 – 10:00	Prof. Frank Vollmer Title: *Single-Molecule Sensing with Optoplasmonic Microcavities: ii) applications* Biography & Abstract
10:00 – 11:00	Prof. Malte Gather Title: *Spectroscopic sensing and control of cellular processes* Biography & Abstract
11:00 – 11:30	Morning Tea Break
11:30 – 12:30	Dr Lucile Rutkowski Title: *Molecular spectroscopy based on optical frequency comb sources* Biography & Abstract
12:30 – 13:30	Prize Giving
13:30 – 14:30	Lunch Break

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10:00	Checkout from David Russell Apartments and onward travel.

Speakers

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Dr Geoffrey Cranch

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Optical fibre sensor technology

Optical fibre sensor technology has been a technological research interest since the 1970s when optical fibre and laser technology were experiencing rapid development for telecommunication applications. Its continued research interest can be attributed to several major commercial and military successes that include the fibre optic gyroscope, distributed acoustic, strain and temperature sensing as well as many niche applications. Major advances over the last three decades in laser technology, optical components and digital signal processing have enabled considerable advances in sensing capability and performance.

In these lectures, I will be presenting the basic principles of operation of optical fibre sensors with a focus on strain sensing. I will show how optical metrology techniques can be applied to provide ultrahigh-resolution measurements, multi-point measurement, and efficient sensor read-out and illustrate the limits of performance of the technology. The final lecture will review a selection of commercial and military successes, review their operating principles and consider some of the drivers behind these successes.

Biography

Dr Cranch received a BSc in Physics from the University of Bath in 1995 and a PhD in Applied Physics from Heriot-Watt University, Edinburgh in 2001. Dr. Cranch has worked in the field of fiber optic sensor technology development for over 25 years, first at the Defence Evaluation and Research Agency, UK and then at the Naval Research Laboratory in Washington DC. He currently leads the Fiber Photonics Section developing fiber optic and photonic sensing technology and devices for precision measurement. The group's focus extends from basic research into novel sensing concepts through to applied research, prototyping and field trial. Application areas for the sensing technology include underwater surveillance and monitoring, structural health, machine and environmental monitoring and experiments supporting explosion monitoring. Dr Cranch has published over 90 journal and conference publications with several invited talks. He has also written two book chapters and holds five patents. Dr Cranch has been Division and Technical Editor (Optical Technology) for Applied Optics from 2010 to 2022 and has served as technical editor for the Journal of Sensors ('11-'14). He has served on the technical and steering committees for the Optical Fiber Sensors (OFS) conference ('07-'present), IEEE Sensors conference ('09-'13) and OSA Sensors conference ('10-'14). He served as general chair for the OFS-27 conference in 2022. He received the Alan Berman Research publication award in 2015 for the development of fiber optic shock wave diagnostics and is a Fellow of the Institute of Physics.

Dr Hanieh Fattahi

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Attosecond and femtosecond spectroscopy at extreme limits

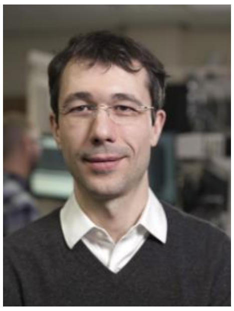
This tutorial is devoted to novel methods for attosecond and femtosecond laser spectroscopy, with an outlook on applications that require extreme spatial resolution. I give an overview on the fundamentals of spectroscopy, and techniques to resolve electron/molecular dynamics. I conclude the tutorial by discussing emerging spectroscopy techniques and their application in hyperspectral imaging.

Biography

Hanieh Fattahi studied Applied physics at Sharif University of Technology in Tehran and received her PhD in Physics at Ludwig Maximilians university of Munich in 2015. She is the recipient of the Minerva fast-track scholarship of the Max Planck Society in 2016 and was elected as a member of "Schiemann Kolleg" in 2017. She has been a visiting scientist of the Chemistry department of Harvard University and Oxford University.

Since 2020, she is leading her independent research group at Max Planck Institute for the Science of Light in Erlangen. She is also the fellow of Max Planck center for Extreme and Quantum Photonics in Ottawa, and Max Planck School of Photonics.

Her research focus is on i) development of mid-infrared and near-infrared few-cycle sources, ii) development of highly sensitive light detection metrologies and iii) Mid-infrared, overtones, and stimulated Raman field-resolved spectro-microscopy.



Prof. Malte Gather

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Spectroscopic sensing and control of cellular processes

Biophotonics has made astonishing advances in the last few decades, today allowing us to extract intricate knowledge about the morphology and composition of biological specimen. However, functional imaging and sensing, in particular to understand processes in biology that are driven by mechanical effects, remains a key challenge. I will discuss new spectroscopic and imaging techniques for recording mechanical activity of cells and tissue that emerge from several developments in my lab. By monitoring resonance shifts of deformable optical micro-cavities and microscopic lasers, we are able to resolve cellular forces in the pN-range and to record cell-contraction induced refractive index changes down to 10^{-5} RIU. Deformable micro-cavities form a "smart Petri dish" for advanced cell culture studies while microscopic lasers constitute bio-compatible local probes for 3D measurements deep within scattering tissue. In addition, I will introduce photonic implants for light-based stimulation and sensing of neuronal activity with cellular specificity and I will explain how careful tuning of resonances, in some cases using strong-coupling between light and matter states, advances the performance of these devices.

Biography

Malte C. Gather studied physics and material sciences at *RWTH Aachen University* and *Imperial College London*. In 2008, he received his PhD with a thesis on crosslinkable organic semiconductors and organic LEDs. As a postdoc at *University of Iceland* and later as Bullock-Wellman Fellow at *Harvard University* he worked on optical amplification in plasmonic waveguides and on opto-biological devices, in particular on lasers based on single biological cells. Malte Gather was assistant professor at *TU Dresden* (Germany) from 2011 to 2013 before getting a full professorship at the *University of St Andrews* (UK). He is currently also an Alexander von Humboldt Professor at the *University of Cologne* (Germany). His research area is at the interface between biophotonics and organic semiconductors.

Prof. Anita Mahadevan-Jansen

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Translating label free optical techniques for clinical use

Medicine is a problem rich environment where there is a critical need for new solutions that ease the life of the patient, the physician and the caregiving staff. For at least some of these problems, biomedical photonics could well be the answer! Optical techniques (both spectroscopy and imaging) can be used to provide real-time assessment for screening, diagnosis, monitoring and guidance of therapy. In this set of lectures – I will overview various label free techniques and their pros and cons as it relates to biomedical applications. We will then discuss 2-3 different medical challenges and the optical solution that was developed and implemented in a clinical setting. These examples include the application of optical imaging for endocrine surgery, optical spectroscopy to study preterm birth etc. As part of this series of lectures, I will provide you with some current challenges in the neonatal intensive care unit and ask you to brainstorm in small groups - one potential solution for one of the challenges and we will discuss how to tackle such challenges in lecture 3.

Biography

Anita Mahadevan-Jansen: Dr. Mahadevan-Jansen translates optical techniques for clinical detection of tissue physiology and pathology. Her primary research at the Vanderbilt Biophotonics Center, is to investigate the applications of optical spectroscopies and imaging for disease diagnosis and guidance of therapy. She received her Bachelor's and Master's degrees in Physics from the University of Bombay (Mumbai), India, and a Master's and PhD degrees in Biomedical Engineering from the University of Texas at Austin. She joined the Vanderbilt engineering faculty in 1996. She is currently the Orrin H. Ingram Professor of Biomedical Engineering at Vanderbilt University and holds a secondary appointment in the Departments of Neurological Surgery, Surgery and Otolaryngology. She is the founding Director of the Vanderbilt Biophotonics Center, a collaborative research center that is focused on the development and translation of light and light-based technologies.

She is the current Immediate Past President of SPIE, the International Society of Optics and Photonics and was the President in 2022. She is a fellow of SPIE, Optica (OSA), American Institute of Medical and Biological Engineering (AIMBE) and was recently inducted into the National Academy of Inventors.

Prof. Piotr Masłowski

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Optical cavities for absorption spectroscopy and frequency metrology

The recent developments of ultra-narrow laser sources as well as the new materials for mirror productions has enabled new experimental approaches based on optical cavities.
The superb control of optical frequencies gave the possibilities to lock tightly the lasers to narrow resonances or measure their shapes and positions with high precision and accuracy. In combination with optical frequency combs, they made possible to sample narrow transitions of cold atoms, creating the optical atomic clocks.

The lecture will make the introduction to the technologies behind those ideas, which will be illustrated with real-life examples of experimental work.

Biography

Piotr Maslowski is an Associate Professor working for Institute of Physics at Nicolaus Copernicus University in Torun, Poland. He obtained his Ph.D. in Physics from Nicolaus Copernicus University in 2008 working on spectral line shapes of atomic species. He has worked at NIST, Gaithersburg in Joseph Hodges group on cavity-ringdown spectroscopy and spend two years in Prof. Jun Ye's laboratory in JILA, University of Colorado in Boulder, USA, working on the developments of direct optical frequency comb spectroscopy. He also contributed to the development of the Sr optical lattice atomic clocks in the National Laboratory for Atomic, Molecular and Optical Physics in Torun. His main scientific interests include novel measurement techniques based on optical enhancement cavities, frequency metrology, accurate and precise molecular spectroscopy with frequency combs or time-resolved broadband spectroscopy of intermediate chemical species. He serves as an Scientific Director of the Institute of Physics at NCU since 2015 as well as was appointed Program and General Chair of EQEC/CLEO EUROPE conference in 2021 and 2023, respectively.

Dr Harry Milton

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Electro-active adjustable Lenses

Variable lenses have shown great promise for ophthalmic and technology applications, including electronic vision correction and fully immersive augmented reality. Typically, these emerging electronic optics utilize a change in refractive index or shape to modify their power. This has shown a great deal of promise when it comes to focus matching of augmented reality optics, and also the correction of the vergence accommodation conflict in augmented and virtual reality, one of the largest issues facing the technology. Additionally, the electronic variation of optical power is promising for the correction of presbyopia, the natural ageing of the eye, where the eye requires a dynamic vision correction in order to replicate the accommodation mechanism of the eye.

In this series of lectures, we will look at the basic optical and engineering principles of several different types of variable lens technology and discuss their strengths and weaknesses. Furthermore, we will look at their implementation in various technologies, including head mounted displays and contact lenses, and address the specific design and optical concerns associated with their form factor. Finally, we will look at common industrial characterization methods and analysis of electronically adjustable lenses, which will give an insight into the practical methods crucial to optical engineers in this field.

Biography

Harry Milton completed his PhD at the University of Manchester where he developed the first electronic contact lens for vision correction. He later worked at Google[x] and Samsung R&D where he worked on electronic vision correction technology for contact lenses and augmented reality systems. He currently works at eVision Optics as a technology director, where he leads electronic lens design for augmented reality, virtual reality and ophthalmic optics. He is an author of 10+ patents, several research papers and the SID Ben Sturgeon Award.

Dr Lucile Rutkowski

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Molecular spectroscopy based on optical frequency comb sources

Optical frequency comb spectroscopy enables precise measurement of weak molecular transitions over a broad spectral range. Their sharp, repetitive spectral features makes them particularly sensitive when coupled with optical cavities, and offer new methods to perform high resolution and broadband spectroscopy in short acquisition time. The increasing availability of non linear methods to generate frequency combs in the mid-infrared and ultra-violet ranges opens up exciting new possibilities for applications in atmospheric sciences and laboratory astrophysics, such as the search for trace species detection, or structural studies of large molecules. The lecture will introduce the instrumental developments that have made this possible, and present some of their latest applications on the characterization of small molecules.

Biography

Lucile Rutkowski is a French CNRS research scientist focusing on the development of mid-infrared frequency comb spectroscopy for laboratory astrophysics and physical-chemistry applications. She obtained her PhD in physics in 2014 developing the Vernier spectroscopy approach before specializing on Fourier transform spectroscopy during her postdoctoral years in Aleksandra Foltynowicz's group. Since 2018, she works in the Department of Molecular Physics at the Institute of Rennes, in France, where she combines comb-based spectroscopy with supersonic jet cooling.

Prof. Frank Vollmer

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Single-Molecule Sensing with Optoplasmonic Microcavities: i) fundamentals ii) applications

Optoplasmonic microcavities based on whispering-gallery modes are sensors developed in the past decade that combine the high quality factors of dielectric microcavities and the small nanometer-scale localization of electric fields by metal nanoparticles to achieve exceptional sensitivity for detecting single molecules in solution. These sensors have enabled the detection of single ions, enzyme activity and various ligand reactions/interactions. I will describes the photonic working principle of these sensors with a focus on the experimental aspects. Reference: https://link.springer.com/book/10.1007/978-3-031-06858-4

Biography

Frank Vollmer is Professor in Biophysics at the University of Exeter, UK. He obtained his Ph.D. in 'Physics & Biology' from the Rockefeller University in NYC, USA, in 2004. He was Rowland Fellow at Harvard University from 2004 to 2009, Scholar-in-Residence at the Wyss Institute at Harvard in 2010, Group Leader (untenured Associate Professor) at the Max Planck Institute for the Science of Light in Germany from 2011–2016 and Instructor in Medicine at Brigham and Women's Hospital/Harvard Medical School where he directed a satellite laboratory from 2011– 2016. Since 2016 he is Professor in Biophysics at the School of Physics, University of Exeter, UK. He received the Royal Society Wolfson Research Merit Award in 2017 and in 2021 the Rosalind Franklin Medal and Prize from the Institute of Physics (IoP). Since 2021 he is Fellow of the IoP.

Poster Schedule & Abstracts

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- Please bring a copy of your poster with you to the Summer School. We will provide velcro to attach these to poster boards.After the summer school ends, we would be grateful if you would take your poster away with you.
- **All posters should be A1 portrait size**
- If there is an error with your abstract below, please contact cdtphotonics@hw.ac.uk with an update as soon as possible.

Monday 3rd July

1. **Material processing of silicon with a novel 2µm wavelength laser source**
   Tara Van Abeelen, Adrian Dzipalski, Stephen Dondieu, Richard Carter, Daniel Esser, Duncan Hand
   Ultra-short, pulsed laser welding allows for the direct bonding of two materials. The desire for the welding of semiconductors grows as modern electronic industries focus on more compact and integrated systems for higher performance and lower costs. Nonlinear effects and longer wavelength transparency regimes make this process more complex compared to the established 1-micron welding of glass. Newly emerging laser systems at 2-micron wavelength shown promise in literature for the processing of silicon. In this project, the aims are to develop a suitable system and demonstrate material processing, including laser welding, using the novel 2-micron laser sources.

2. **Epsilon near zero Metasurfaces in the visible**
   Iman Alhamdan, Sebastian Schulz
   Epsilon near zero (ENZ) materials are materials with a vanishing permittivity around a spectral point known as the epsilon near zero wavelength(λENZ). They are known for their enhanced nonlinear optical properties that elect them for different optical applications. Controlling the localized surface plasmon resonance (LSPR) of plasmonic antennas without altering their size or shape is one of the many implementations of ENZ materials. Some transparent conductive Oxides are naturally occurring ENZ materials like indium tin Oxide which has a λENZ in the

near-infrared region. This makes them suitable for telecommunication and beam steering applications. Optimizing the ITO's λENZ to the visible range will open the frontier for augmented reality applications and chemical sensing. This work aims to develop and optimize a multilayer ENZ metasurface in the visible range that incorporates ITO and gold nanoantennas. A finite-difference time-domain (FDTD) simulation for a metal-insulator-metal (MIM) design that contains a layer of Indium Tin Oxide (ITO) sandwiched between two SiO_2 spacers with gold nanoantenna on the top shows high efficiency in reflection. Another simulation for a design in transmission was performed by removing the back-reflecting metal and one of the two spacers. Results show high efficiency in transmission mode for the proposed design.

3. **AlGaInAs/InP 1.55 μm passively mode-locked laser**

   Mohanad Al-Rubaiee, Shengwei Ye1, Lianping Hou, and John Marsh

   Monolithic mode-locked lasers (MLLs) are a highly suitable option for generating short pulses for various applications, owing to their compact size, mechanical stability, durability, and wide gain spectrum. The monolithic design can be customized to enable mode locking at frequencies ranging from below 10 GHz to over 100 GHz. The objective of this research is to develop a 9.83 GHz 1.55 μm all-active passively mode-locked laser using an AlGaInAs/InP epitaxial structure with an active layer comprising three quantum wells.

4. **Learning from Limited Representation**

   Christopher Boland, Sonia Dahdouh, Sotirios Tsaftaris, Keith A. Goatman

   In recent years, numerous papers have reported clinician-level performance of deep learning models for disease classification from medical images [1]. This work provides a strong rationale for clinical adoption. However, other studies suggest that these models are not equally effective for all demographic groups [2,3]. The cause of these performance disparities is not yet fully understood, but these findings underscore the need for rigorous testing to detect any biases that could negatively impact already underserved patient populations. Identifying the root causes is essential to develop effective strategies for mitigation. We present a study on chest X-ray disease classification that confirms the presence of performance disparities across multiple tasks. We identify features of the data that are strongly correlated with model performance across demographic groups. However, controlling for these at test time cannot fully address gaps in model efficacy. Other features of specific sub-populations that the data does not record may also contribute to differences in performance. Further experimentation is needed to fully comprehend the primary drivers of these performance differences, inform effective methods to mitigate them, and develop more equitable models for healthcare.

5. **Tunable Optical Metasurfaces for Industrial Applications**
   Jemma Elizabeth Callaghan
   The aim of this project is to design and demonstrate through simulation a proof-of-concept for a beam steering or beam forming module, based around an active optical metasurface. This metasurface should be capable of dynamically tuning light properties such as phase and polarisation and may be electrically tuned. There must be an assessment of which metasurface material and tuning mechanism is most favourable for this application. Whether or not the resulting module is suitable for commercialisation will be investigated.

6. **Basic Demonstration of Coherent Beam Combination of three beams**
   Patrick J. Foley, Ian J. Thomson, M. J. Daniel Esser
   Coherent Beam Combination is a technique which can be used to overcome the scaling limits of single laser sources. In this work, a basic demonstration of CBC of three mW power beamlets is shown. The purpose of this was to demonstrate the importance of the multiple parameters which all need to be controlled to ensure efficient CBC is achieved.

7. **Fibre coupled on-chip integrated CO2 sensor at 2 μm for trace gas detection**
   Femy Francis, Keenan Philip, Ann Harvey and Andrea Di Falco
   Infrared – Tunable Diode Laser Absorption Spectroscopy (IR-TDLAS) is a versatile technology that enables the continuous, real-time monitoring of gases with high sensitivity and remote accessibility suitable for industrial and environmental trace gas detection. But the wide area deployment of this technology is limited due to its bulkier optical components; particularly the optical gas cell which requires a large optical pathlength for high sensitivity. Through this project we aim to develop IR -TDLAS based fibre coupled on-chip optical sensors for CO2 with a reduced footprint. Here we replace the conventional gas chamber of TDLAS sensors with Slotted Photonic Crystal Waveguide (SPCW) made on Silicon on Insulator (SOI)

platform. SPCW geometry of the waveguide combines the properties of both photonic crystal and slotted waveguide, i.e., to slow down light and increase the electric field confinement leading to an enhanced light-gas interaction crucial for sensing. These optical waveguides are later fibre-coupled with a tunable laser at 2μm to study the absorption spectra.

8. Long-term optical gas sensor deployment: research tools and practical challenge

William TT Gash, Dr William N Macpherson

This project will develop an optically interrogated, in situ gas sensor system to support ongoing long-term materials ageing experiments conducted by the Atomic Weapons Establishment (AWE). AWE is responsible for maintaining the UK's nuclear deterrent throughout the whole product lifecycle. A key aspect in this role is understanding how materials ageing processes can impact material properties, and hence the ability to understand and predict the effect of these material ageing processes is a key part of underwriting the UK's nuclear stockpile. Long-term materials ageing experiments provide a valuable method for collecting the data required to support such predictions, and optical sensors have been identified as a possible tool for real-time, in situ measurement of the test environment whilst also not perturbing the experiment.

Optically interrogated techniques have been chosen as a suitable sensing solution thanks to several desirable characteristics. An optical sensor can have a smaller form factor than traditional gas sensors; can easily be chemically compatible with the test volume; can be implemented with fibre optics to enable remote sensing; and need not introduce an electrical current into the system. Alongside these characteristics, absorption-based gas sensing techniques that are mature and relatively easy to implement exist, such as tuneable diode laser absorption spectroscopy (TDLAS). While fibre-implemented optoelectronic gas sensing is a well-understood field of research, the novelty herein lies in overcoming the constraint of being unable to rely upon periodic calibration with a known calibrant to ensure sensor reliability over great timescales.

9. **Joint Spectral and Textural Feature Extraction in Hyperspectral Images for Corrosion Detection**

   Aoife Keane

   This study focuses on the joint extraction of textural and spectral features from hyperspectral images (HSI) of induced corrosion. The hyperspectral images were acquired in the visible-near infrared (VNIR) range of 400-900nm. The textural features were computed from local binary patterns (LBP) of the first principal component (PC) of the HSI. These feature vectors are then fed into a SVM for corrosion detection. This work has shown that by combining both textural and spectral features, more accurate and robust models can be developed for corrosion detection.

10. **Identification of bacterial biofilms in industrial pipes using fluorescence**

   Minahil Khan, Thomas F Krauss

   Bacterial contamination is an important issue in industrial manufacturing and there is a need to detect and identify bacteria in a label-free and a cost-effective manner. A particular challenge is in-line detection, i.e. the detection directly in an industrial process plant without the ability to take samples to a remote laboratory, which is the goal of this project. We use autofluorescence, because bacteria contain biomolecules such as flavins and porphyrins that autofluoresce in the green and red spectral region, respectively. Initial experiments were performed on Escherichia coli and Halomonas, both of which show strong autofluorescence in the green and weaker signals in the red. We also aim to resonantly enhance this autofluorescence signal using guided mode resonances (GMR). The future goal is to attach a miniaturized set-up directly to the process pipes that can detect and identify bacterial contamination.

11. **Liquid crystal lasers: a combined molecular-electromagnetic model towards improved higher power stability**

   I. Pakamoryte, D. Marenduzzo, N. Polydorides, P. J. W. Hands

   Dye-doped chiral nematic liquid crystal lasers are a topic of increasing importance in soft-matter photonics. Broad wavelength tuneability (460-850 nm) and low cost and self-organising optical cavities make LC lasers extremely useful for a wide range of potential applications: for example, in fluorescence microscopy, enabling precise

wavelength control for targeted fluorophore excitation; and in low speckle laser based imaging. However, liquid crystal laser stability and power output are limited by several factors, including temperature, choice of materials, and pump pulse parameters. Pump pulse intensity and repetition rate must be carefully controlled to avoid thermal excitation, optically-induced reorientation, and triplet state generation, although these are mostly temporary. In extreme cases, permanent degradation (i.e.photobleaching) of the dye is also possible.
A comprehensive study of the relative importance of the above effects under a variety of different experimental conditions has not been made. We will present a molecular-electromagnetic chiral nematic liquid crystal laser model, which we are developing to further investigate the molecular dynamics of dye-doped chiral nematic liquid crystal under the pump beam illumination over time. It is hoped that by fully understanding this parameter space, higher power lasers with stable performance can be produced,that are suitable for commercial applications.

12. **Fabrication of Silicon Nitride Devices for Frequency Comb Generation**
Cosmin Ionut Suciu, Jonathan Silver, Marc Sorel
Silicon nitride has a high Kerr coefficient, and low losses in the near IR and visible regions, making it ideal for non-linear Four Wave Mixing (FWM) applications, such as parametric amplification and frequency comb generation. The project focuses on fabricating 800 nm tall waveguides and microresonators, as the best dispersion for FWM is achieved around this height. The main fabrication challenge is etching the material, for which a dry (plasma) etching recipe with a $CHF_3/O_2/N_2$ chemistry was picked. This is because it offers good selectivity over the masking material and allows us to etch through the whole 800 nm of silicon nitride. The recipe however is yet to be well optimised for anisotropy, which determines the verticality of the sidewalls and how well the dimensions of the waveguides are preserved. This is done by adjusting tool parameters and gas flows, to obtain etched features that look vertical and have no shrinkage when inspected using electron microscopy. The recipe can later be fine-tuned using propagation loss testing.

13. **Optical Spectroscopy to Enable Screening in the Liver Transplant Theatre**
Shannon P. Thompson, Colin J. Campbell, Gabriel C. Oniscu
The rising prevalence of liver disease, caused by increased exposure to risk factors such as obesity and alcohol consumption, is accelerating the number of patients

who require a transplant. As a result, demand for liver transplants is exceeding the number of organ donors. To expand the donor pool, acceptance criteria for donor organs must be broadened; however, these are associated with increased patient risk. The use of marginal donor livers, that would have otherwise been discarded, necessitates an improved method for viability assessment to predict liver function as current methods are subject to the surgeon's experience. Raman spectroscopy has recently shown promise as a quantitative tool to assess liver quality prior to transplantation. This application has been made possible by the diagnostic window opened by advanced novel preservation techniques. Understanding bile composition provides vital information about liver health. In this study, initial investigations utilising NMR spectroscopy revealed that the main components of bile were lactate and conjugated bile acids: taurocholic acid and glycocholic acid. Abnormal concentrations of these components in the bile can indicate liver dysfunction. Raman spectra was also successfully acquired for these components; however, further work is needed to reduce the fluorescence background in the Raman spectra for bile. Overall, the main bile components and the spectral signatures associated with these in both NMR and Raman spectra have been identified and these could potentially be used to inform about liver health and assist in clinical decision making.

14. Time-resolved fibre optic distributed temperature sensing with CMOS SPAD arrays

<u>Caitlin Tye</u>, Katjana Ehrlich, Andrew Green, Michael Tanner

Time-resolved fibre optic distributed temperature sensing maps out the temperature profile along the length of an optical fibre, using time of photon travel to determine location. One of the main benefits of using an optical fibre as a temperature sensor is that the optical fibre can replace multiple individual sensors. Additionally, the flexibility and size of the optical fibre enable access to otherwise inaccessible environments such as mountain snowpacks or under lakes. Here we present temperature measurements along an optical fibre using a time resolved 512 pixel single photon avalanche diode (SPAD) line sensor array, RAII. In time correlated single photon counting mode this obtains the intensity of the backscattered Raman light from the fibre as a function of time and wavelength. The arrival time of the backscattered photons is used to determine the position of the Raman scattering in the fibre. At the different scattering positions, the temperature of the fibre is obtained by taking the ratio of the temperature dependent Raman Stokes (red-shifted) and Raman anti-Stokes (blue-shifted)

scattering. In contrast to previous work based on individual detectors, the use of a SPAD array with integrated (on-chip) timing electronics allows multiplexed single photon counting where numerous detectors measure the Stokes / anti-Stokes signals simultaneously. This increases count rate, and therefore decreases measurement time for practical application.

15. Optical Coherence Tomography using Harmonic Images

Dorian R. Urban, Tom Vettenburg, Miguel Preciado, Pavel Novak

Optical Coherence Tomography (OCT) is an interferometric imaging technique capable of cross-sectional imaging of biological tissue and other materials. The technique is widely used from dentistry to material inspection, though here we focus on its predominant application in ophthalmology. The imaging depth of conventional OCT is limited to a few millimeters, making it impossible to image the entire depth of the eye in a single capture. Here we demonstrate an OCT system that synthesizes harmonic images via opto-electronic frequency shifting. The axial position of the harmonic images can be controlled independently of the reference arm position. We demonstrate this method by generating a harmonic image of a model eye and discuss the reconstruction process required to recover a high-resolution image.

16. Miniaturizing Focus Variation Sensors for Optical Metrology Using Metalenses.

Pengqian Yang, Haydn Martin, Andrew Henning, Jane Jiang

With the increase in nano-processing technology and the improvement of computational electromagnetic theory, attention has been focused on artificial materials such as metamaterials to obtain ultra-compact devices with excellent optical properties. Metamaterials are artificially produced unique materials consisting of cells with dimensions close to subluminous wavelengths, arranged in an orderly periodic pattern. This study will evaluate and validate the potential of metalens as miniaturised focus change sensors and expand the applications of metalens through simulation and design.

17. Self-referencing wide spectrum interferometry optimised for point of care biosensing applications

Alan Yahya, Thomas Krauss and Isabel Barth

Optical interferometry realised by a metasurface that both polarises light and introduces a lateral shear allows for a setup with minimal loss of light due to components or noisy optical modes. Resonant reflection is achieved using a 2-dimensional nanosurface, and the use of shear interferometry imaged by a CMOS camera permits low integration times for instantaneous read-out in point of care applications. Using a guided mode resonance approach we achieve a similar figure of merit to standard surface plasmon resonance based biosensors, but realised with a far lower material cost, by using inexpensive optical components and a 3D printed resin body for the sensor components. Our interferometric system is self-referencing and common-path, which means it is robust to mechanical vibrations. A water-soluble biological sample is added to the sensor surface, which is bio-functionalized to only bind with a specific antigen or biomarker, and evanescent tail sensing with a length based on the effective refractive index of the chosen nanosurface material and chosen optical mode (TE or TM) gives the change of refractive index caused by the bound target molecules. This then allows us to determine the concentration of those biomarkers, providing useful clinical information.

Wednesday 5th July

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1. **Mussel-inspired one-step biofunctionalisation protocol for photonic biosensors**
   Shrishty Bakshi, Kezheng Li, Pin Dong, Isabel Barth, Casper Kunstmann-Olsen, Steven Johnson and Thomas F. Krauss
   Photonic biosensors hold great potential for developing point of care diagnostic tests because they offer miniaturisation, low-cost realisation and the ability to detect analytes at very low concentration. A significant obstacle is the lack of a robust, cost effective and reproducible surface chemistry. Here, we studied a mussel-inspired polydopamine-based surface coating as a robust one-step method for biomolecule immobilisation on photonic biosensors. The polydopamine protocol is very easy to implement, hence does not require highly trained personnel. It is resistant to hydrolysis, which is one of the major disadvantages of currently used protocols and a great hindrance towards large scale commercialisation. The polydopamine protocol helps to immobilise bioreceptors with high density resulting in a strong signal for antigen detection with wide dynamic range and very low limit of detection (pg level). We demonstrate the detection of a wide range of clinically relevant antibody and biomarkers such as C-reactive protein, Tumor necrosis factor-α, Interleukin-6, Immunoglobulin etc. The polydopamine surface chemistry is also sufficiently robust to allow performing measurements in complex biofluid such as 10 % human serum with a clinically relevant limit of detection as low as 10 ng/mL for immunoglobulins.

2. **Mode selective photonic lanterns in biophotonics**
   R.I. Becerra-Deana, M. Poinsinet de Sivry, S. Virally, N. Godbout, C. Boudoux
   Various biomedical applications utilize optical fibers, including microscopy, endoscopy, and light-based therapies. They have become an essential tool for the early diagnosis of diseases in biomedical optics because they can reach inaccessible parts of the human body with alternative techniques. A single-mode fiber is commonly used for coherent detection, while the multimode fiber provides a high light transmission rate. This project presents mode selective photonic lanterns (MSPLs), fiber-based components combining a multimode performance with a single-mode. These devices are made by fusing and tapering several optical fibers

creating a few-modes structure in which each mode is coherently sorted into different fibers at the output. MSPLs are low-loss devices with values around -0.2dB of excess loss, wavelength- and phase-independent in a bandwidth of 500 nm, and with high isolation between each mode reaching 25dB, allowing them to be implemented for illumination or detection in several areas, such as imaging and sensing. This project shows some preliminary results of the fabrication process and implementation of MSPLs in Optical Coherence Tomography (OCT), providing a specific contrast.

3. **LNOI waveguides for frequency generation in the MIR**

Riccardo Brameri, Cosimo Lacava, Ilaria Cristiani, Mathieu Chauvet

The Medium InfraRed (MIR) represents a fundamental window of the electromagnetic spectrum to detect and analyse atmospheric pollutants (e.g. N2O, CO2, C2H2, Methane, etc). In this work I will present the recent results that I obtained regarding the design and the characterization of LNOI integrated waveguides for DFG mid-IR frequency generation.

The waveguides are designed to exploit the DFG non-linear scheme to synthetize frequency lines at 2.8-3.8 μm regions, starting from custom realized compact pump lasers positioned at the 1 μm and 1.55 μm regions.

The designed waveguides were 2 cm long, based on a square section 8 μm x 8 μm. The LiNbO3 lays over a SiO2 substrate 0.6 μm thick, bounded to a silicon wafer through a gold lamina. To reach the phase matching and so a high conversion efficiency the waveguides present a periodic inversion of the ferroelectric domain of the crystal. This inversion is achieved setting a specifically laser cut titanium mask over the LiNbO3 and applying high voltage pulses. The poling period is set between 24.4 and 25.2 μm to be able to cover a wide frequency band. The wafer is polished to reach the wanted waveguide height, then waveguides and chips are diced.

4. **Design of a Short Pulse Optical Parametric Amplifier for a 10 Hz Petawatt Facility**

S. Buck, D. Reid, M. Galimberti

The design and challenges of a 4-stage optical parametric amplification system is presented including layout, amplification modelling, and diagnostics. The system will be required to amplify broadband (740-850 nm) pulses from the micro-joule level up to 1.5 J and will be a key section of a new 10 Hz petawatt laser system for the Extreme Photonics Application Centre.

5. **Development of a Cross-Polarised Imaging System for Assessing the Quality of Large Aperture Titanium-doped Sapphire Crystals**
Danielle Clarke, Aleksander Flak, Mariastefania De Vido, Paul Mason and M J D Esser
Growing good quality, large-aperture Titanium-doped Sapphire crystals, with the high doping concentrations required for laser operation, is expensive and time consuming. During crystal growth, misalignments can occur, causing defects, which inhibit laser performance. This can be minimised by slowing the growth process down, which is feasible for small aperture crystals but becomes very demanding for the large-aperture crystals used in high average power laser systems. Assessing the quality of crystals is important so the best quality crystals can be selected for use in these laser systems. Here, we report on the development of a large-aperture cross-polarised imaging system for assessing the quality across the aperture of the gain media crystals.

6. **Multimodal Generation of Radiology Reports using Knowledge-Grounded Extraction of Entities and Relations**
Francesco Dalla Serra, William Clackett, Chaoyang Wang, Hamish MacKinnon, Fani Deligianni, Jeffrey Dalton, Alison Q O'Neil
Automated reporting has the potential to assist radiologists with the time-consuming procedure of generating text radiology reports. Most existing approaches generate the report directly from the radiology image, however we observe that the resulting reports exhibit realistic style but lack clinical accuracy. Therefore, we propose a two-step pipeline that subdivides the problem into factual triple extraction followed by free-text report generation. The first step comprises supervised extraction of clinically relevant structured information from the image, expressed as triples of the form (entity1, relation, entity2). In the second step, these triples are input to condition the generation of the radiology report. In particular, we focus our work on Chest X-Ray (CXR) radiology report generation. The proposed framework shows state-of-the-art results on the MIMIC-CXR dataset according to most of the standard text generation metrics that we employ (BLEU, METEOR, ROUGE) and to clinical accuracy metrics (recall, precision and F1 assessed using the CheXpert labeller).

7. **Extrapolated Phase Screens for Simulating Optical Turbulence in Complex Environments**

Ultan Daly, Zhaozhong Chen, Andrew Lord, Martin P.J. Lavery

Free-space optical communication promises high-bandwidth communication systems with a low infrastructure cost. One of the major complications to realising this technology is turbulence, which introduces refractive index variations throughout the channel that distort the optical beam, reducing the system performance. Proposed urban free-space optical communication channels can have complex turbulence distribution profiles, requiring expensive site surveys to determine expected beam distortions. Alternatively, expected beam distortions can be determined by simulating optical propagation through computational fluid dynamics (CFD) simulations of a proposed channel. However, the required CFD resolution to capture all relevant optical turbulence length scales is a computationally difficult task, making it an unsuitable approach for longer channels. In this work we utilise a low-resolution Large Eddy Simulation to capture the effect of low-frequency eddies, and the turbulence profile distribution of a channel. Statistically representative high-frequency components of the screens are then extrapolated under the assumption of Kolmogorov turbulence. We investigate the power spectral densities of the generated screens and find good agreement with the Kolmogorov power law. Additionally, we analyse the results of optical propagation through a simulated channel using extrapolated phase screens, and compare the results to propagation through a purely statistical channel.

8. **Development of an optical sensor for the detection of nitroaromatic compounds**

Michele Duarte Tonet; Eli Zysman-Colman; Graham Turnbull

Besides having a huge impact in terms of security and environmental preservation, the detection of explosives also contributes to the tracking of dangerous environmental hazards, which represents a barrier to the redevelopment of post-conflict areas. In this context, fluorescence spectroscopy is a powerful technique for optically sensing explosives as well as other nitroaromatic compounds[1, 2]. In fluorescence sensors, the photophysical and chemical interaction between the fluorophore and the target analyte leads to a change in emission intensity, efficiency, wavelength and/or lifetime of the fluorophore molecule, allowing the development of non-destructive and flexible sensors with high sensitivity and fast response (10-8 – 10-10 s) [3]. In this work we present a comparison study between three classes of organic emitters (exhibiting: fluorescence, phosphorescence and thermally activated delayed fluorescence - TADF), which are used as fluorophores towards the detection of 2,4-dinitrotoluene (DNT). Steady-state and time-resolved photoluminescence measurements were performed in solution, where all molecules showed quenching in emission. Differences in sensing response, as well as the mechanisms responsible for the fluorescence quenching in each system, are further explored and discussed by using Stern-Volmer and photoluminescence lifetime analyses.

1. Junaid, H.M., et al., Fluorescent and colorimetric sensors for selective detection of TNT and TNP explosives in aqueous medium through fluorescence emission enhancement mechanism. Journal of Photochemistry and Photobiology A: Chemistry, 2022. 428: p. 113865.
2. Verbitskiy, E.V., et al., Design of fluorescent sensors based on azaheterocyclic push-pull systems towards nitroaromatic explosives and related compounds: A review. Dyes and Pigments, 2020. 180: p. 108414.
3. Demchenko, A.P., Basic Principles, in Introduction to Fluorescence Sensing, A.P. Demchenko, Editor. 2015, Springer International Publishing: Cham. p. 1-37

9. Prediction of Radiation Pneumonitis in NSCLC Patients Receiving External Beam Radiotherapy Using a Radiomic Analysis of Pre-Treatment CT Images

Matthew Gil, Stephen Marshall, Stephen Harrow, Bill Nailon

Radiation pneumonitis is an adverse event that can occur in patients receiving a lung dose during external beam radiotherapy (RT). The aim of this study to produce a methodology to predict the occurrence of radiation pneumonitis (RP) in lung cancer patients receiving external beam RT using a radiomic approach applied to the lung region in planning CT images. A retrospective dataset of RT planning CT images, dose maps and clinical features for 64 patients with known pneumonitis outcomes where 12 patients developed grade 2 or above pneumonitis, was used. Radiomics features were calculated from the lung region of the CT image and combined with dosimetric and clinical features to build a feature table. A simple artificial neural network was applied to this feature table to classify the patients into groups that either did or did not develop pneumonitis using a 10-fold cross validation approach this achieved a classification accuracy of 79.7% with a sensitivity and specificity of 80.8% and 75.0% respectively and an AUC ROC of 0.81.

10. **Ultrafast laser inscription**

    H. Hall, H. Bookey

    This poster details the use of ultrafast laser inscription in the creation of a waveguide laser and the etching of borofloat-33 glass in the use of components in various devices

11. **Spatial Coherence Filtering in Free-Space LIDAR**

    Paul Hawthorne, Mark W.McDonald, Ian Park, Duncan P.Hand

    A scanning LIDAR system that uses a single pixel detector can be highly attractive, with simple data processing coupled with low cost and complexity. However, the impact of ambient light noise is much greater than with a multiple pixel system, if there is no steering on the observed field of view (FoV).

    A potential means of overcoming this is to filter for transverse spatial coherence. Such filters have been discussed and evaluated in the literature, typically based on an axicon or a spiral phase plate that creates a ring with coherent light. Incoherent light, in contrast, smears the light out diffusely, allowing for spatial separation and thus, filtering.

    The focus of the existing literature tends to be in optical communication or underwater ranging, whereas a free-space LIDAR environment has distinct issues that inhibit the practicality of the filter if a direct replication is performed.

    This work thus focusses on exploring the practical implementation of these filters in a free-space LIDAR environment.

12. **Enabling Interoperability and High-Speed Image Processing in Space-Qualified Optical Fibre Networks**

    Nick. Kabawa, Keith Wilcox, Steve Parkes

    A study on the interoperability of parallel optical transceivers in spacecraft data handling systems. We investigate the feasibility of integrating transceivers from different manufacturers, showcasing their compatibility and interoperability. Additionally, We showcase the advantages of high bitrates for on-board image processing by presenting a novel redesigned processing system that enables faster and more efficient data analysis. Our findings contribute to advancing space communication technologies by promoting interoperability and unlocking new possibilities for on-board image processing applications.

13. An Experimental Study Of Millisecond Fibre Laser Percussion Drilling of Alumina-Alumina Ceramic Matrix Composite

Nathaniel Marsh, Duncan Hand, Tian Long See, Sundar Marimuthu, Helen Elkington, Joseph Nix

Alumina-Alumina Ceramic Matrix Composites are a set of technical ceramics consisting of an alumina ceramic matrix with alumina ceramic reinforcing fibres, offering high temperature performance, high oxidation resistance and high bending strength while also being tougher and less brittle than monolithic alumina due to fibre-in-matrix interface behaviour which helps to arrest cracks and prevent material failure. These desirable material properties traditionally mean CMCs are difficult to machine, especially with tool based processes, and are a prime candidate for non-conventional machining research, though to date little research is published on laser machining of Ox-Ox CMC. This work presents a parametric study of percussion and trepanning drilling of 5-10mm thickness ox-ox ceramic matrix composites, using a 20kW peak power QCW millisecond fibre laser. Samples were analysed for hole morphology, recast layer thickness and spatter deposition. Thermal imaging, high speed imaging and XCT were used to inform key aspects of repeatability and quality control of the drilling process. This is supported by a regression analysis to determine the effects of process parameters (peak power, repetition rate etc) on these response variables, and multi objective optimization methods to determine optimal machining parameters for high quality results.

14. Multimodal Screening Tool for Rapid Substance Classification

Marek Michalowski, Emma Le Francois , David Stothard , Paul Murrayb, Adam Polak

Common crime scene scenarios can involve a range of unknown and potentially hazardous materials such as body fluids, toxins, drugs amongst others. To assess the risks and employ correct handling procedures, appropriate for the type of substance encountered on the ground, the operatives need to know what type of substance they are working with. As a part of this feasibility study, we have developed a multi-modal system based on three independent techniques assisted by a machine learning algorithm, capable of classifying unknown substances into 'biological' or 'chemical' category. We also show a route to a miniaturised instrument, more suited to real life scenarios.

The design is based upon three well established scientific techniques – Attenuated Total Reflection (ATR) infrared spectroscopy, fluorescence spectroscopy and microscopic imaging, used as complementary sources of data for the classification algorithm set to distinguish biological samples from chemical ones. The results of this study show satisfying classification accuracy and demonstrate good potential for rapid screening of chemical and biological materials.

15. Whispering gallery mode microspheres for ammonia gas sensing and Er3+ doped tellurite microlaser applications

Snigdha Thekke Talakkal, Davor Ristic, Danil Zhivotkov, Gualtiero Nunzi Conti, Mile Ivanda

Microsphere resonators based on whispering gallery modes (WGMs) have benefits of ultrahigh Q factor, small mode volume, ease of fabrication, and low cost. We reported the refractometric gas sensing sensitivity and the effect of thickness of the sol-gel silica layer coated to the microsphere to detect small traces of ammonia. A porous silica layer is made using the sol-gel method and it is coated to the sphere using dip coating. The study reveals that different modes of the same microspheres have different sensitivities. It is concluded that the observed whispering gallery modes have different values of the radial index p. Additionally, a theoretical analysis of the refractometric sensitivity of a spherical microresonator coated with a porous sensing layer is presented. Furthermore, our work is based on Er3+ doped microlasers fabricated via the plasma torch method. Tellurite glass has been proven to be an excellent host for rare earth ions, resulting a powerful and broad stimulated emission cross section, making it a viable material for microlasers. We achieved single and multimode lasing in 1560 nm-1610 nm wavelength region with both 0.98 μm and 1.48 μm pump lasers. A peak at 1565.3 nm shift to the lower wavelength side as the pump power increased.

Saturday 8th July

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1. **Ultra-Compact Metrology Systems using Nanophotonics Elements**
   J.H.T. Chan, H. Martin, A.J. Henning, X. Jiang
   The project goal is to achieve the goal of on-machine metrology, aligning with the goals of Industry 4.0 and enabling machines with ability to inspect via sensors while carrying out automated correction of manufacturing defects in real time, saving energy, costs and reducing material wastes. Optical metrology typically requires bulk optics that are heavy, large in scale that obstruct inspection and do not allow reaching tight spaces, and often have to be taken off assembly line for inspection, therefore inducing errors in measurement. Optical metasurfaces are much smaller in scale as well as lighter, hence allows reduction in size of the entire metrology system and enabling in-situ measurements, which is further enhanced by integration of metasurfaces on fibre tip, allowing parts to be monitored in real time, speeding up manufacturing process and reducing waste and time.

2. **Ordinary and extraordinary modulated light pulses in a nonlinear Kerr-type optical waveguide**
   Hatou-Yvelin Donkeng, William Kamgaing Mabou), Fabien kenmogne^(2,6) and David Yemélé
   The purpose of this work is the description of the behavior of modulated light pulse in the nonlinear birefringent optical waveguides by taking into account the orientation of the optical axis with respect to the direction of propagation of the incoming pulse. The dynamics is governed by the nonlocal nonlinear Schrödinger (NNLS) equation involving nonlinear Kerr-like responses with nonlocality. Firstly, the multiple time scale method is used to investigate the behavior of the pulse in the waveguide whose the optical axis is perpendicular to the direction of propagation of the pulse. It appears that the light pulse propagates in this waveguide in a nonlinear regime by splitting into two different rays which propagate with different group velocity: an ordinary ray and an extraordinary ray whose propagation is described by the different nonlinear Schrodinger equations involving nonlinear Kerr-like responses. Next, we turn attention to the waveguide whose the optical axis is parallel to the direction of propagation of the incoming pulse. Then we find that the two modes continue to exist, and are again described by different nonlinear Schrodinger equations. In addition, we show that for some parameter regime, the

two modes becomes identical and describe by the same nonlinear Schrodinger equation

3. **Fieldresolved Spectro-Microscopy**
Andreas Herbst, Anchit Srivastava, Soyeon Jun, Kilian Scheffter, Hanieh Fattahi
Field resolved spectroscopy is a technique to measure the molecular response of a sample in time domain by sampling the electric field of the ultrashort, CEP stable excitation pulse after the interaction. The frequencies corresponding to the characteristic molecular response can be detected as a ringing signal in the time domain. Temporal gating allows for sensitive detection with a high dynamic range. This scheme can be combined with a microscope, enabling quantitative in vivo label free spectroscopic imaging with spatial resolution below the near infrared excitation light's refraction limit, as the signal is generated via nonlinear mixing of the excitation pulse with a short-wavelength probe pulse, allowing changes in spectrum and phase to be measured and monitored with high spatial resolution.

4. **Killing cancer with light: simulation and optimisation of photodynamic therapy for glioblastoma**
Louise Finlayson, Lewis Mcmillan, Szabolcs Suveges, Douglas Steele, Raluca Eftimie, Dumitru Trucu, C.Tom A. Brown, Ewan Eadie, Kismet Hossain-Ibrahim and Kenneth Wood
Glioblastoma is the most aggressive form of brain cancer with a median survival rate of 14.6 months when treated with the current standard of care. Evidence suggests that extent of surgical resection improves survival: over 80% of recurrences originate adjacent to the cavity left after resection surgery. However, there is prospect to use photosensitising drugs to treat tumour left in the cavity wall intraoperatively via photodynamic therapy (PDT). Preliminary results of a recent clinical trial show an improved median survival rate of 23.1 months. The trial involves using a scattering fluid filled balloon to deliver treatment light to the cavity wall intra-operatively at the end of resection surgery. We model this setup using Monte Carlo Radiative Transport (MCRT) with the aim of finding the optimal light delivery protocol needed for the best outcome.
A MCRT code using a 3D brain model and containing a mathematically modelled glioblastoma was produced to simulate the clinical trial protocol. Algorithms were added to account for temporal and spatial variations in the light distribution and concentrations of photosensitising drug and oxygen. By varying several initial

conditions, the simulation calculates which factors most affect overall cell kill, helping to identify a strategy for optimising treatment outcome.

5. **The topology-overlap trade-off in retinal arteriole-venule segmentation**
Ángel Víctor Juanco Muller, Keith Goatman, Joao F.C. Mota, Corné Hoogendoorn
Retinal fundus images can be an invaluable diagnosis tool for screening epidemic diseases like hypertension or diabetes. And they become especially useful when the arterioles and venules they depict are clearly identified and annotated. However, manual annotation of these vessels is extremely time demanding and taxing, which calls for automatic segmentation. Although convolutional neural networks can achieve high overlap between predictions and expert annotations, they often fail to produce topologically correct predictions of tubular structures. This situation is exacerbated by the bifurcation versus crossing ambiguity which causes classification mistakes. This paper shows that including a topology preserving term in the loss function improves the continuity of the segmented vessels, although at the expense of artery-vein misclassification and overall lower overlap metrics. However, we show that by including an orientation score guided convolutional module, based on the anisotropic single sided cake wavelet, we reduce such misclassification and further increase the topology correctness of the results. We evaluate our model on public datasets with conveniently chosen metrics to assess both overlap and topology correctness, showing that our model is able to produce results on par with state-of-the-art from the point of view of overlap, while increasing topological accuracy.

6. **Stand-Off Hydrogen Detection Using Single-Photon Quantum Raman Spectroscopy**
E. Kelly, R. Spesyvtsev, M. Warden, J. Leck1, D. Li, A. Allen, S. Malone and D. Stothard
Within the nuclear sector, condition monitoring of waste storage containers is significantly important. These containers house materials which naturally evolve over time, releasing hydrogen (H2). Given the nature of both the materials and the storage sites, developing a technology capable of remote detection is essential to confirm the materials are behaving as predicted, maintain the health and safety case, and prevent potential incidents within the stores. We have developed a system

which identifies and quantifies gas molecules, at ranges of up to 80m. The system will be downsized into a 'portable' instrument, capable of molecular identification through time-of-flight (ToF) measurements and Raman spectroscopy. Enhanced by state-of-the-art quantum single-photon avalanche diodes (SPADs) and ultraviolet (UV) excitation sources, the species, concentration, and position of target gases can be identified. After in-laboratory success, at a range of ~40m (limited only by the area available), the system was taken out into the field, for more 'real-life' testing, where successful results were demonstrated at an increased range of ~60m.

7. **Metasurface spectrometer for compact sensors**

Joseph G. Kendrick, Andrew J. Henning, Haydn Martin, James Williamson, Dawei Tang, Nityanand Sharma, Xiang Jiang

One of the main issues within manufacturing today is the high scrappage rate and production of defective workpieces. This issue can be solved by incorporating more optical systems within manufacturing. Although many lenses are too big and bulky for current manufacturing processes, therefore a miniaturised sensor can combat this issue. For example, current line spectrometers today are too bulky due to having too many large components. Metasurfaces can reduce the size and number of components found within various optical setups. These devices are formed from nanostructures with sub-wavelength spacing arranged on a substrate designed to manipulate light. We have created a metasurface that can mimic the functions of a spectrometer with a fraction of the size and weight. The metasurfaces have been fabricated by etching GaN nanopillars on an Al2O3 substrate by Kelvin Nanotechnology. This metasurface will eventually be incorporated into the single-shot dispersive profile interferometer (SDPI), a device that can measure the height along the surface of a measurand. Within this work, experimental results have been produced to demonstrate that the metasurface devices work as intended and show a significant reduction in size and weight compared to traditional spectrometers.

8. **Multimode fibre influence on single photon avalanche diode timing jitter**

A. Lee, A. Tello Castillo, C. Whitehill and R. J. Donaldson

The timing jitter of a single-photon avalanche diode (SPAD) can be a limiting factor for the performance of quantum key distribution (QKD). Within QKD receiver modules, single mode fibre coupling has been extensively studied due to optical fibre-based demonstrations. However, multimode fibre, which is utilized for free-space demonstrations because it reduces the coupling losses, has been less studied, but is understood that multimode fibres will increase the timing jitter as the fibre core diameter increases and in turn, decreases the performance of the detector. Here, a collection of experimental analysis covering the relationships between characteristics of multimode fibre such as length, core diameter and incident spot size and how this impacts the timing jitter of the detector is presented. Additionally, an analysis on the use of graded-index multimode fibres, mitigating for a portion of the impact on quantum bit error rate (QBER) due to multimode characteristics which can improve implementation of these receiver systems.

9. **PyMieSim: an open-source library for fast and flexible light scattering simulations**
   Martin Poinsinet de Sivry-Houle, Rodrigo Itzamná Becerra Deana, Nicolas Godbout, Caroline Boudoux
   Introducing PyMieSim, an advanced Python package designed for comprehensive analysis of Mie scattering phenomena. PyMieSim offers a fast and versatile solution by incorporating three distinct solvers to handle various types of scatterers: homogeneous spheres, infinite cylinders, and core/shell spheres. With this package, users can simulate the interaction of light within a complete optical system, comprising a light source, a scatterer, and a detector. Moreover, PyMieSim empowers users to compute the full set of optical properties of the system. Additionally, the package allows users to define ranges for different attributes of the optical system and observe the corresponding properties within those specified ranges. This tool finds applications in diverse fields such as optical imaging, flux cytometry, and particle sizing, opening up new possibilities for research and analysis in these domains.

10. **Upconversion of Single Photons for Environmental Sensing**
    Ruaridh Smith, Bienvenu Ndagano, Andrew Weld, Xiao Ai, Arthur Cardoso, John G. Rarity , Andy Astill, Lewis Wright, Krish Pandiyan, Corin B. E Gawith, Loyd J. Mcknight
    We report on our progress towards infrared environmental gas sensing with a waveguide-based photonic upconversion detector. The system establishes a method for gas interrogation in the SWIR wavelength region where efficient compact

detectors are not readily available. This is achieved by combining SWIR light with a pump laser in a zinc indiffused MgO:PPLN waveguide to generate upconverted light in the near-IR. Single photon detection is then possible on high efficiency silicon detector technology. Our upconversion detection results are presented along with an outline of the overall active imaging system, which is capable of absorption-based gas sensing in real-world scenarios.

11. **Metalenses for Metrological Applications**
Daniel J. Townend, Andrew J. Henning, Haydn Martin, Xiangqian Jiang
Optical metasurfaces, also known as a metalenses, are artificial surfaces comprised of subwavelength elements that manipulate incident light. These subwavelength elements are commonly known as meta-atoms, and usually take the form of dielectric or plasmonic nanoantenna which can precisely change the properties of incident light such as its amplitude, phase, and polarisation. It is the optimal time to incorporate metasurfaces into established metrological systems due to extensive development in the area over the past decade. This will allow the metrological systems to become lighter and less bulky, opening up many opportunities. This work presents some of our initial metasurfaces, a metasurface confocal and a metasurface tip-tilt sensor. The metasurface confocal operates like a traditional confocal microscope but with a single surface. This metasurface combines both the functionality of a beamsplitter and lens by interleaving two lenses together. The tip-tilt sensor functions as three chromatic confocal sensors in one surface. When a surface is placed in the focal plane of these lenses, the signal back will indicate if the surface is tipped or tilted compared to the metasurface. Both metasurfaces are used to demonstrate the feasibility and readiness of metasurfaces to be utilised in optical instrumentation for real world applications.

12. **Low-Cost Sensor for Environmental Contaminant Detection**
David Webster, Graham Turnbull, Ifor Samuel, Iain Baikie
Microplastic pollution of the water table is an ongoing issue that requires the development of efficient and affordable sensors to aid in the detection of contaminants. This project aims to develop a low-cost, reusable detector that can give fast and accurate detection in situ.

13. **TBC**
Suki Yau

Attendees

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First Name	Surname	Institution
Iman	Alhamdan	University of St Andrews
Mohanad	Al-Rubaiee	University of Glasgow
Shrishty	Bakshi	University of York
Rodrigo Itzamná	Becerra Deana	Polytechnique Montréal
Christopher	Boland	University of Edinburgh
Samuel	Buck	Heriot-Watt University
Riccardo	Brameri	Università degli studi di Pavia
Jemma Elizabeth	Callaghan	Heriot-Watt University
Justin	Chan	University of Huddersfield
Alastair	Clarke	Heriot-Watt University
Danielle	Clarke	Heriot-Watt University
Natasha	Crossley	Heriot-Watt University
Francesco	Dalla Serra	University of Glasgow

Ultan	Daly	University of Glasgow
Hatou-Yvelin	Donkeng	University of Dschang
Michele	Duarte Tonet	St Andrews University
Louise	Finlayson	University of St Andrews
Paddy	Foley	Heriot-Watt University
Femy	Francis	University of St Andrews
William	Gash	Heriot-Watt University
Matthew	Gil	University of Strathclyde
Kamalpreet	Gill	University of Strathclyde
Brendan	Hall	University of Strathclyde
Harry	Hall	Heriot-Watt University
Paul	Hawthorne	Heriot-Watt University
Andreas	Herbst	Max Planck Institute for the Science of Light
James	Jackson	Heriot-Watt University
Angel Victor	Juanco Muller	Heriot-Watt University

Nick	Kabawa	University of Dundee
Aoife	Keane	University of Strathclyde
Ellis	Kelly	University of Strathclyde
Joseph	Kendrick	University of Huddersfield
Alexandra	Lee	Heriot-Watt University
Nathaniel	Marsh	Heriot-Watt University
Euan	Martin	University of Strathclyde
Kieran	McGovern	Heriot-Watt University
Marek	Michalowski	University of Strathclyde
Minahil	Khan	The University of York
Martin	Monaghan	University of Strathclyde
Miguel	Moran Coto	Heriot Watt University
Ieva	Pakamoryte	The University of Edinburgh
Martin	Poinsinet de Sivry	Polytechnique Montréal
Aisha	Rafiq	AWE
George	Rowley	AWE

Ruaridh	Smith	Fraunhofer Centre for Applied Photonics
Cosmin	Suciu	University of Glasgow
Snigdha	Thekke Thalakkal	Institute Ruder Boskovic
Shannon	Thompson	University of Edinburgh
Daniel	Townend	University of Huddersfield
Caitlin	Tye	Heriot-Watt university
Dorian	Urban	University of Dundee
Tara	van Abeelen	Heriot Watt University
Calvin	Wan	Heriot-Watt University
Kuo	Wang	University of Glasgow
David	Webster	University of St Andrews
Agnes	Wojtusiak	Heriot-Watt University
Alan	Yahya	University of York
Pengqian	Yang	University of Huddersfield
Suki	Yau	Heriot-Watt University

Further Information

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Poster Prizes

Prizes will be awarded for posters presented during the sessions.
Voting will commence after each poster pitch session has concluded. There will be three prizes awarded for 1st, 2nd and 3rd of £100, £50 and £25.

Photo Competition

We will be holding a photo competition during the summer school for a mystery prize. Please send all your photos you want to enter into the competition to c.bush@hw.ac.uk

Competition rules

- Please make sure you have permission of anyone in the photo.
- Please do not do anything dangerous to take a photo.
- Your picture may be used in the CDT in Applied Photonics Annual report, advertising, social media etc. If this happens you will be credited.

Getting to St Andrews

By Public Transport

Leuchars Rail Station: The closest train station to St Andrews is Leuchars. Trains run regularly between Edinburgh and Leuchars.

Bus From Leuchars: A regular bus service travels back and forth from the town and the train station, approximately every 10 minutes. The 99 bus takes approximately 12 minutes between the rail station and bus station and costs £4.30 for a single ticket. This can be bought on the bus with cash or card, or from the station.

Taxi From Leuchars There is also a taxi rank outside the station which will cost approximately £15 for a single journey to St Andrews.

From Edinburgh Airport

Train: The closest rail station to Edinburgh Airport is Edinburgh Gateway. This is just a few minutes away by Tram from the airport tram stop. From here you can travel to Leuchars rail station in just over an hour.

Airport Shuttle: A shuttle bus service runs between Edinburgh Airport and St Andrews costing approximately £30. **(https://www.standrewsshuttle.com)**

About the venues

Accommodation: David Russell Apartments, Buchanan Gardens, St Andrews KY16 9LY
David Russell Apartments each feature 5 double bedrooms and a well-equipped kitchen/diner. Each bedroom boasts an en-suite shower room, a double bed and a TV.

For those arriving by car, there is ample parking in the car park at David Russell Apartments.

Lectures & Posters: School of Medicine, University of St Andrews, North Haugh, St Andrews KY16 9TF

Hackathon: School of Physics and Astronomy, University of, N Haugh, St Andrews KY16 9SS

Meals

All meals are included for all delegates attending the summer school.

Breakfast & Dinner: Provided at David Russell Apartments for the participants staying in the University accommodation except on Wednesday 5th July, where the evening meal will be served at Lower college hall for those invited to the formal dinner. All summer school attendees and speakers are invited. During the Hackathon on 6th July the evening meal will be brought to participants in physics.

Lunch & Tea breaks: will be served in the foyer of the Medical Sciences Building except on 6th July during the Hackathon, where this will be served in the Physics foyer

Internet connection: If you are visiting from an institution that participates in the eduroam scheme, you can connect to "eduroam". To log in you should use the credentials supplied by your home institution.

Alternative internet access: Free BT Wifi is available

Social Events

We have social activities happening throughout the summer school as well as some free time to explore the picturesque surroundings of St Andrews.

Sunday 2nd July:	Welcome drinks reception
Monday 3rd July:	Observatory Tour
Tuesday 4th July:	Ceilidh
Wednesday 5th July:	Formal Dinner
Thursday 6th July:	Pizza
Friday 7th July:	Board Games Night
Sunday 9th July:	Beach Activities / Walk to Craigtoun Park / Golf
Monday 10th July:	Pub Quiz