PHD OPPORTUNITIES

THE MATTER COMMUNITY



THE MATTER COMMUNITY

Community Head
Professor Will Branford
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Research mission

The Matter community tackles problems ranging from fundamental physics to climate change. Our theoretical and experimental research aims to enhance the efficiency of renewable energy, design new materials for imaging, sensing and computation, and build novel quantum sensors and simulators. We seek to understand how collective phenomena emerge in large interacting ensembles, explore how matter behaves on nanometre sizes cales and attosecond time scales, and probe the character of dark matter and the fundamental symmetries of nature.

Research areas

- Cold Atoms and Molecules
- Complexity and Networks
- Correlated Quantum Systems
- Ion trapping
- Materials Physics
- Metamaterials
- Nanomagnetism
- Neuromorphic Computing
- Plasmonics & Nanophotonics
- Plastic and Optoelectronics
- Renewable Energy and Material for Energy Efficient Use
- Research at the Interface with Biomedical Sciences
- Security and Sensors
- Superconductivity
- Topological Matter

Our research is funded by various sources including the European Union, the Engineering and Physical Sciences Research Council, the Science and Technology Facilities Council, and the Royal Society. We have strong links with other major laboratories in the UK and with industry.





Dr Niladri Banerjee
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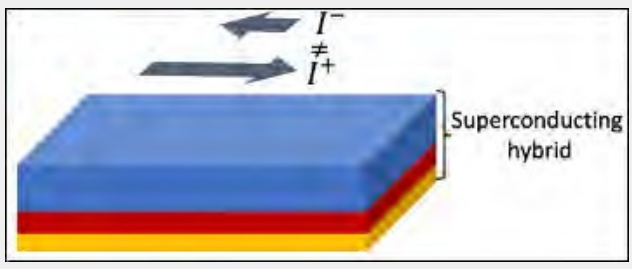
Prof. Lesley Cohen
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Electronic transport of superconducting spin-orbit coupled hybrids

Our work in the last decade helped to establish the field of triplet superconductivity which, in contrast to conventional superconductivity, carries a net spin or magnetism. The combination of magnetism and superconductivity open intriguing possibilities of new devices for quantum technologies and low-dissipation computing. We have recently demonstrated that relativistic spin-orbit coupling can drive the conversion of conventional to unconventional superconductivity in ultra-thin film hybrids. Interestingly, such hybrids also show non-reciprocal current flow similar to a diode. The project will investigate the underlying physics including the role of the spin-orbit field underpinning this diode effect.

In this project you will:

- Learn and use thin film deposition
- Develop expertise in nano fabrication using standard optical and/or electron beam lithography and etching.
- Learn low-noise and low-temperature electronic and magnetic measurements.
- Advanced data analyses and simulation and modelling of experimental results







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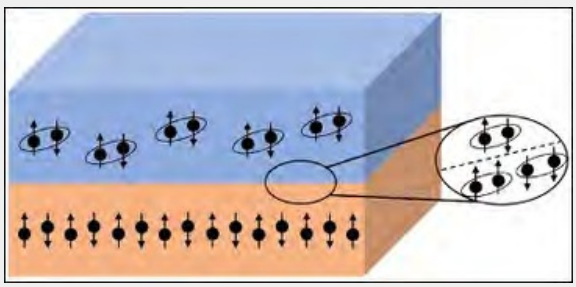
Superconductor-antiferromagnet proximity effects

Bringing two dissimilar materials in close contact often results in unexpected emergent phases with unusual properties. One example is a superconductor/ferromagnet hybrid where the interaction between superconductivity and magnetism under some special conditions can produce a unconventional superconductivity with a net spin or magnetism. Studying such phases can lead to future devices and applications in low-dissipation information processing or quantum technologies.

In this project, we will investigate the coupling of superconductors with antiferromagnets where the electron spins are antiparallel. Oddly, even in such systems unconventional and topological superconductivity has been predicted under special circumstances which we will investigate experimentally.

In this project you will:

- Perform advanced thin film deposition using pulsed laser deposition and/or sputtering
- Develop expertise in nano fabrication using standard optical and/or electron beam lithography and etching.
- Learn low-noise and low-temperature electronic and magnetic measurements.
- Advanced data analyses and simulation and modelling of experimental results.







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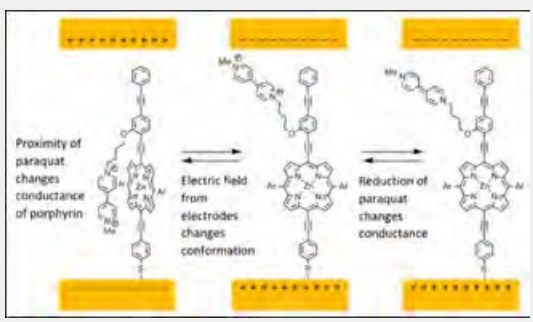
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Organic memristive devices for neuromorphic computing

Memristor is a programmable non-volatile memory resistor which remembers even without an external power. Their low-energy consumption and fast switiching speeds are attractive for information storage. Interestingly, they can also emulate biological synapses and neurons for neuromorphic computing. This project will investigate asymmetric organic molecules such as porphyrin where an electric field-induced conformational change leads to a change in conductivity of the molecule. These molecular switches will be used to designed self-assembled monolayers and various memristive device architectures explored for applications. The project activities will be closely linked to the large consortium grant on Quantum Engineering of Energy-efficient Molecular Materials.

In this project you will:

- Perform solution processing, spray coating and ink-jet printing of asymmetric organic molecules
- Develop expertise in nano fabrication using standard optical and/or electron beam lithography.
- Learn low-noise electronic, thermal and heat capacity measurements.
- Advanced data analyses and simulation and modelling of experimental results







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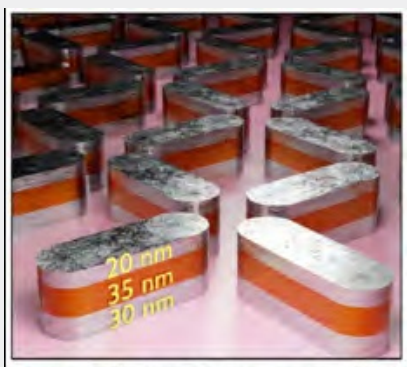
Artificial spin ice-based reprogrammable superconducting electronic devices

Geometrical frustration can be generated in an array of nanomagnets where several degenerate configurations exist and are important for microelectronic memory and logic devices. Incorporating a superconducting layer underneath these spin ice lead to a vortex lattice int he superconductor coupled to these nanomagnets with remarkably highd egeneracy and fully magnetic field reprogrammable geometric frustration.

This project will investigate the fundamental physics in these systems including the effect of nanomagnet dimensions, anisotropy on the vortex lattice, and possibility of generating highly degenerate field-free vortex lattices for computing applications.

In this project you will:

- Perform low noise low temperature electronic measurements
- Learn nanofabrication
- Perform Ferromagnetic resonance spectroscopy measurements
- Magnetic simulations
- Magnetometry and magnetic force microscopy



Nanomagnetic array with two magnetic layers







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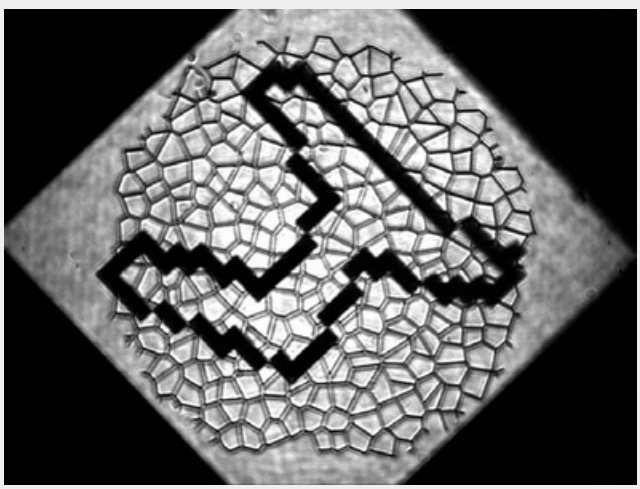
Dr Jack Gartside
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Optical Neuromorphic Computing

Neuromorphic computing, beyond the traditional von Neumann architectures of our personal computers, is poised to revolutionise the way we perform calculations, inspired by how the human brain works, and with better performances at a much lower energy cost. You will implement neural networks on random lasing networks which are controlled by laser illumination. The pattern of illumination can be controlled by a digital mirror device and the highly non-linear physics of competing lasing modes controls the computation.

In this project you will learn the following skills and techniques:

- Optical spectroscopy measurements
- Graph theoretical simulation methods
- Neuromorphic computing methods, such as reservoirs and convolutional neural networks.
- Hyperspectral imaging









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Prof. Rupert Oulton

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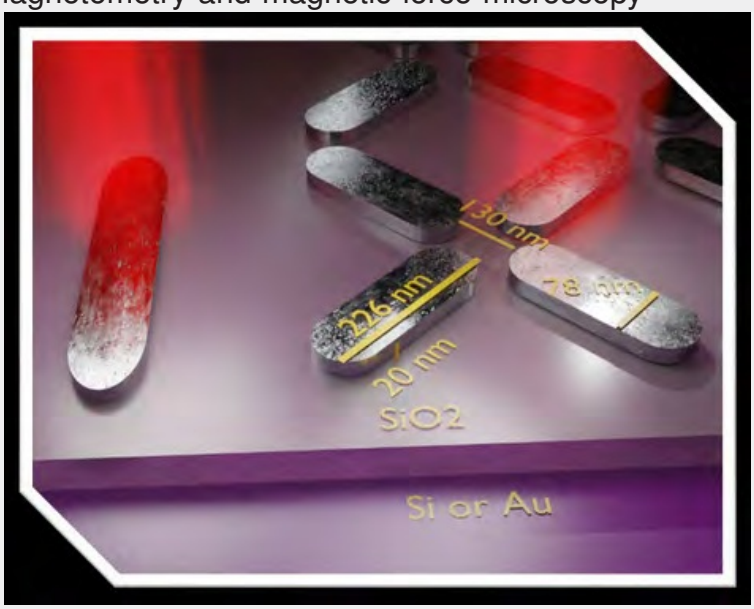
Research Fellow
j.carter-gartside13@imperial.ac.uk

Rewritable magnetic nanostructures

We have recently developed a method of writing any magnetic pattern we choose into magnetic nanostructured arrays that are usually calledA rtificial Spin Ice using a continuous wave laser at very low power. The aim of this project will be to understand the fundamental physics of the writing by fabricating artificial spin Ice structures and studying them by ultrafast and CW optical experiments. We will also explore the possibilities for neuromorphic computing technology.

In this project you will learn the following skills and techniques:

- Nanofabrication
- Continuous-wave and ultrafast magneto-optic measurement
- Magneto-optic writing
- Magnetic simulations
- Magnetometry and magnetic force microscopy





Dr Joe Cotter

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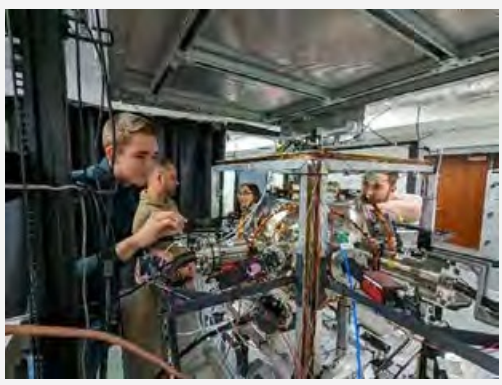
Atom interferometry for inertial sensing

Our atom interferometers use laser light to prepare the internal and motional states of a cloud of laser-cooled rubidium atoms. This device can be extremely sensitive - for example the instrument in our laboratory can sense changes of a few billionths of the acceleration due to gravity. The sensitivity and accuracy of such a device will enable navigation without the use of external signals such as Sonar or Satellite communications.

In this project you will:

- Join a team comprised of students, postdocs, and academics that is developing innovative quantum technologies.
- Laser-cool rubidium atoms to a few tens of microkelvin.
- Use the laser-cooled atoms to measure accelerations with high precision and accuracy.
- Advance current technology in collaboration with industry to build a more compact and reliable system that can be used in field trials.
- Test and characterise the performance of the system in field trials on the tube, ships and submarines.
- Become an expert in vacuum and laser science, optics and imaging, 3D modelling, computer automation and interfacing, numerical modelling,and statistics and data analysis.









Dr Julie Euvrard

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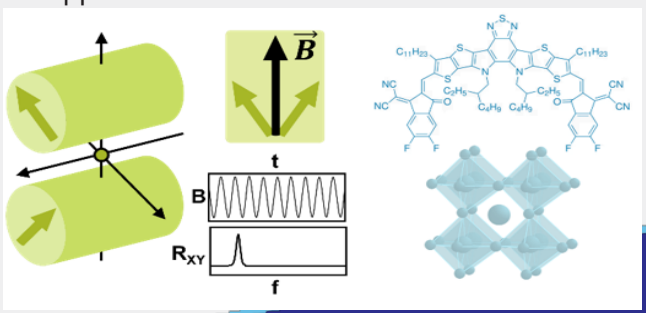
This project is associated with a fully funded studentship for home students!

Accessing charge transport and optoelectronic properties of emerging semiconductors with advanced photo-Hall effect

New device functionalities can be addressed with rapidly developing emerging semiconductors encompassing polymers, 2D materials, quantum dots and perovskites, among others. Yet, maturation of emerging semiconductor-based technologies is hindered by poor knowledge of their properties as reliable electrical measurements of new and generally low-mobility semiconducting materials constitute a major bottleneck.
In this project, you will use unique photo-Hall effect capabilities to develop reliable, polyvalent and accessible measurement of electronic, optoelectronic, and interface properties in emerging semiconductors. Various avenues can be explored depending on the interests of the applicant including:
- The development of simultaneous Hall, magnetoresistance, and transistor measurements to quantitatively assess the degree of charge delocalisation in low-mobility semiconductors (typically organic semiconductors and QDs).
- Develop photo-Hall effect on Hall heterostructure device for exciton dissociation characterisation (organic semiconductors).
- Extend the carrier-resolved photo-Hall analysis through measurements of specifically designed Hall devices (halide perovskites, potentially 2D semiconductors).
- Enable characterisation of device interfaces (e.g., with hole/electron transport layers) using photo-Hall effect (halide perovskites).

In this project you will:

- Fabricate halide perovskite and/or organic semiconductor samples and devices.
- Perform optical (UV-vis, PL...) and material (SEM, XRD...) characterisation to control the morphology and quality of the perovskite films and interfaces.
- Conduct advanced Hall and photo-Hall measurements combined with other electrical characterisation techniques.
- Develop models to analyse and understand the obtained experimental data.
- Relate fundamental semiconductor properties with device efficiency (focusing on photovoltaic application).
- Join Echoes Lab and develop as a scientist within a Team of passionate and supportive researchers.







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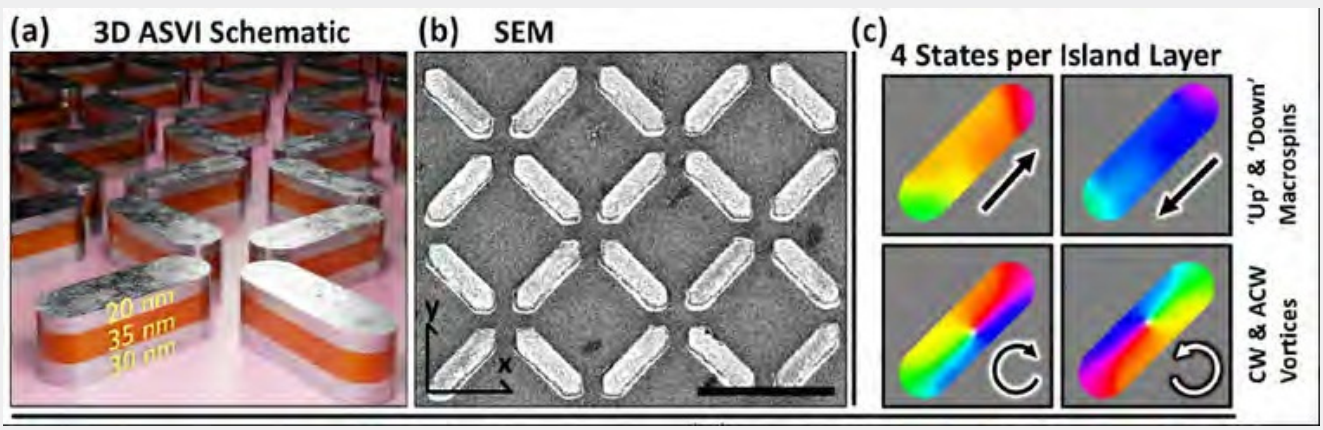
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3D Reconfigurable Magnonic Crystals

Magnonic crystals are materials that control the dispersion of GHz spin waves in ferromagnets. We have shown a multilayer architecture of nanomagnets greatly increases the coupling strength, and so the degree of control in the system. The project will explore the fundamental physics, including metamaterial properties and the role of topology and chirality, behind phenomena such as magnon frequency combs. Ferromagnetic resonance spectroscopy experiments and simulations will be used to optimise nanostructure design for computing applications.

In this project you will:

- Nanofabrication
- Ferromagnetic resonance spectroscopy measurements
- Magnetic simulations
- Magnetometry and magnetic force microscopy







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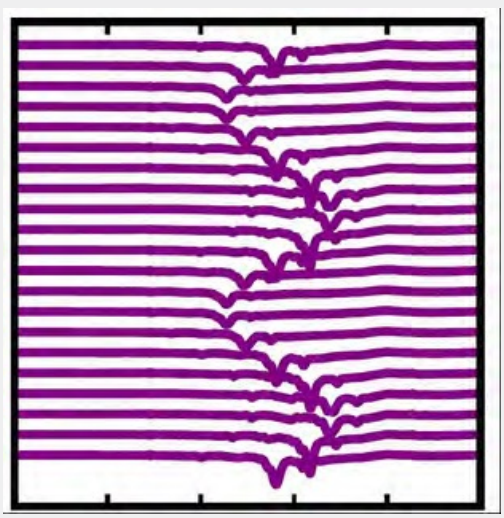
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Magnetic Neuromorphic Computing

Neuromorphic computing, beyond the traditional von Neumann architectures of our personal computers, is poised to revolutionise the way we perform calculations, inspired by how the human brain works, and with better performances at a much lower energy cost. You will implement neural networks in nanomagnetic arrays where the nanomagnets are both the memory elements and the logic processors, and the interaction weights between them are controlled by the exact magnetic configuration.

In this project you will learn the following skills and techniques:

- Nanofabrication
- Magnetic simulations
- Magnetometry and magnetic force microscopy
- Ferromagnetic Resonance Spectroscopy
- Neuromorphic computing methods





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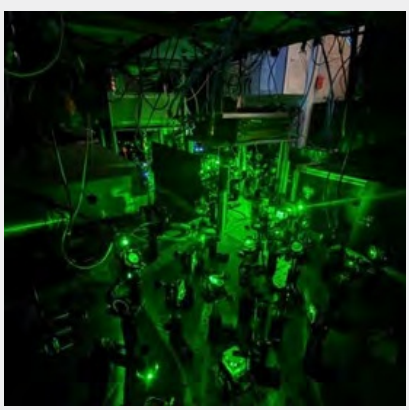
Testing fundamental physics with ultracold molecules

An array of laser-cooled heavy polar molecules can be used for precision tests of fundamental physics beyond the Standard Model of Particle Physics. The low-energy table-top experiments open a window to high-energy physics and allow us to explore new physics at energies beyond the reach of particle accelerators such as CERN.

In this project you will:

- Join a team comprised of students, postdocs, and academics developing innovative quantum technologies
- Learn how to use precisely controlled lasers to manipulate a beam of molecules and slow the molecules using radiation pressure
- Use a combination of magnetic and laser fields to trap and cool the molecules
- Arrange the molecules into a regular array by loading them into an optical lattice
- Implement a measurement protocol to search for small energy shifts induced by the electric dipole moment of the electron
- Become an expert in vacuum and laser science, optics and imaging, 3D modelling, computer automation and interfacing, numerical modelling, and statistics and data analysis











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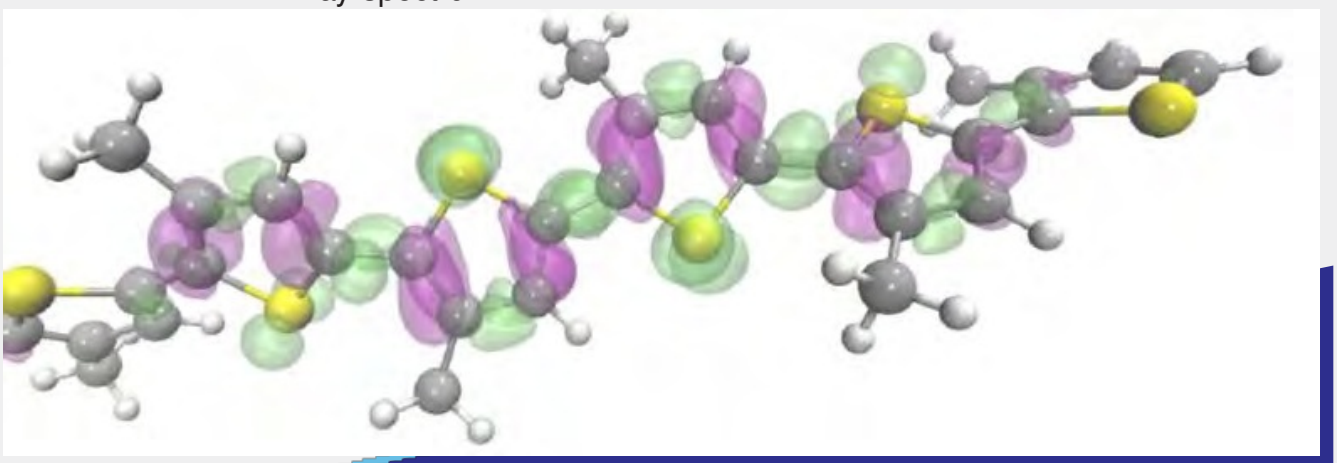
Dr Mary Matthews
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Measuring ultrafast electronic dynamics in organic semiconductors and photoswitching materials

The project will apply time-resolved x-ray spectroscopy to the investigation of exciton dynamics, and the ultrafast evolution of charge separation, in organic semiconductors, thin film photo-switch and 2D materials. Recently we have measured initial exciton dynamics in an organic semiconductor polythiophene (P3HT) using time-resolved carbon K-edge x-ray spectroscopy. A promising new material for photovoltaics, Y6, will be probed at C K edge (290 eV), N K edge (410 eV) and F K edge (697 eV) sites using our laboratory based high harmonic source combined with x-ray free electron laser (XFEL) sources. These ultrafast X-ray measurements will allow the full reconstruction of the crucial early time exciton dynamics through probing at multiple atomic edges.

In this project you will:

- Work with collaborators at Imperial and Madrid to produce thin film format organometallic photoswitches and Y6 samples
- Perform preliminary characterisation and x-ray absorption measurements at the Extreme Light Consortium (XLC) at Imperial College
- Use the XLC high harmonic generation attosecond supercontinuum source and dispersive wave pump pulses to make measurements with unprecedented < 5 fs temporal resolution
- Play a key role in preparation for XFEL beamtimes, leading beamtimes and analysing data
- Develop simulations working closely with theoretical collaborators to model the exciton dynamics and the time-dependent changes to the x-ray spectrum





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Attosecond dynamics of electronic coherence in condensed matter

This is a new opportunity for a UK researcher to undertake a fully funded (3.5 year) PhD in experimental attosecond science. The research will take place in the Blackett Laboratory Extreme Light Consortium (Imperial College) and at international X-ray free-electron laser (XFEL) facilities e.g. in Hamburg, Stanford and Switzerland. The research team is led by Prof. Jon Marangos and comprise colleagues from the Light and Matter communities in the Imperial College Physics Department.

The topic of the research is probing electronic coherence at attosecond time-scales through the strong field non-linear optical/x-ray response in the condensed phase.This is an emerging area promising to extend attosecond science from AMO physics to condensed matter and materials by providing the tools to study sub-femtosecond electron dynamics in the condensed phase. The researcher would work on applying attosecond x-ray pulses from an XFEL to solution phase and solid metal targets to extend impulsive stimulated x-ray Raman scattering (a method we pioneered[1][2] as a way to prepare and track the dynamics of electronically excited states in the condensed phase with attosecond resolution. There would be an in-house laboratory based component investigating the strong field interaction of optical lasers with liquid and solid-state targets.

In this project you will develop skills in multiple areas of advanced research:

- Analysis of big-data sets using correlation and AI based methods
- Ultrafast and x-ray measurement methods
- Theoretical aspects of condensed phase electron dynamics and non-linear optics
- Simulation and theory to support interpretation
- Integration within an international research team

We are looking for a highly motivated researcher with a good BSc and with (or about to obtain) a MSc (or equivalent) in a Physical Sciences discipline (including Physics, Chemistry or Materials). The funding is available for anyone who qualifies as a home (UK) student. Applications must be submitted by February 20th, if you intend to apply or are interested please contact Jon Marangos j.marangos@imperial.ac.uk as soon as possible.

References:
[1] J. T. O'Neal et al Physical Review Letters 125, 073203 (2020)
[2] Alexander, O., et al. (2024). Science Advances, 10, eadp0841. https://doi.org/10.1126/ sciadv.adp0841



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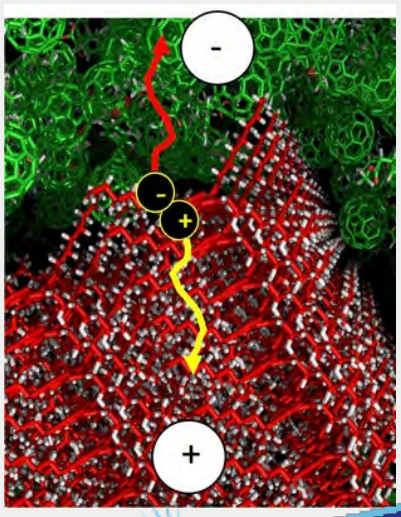
Reducing non-radiative recombination from molecular solar cells

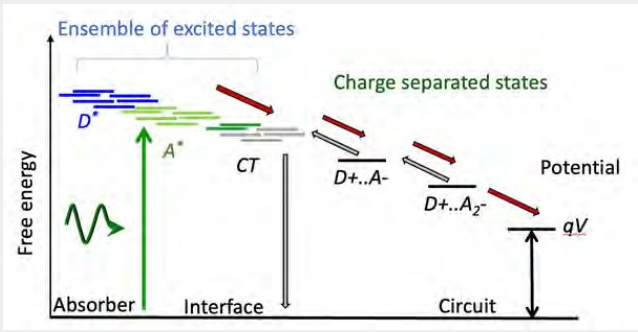
Organic semiconductors are promising materials for solar photovoltaic energy conversion that have achieved over 20% power-conversion efficiency. Further advances are limited by non-radiative charge recombination that occurs via states at the interface between the electron donating and electron-accepting components of the photoactive layer [1,2]. In principle these losses can be reduced. Two strategies are 1) to manipulate the structure of the interface, to enhance the role of energy transfer relative to charge transfer and 2) to control the vibrational degrees of freedom of the interfacial states. A third approach is to minimise losses in wider optical gap materials, which have been relatively underexplored.

In this mainly experimental project you will make solar cell devices, characterise the materials using electrical, spectroscopic and structural probes, and interpret behaviour in terms of models of device behaviour and the chemical structure of the materials used. The goal will be to extract design rules to guide the development of high-performance solar cells with reduced non-radiative losses.

In this project you will:

- Design, fabricate and measure organic solar cells using different materials;
- Explore the effect of material choice and microstructure on performance using optoelectronic, spectroscopic and structural measurements;
- Interpret your results with molecular and device models;
- Work with chemists and theorists to design and test materials for higher device performance.





References:
[1] Azzouzi et al., Phys. Rev X (2018) https://doi.org/10.1103/PhysRevX.8.031055
[2] Azzouzi et al., Energy Env. Science (2022) https://doi.org/10.1039/D1EE02788C



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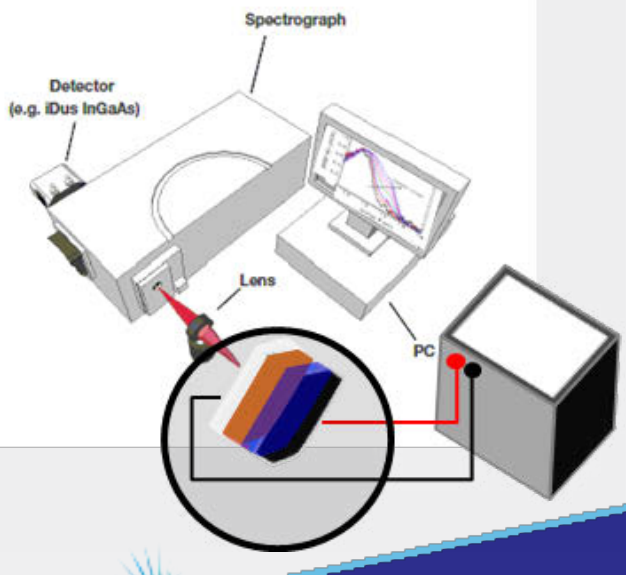
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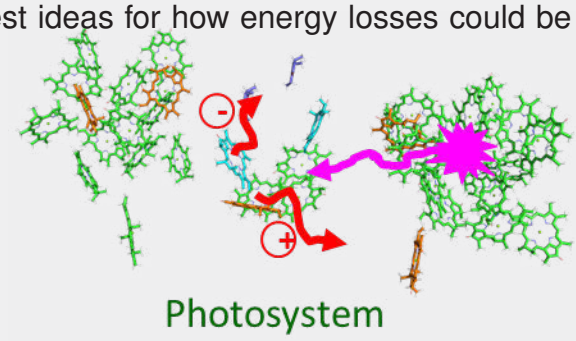
Understanding solar energy conversion in natural and artificial molecular systems

The process of converting solar photons into electrochemical potential energy in a molecular solar cell is analogous to the first few stages in natural photosynthesis [1]. Interestingly, the natural photosystems appear to suffer from lower non-radiative recombination. In this project we aim to study the energy conversion and loss pathways in both natural and artificial molecular solar energy conversion, in order to learn from the natural photosystems. Measurements of the light emitted by the systems (luminescence) in different conditions can provide information about the energy conversion and is key to understanding behaviour. Measurements can be interpreted using physics-based models of photochemical solar energy conversion and by comparing systems with different molecular structure. We aim to understand the factors limiting energy conversion in both natural and solar cell systems, and develop improved solar cell designs. We also hope to understand new types of photosystem that work using far-red light [2].

In this project you will:

- Develop an experimental system to measure luminescence from photosystems under applied electric field and / or light;
- Interpret the results using a combined quantum and kinetic model of energy conversion.
- Compare equivalent processes in photovoltaic and photosynthetic systems;
- Propose and test ideas for how energy losses could be reduced;





References:
[1] R. T. Ross., J. Chem. Phys. (1967) https://doi.org/10.1063/1.1840606
[2] D. Nurnberg et al., Science (2018) https://doi.org/10.1126/science.aar8313



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Charge storage and transport physics in organic mixed-conductor materials

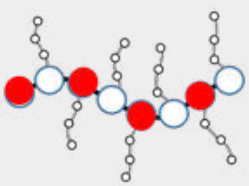
Conjugated polymer based mixed (electron- and ion-) conductors are promising candidates for electrochemical energy storage, electrochromics, sensing and bio-compatible electronics because they are abundant, low cost, non-toxic, flexible, compatible with water electrolytes [1,2]. They are also model systems to understand charge transport physics under controlled levels of electrochemical doping. We want to explore the mechanisms that control charge accumulation and charge transport in such electrodes by understanding the microscopic interactions between polymer and electrolyte, and the impact of polymer chemical structure on electronic properties. Chain conformation and connectivity is expected to control charge transport [3,4] and ultimately charging. The project will involve experimental (in situ electrochemical, spectroscopic, optical and structural) characterisation of different materials, device fabrication and testing, and interpretation of findings using molecular and device models, with the aim of understanding the limits to charge transport and accumulation in these materials.

In this project you will:

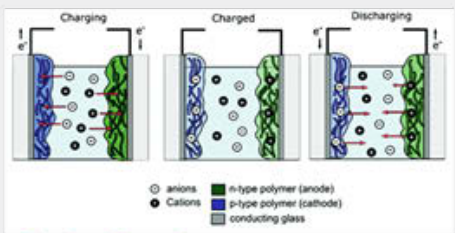
- Design and fabricate mixed conducting polymer electrodes and measure their charge accumulation and charge transport properties;
- Explore the effect of molecular structure and electrolyte on performance and work

with materials chemists to design better materials;

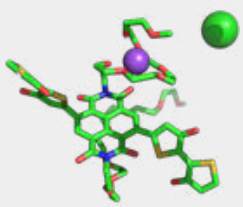
- Interpret your results with molecular and device level models;
- Identify factors limiting charge accumulation and transport in these materials.



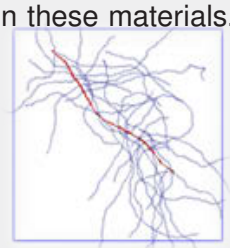
Polymer design



Device function



Charging mechanism



Transport mechanism

References:
[1] D. Moia et al. Energy & Env. Sci (2019) https://doi.org/10.1039/C8EE03518K
[2] A. Giovannitti et al., Chem. Mater (2018) https://doi.org/10.1021/acs.chemmater.8b00321
[3] N. Siemons et al., PNAS (2023) https://doi.org/10.1073/pnas.2306272120
[4] J. Coker et al., PNAS (2024) https://doi.org/10.1073/pnas.2403879121





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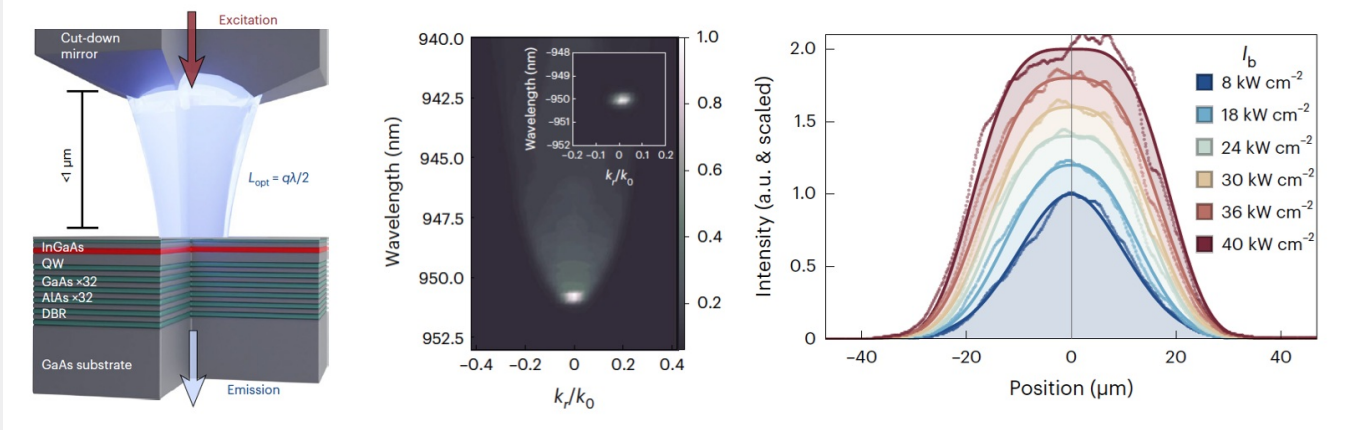
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Bose Einstein condensation of light in semiconductor open microcavities.

This project investigates experimentally the condensation of light in open microcavities made of group III-V semiconductors. Bose-Einstein condensation is the macroscopic occupancy of the ground state of a system of bosons as it is cooled down. Unlike cold atomic gases, confined photons in microcavities have a small effective mass allowing condensation at room temperature. Photon condensation was first demonstrated using an optical cavity filled with an organic dye [1]. Our group recently demonstrated that the same behaviour is possible with inorganic semiconductors [2]. (See this News & Views article for an overview [3]) This is important as organic materials are difficult to electrically inject and present limited prospects for application. Recent theory suggests that photon condensates exhibit unique quantum correlations for quantum sensing applications.

The aim of this PhD project is to study how photons interact with each other to manifest quantum states of light - all produced on demand from a single device at ambient conditions. We will for example study squeezed states of light and superfluid dynamics - so-called “Liquid-Light”.

[1] Klaers et al, “Bose–Einstein condensation of photons in an optical microcavity” Nature 468, 545 (2010)
[2] Schofield et al “Bose–Einstein condensation of light in a semiconductor quantum well microcavity” Nature Photonics 18, 1083–1089 (2024)
[3] Fainstein & Usaj “A Technology Friendly Photon Condensate” Nature Photonics 18, 999–1001 (2024)







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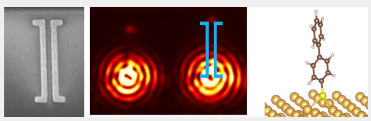
Prof. Stefan Maier
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The roles of photons, electrons, and molecular vibrations in plasmonic photo-catalysis

The ingredients of light, gold nanoparticles with suitable reactants enables photo-chemical reactions, such as water splitting and CO2 processing, which can address some of the world's sustainability problems. Our group is part of a UK team including the Universities of Manchester, Cardiff and Bath as well as King's College London working on plasmonic photo-catalysis (www.cplas.org). The Physics is fascinating as it is poorly understood. It involves the interaction of energetic of photo-excited "hot" electrons coupled to the vibrations of reactant molecules all on ultrafast timescales.

The aim of this PhD project is to explore and understand better the physics of the metal-molecule interface and the roles of photons, electrons and molecular vibrations [1]. In many respects the project explores the physics of ultrafast opto-mechanical coupling between light and molecules. Meanwhile, the many body dynamics may also be described using thermal and statistical mechanical techniques. The goal is to harness this knowledge for applications in photo catalysis as part of the wider catalysis team. You will be using a range of optical spectroscopy technique including, ellipsometry, Raman spectroscopy, and ultrafast pump probe spectroscopy [2].

[1] Stefancu et al "Optical and electrical probing of plasmonic metal-molecule interactions" Science Advances https://doi.org/10.48550/arXiv.2507.12128 (2025)
[2] Fu et al "Near-unity Raman β-factor of surface-enhanced Raman scattering in a waveguide" Nature Nanotechnology 17, 1251 (2022)



In this project you will:

Join our team exploring the control of light-matter interaction and its applications and the world-wide nanophotonics community. Our team also studies quantum imaging, condensates of light and metamaterials.

Join a large interdisciplinary multi-university UK team studying photo-catalysis and its applications. This is a group of Physicists, Chemists and Materials Scientists exploring a surprising poorly understood field.

Apply experimental techniques include spectroscopy, pump-probe spectroscopy, photon timing and correlation.

Use theory techniques such as quantum statistical mechanics and the physics of light-matter interactions in nanophotonic structures. There will also be opportunities for electromagnetic simulation of nano-scale structures.

Learn and apply micro and nanofabrication techniques including electron beam lithography, direct laser writing lithography and material evaporation/deposition.





Prof. Jasper van Thor
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Prof. Jon Marangos
Lockyer Chair in Physics
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X-ray Free Electron Laser Science

A fully funded 4-year PhD position is available in the group of Professor Jasper van Thor at Imperial College London. The PhD is supported by the STFC UK Hub for the physical sciences on XFELs (HPSX) and Imperial College. The project will involve all aspects of executing and analysing ultrafast X-ray crystallography experiments at X-ray Free Electron Lasers (XFELs). The project involves developing methods and experiments in order to increase the time resolution towards few-femtosecond and attosecond resolution. The PhD project will include experimental components involving sample environment, optics, diagnostics, beamline instrumentation and detector data processing, as well as computational aspects involving crystallographic data analysis and modelling. The project will be co-supervised by Professor Jon Marangos in the physics department. A part of the project will include work in the physics department on the configuration and use of a laser driven plasma hard X-ray source 'The Imperial College Laboratory for Ultrafast X-ray Diffraction (LUXD)'. The new LUXD facility will allow pump-probe femtosecond chemical crystallography.

Eligibility:
You will have either a physics, chemistry or biochemistry undergraduate degree with a 2:1 result or better. Additionally, a Masters degree with Merit or better in a relevant physics or chemistry topic will be preferred. Only students classified as Home (UK) for fees purposes are eligible to apply. The 4-year PhD studentship is jointly funded by STFC XFEL Physical Sciences Hub and Imperial College London Life Science Department. Applications should be emailed to Jasper van Thor and should include a CV and a cover letter with a personal statement. The CV should contain names and contact details for three references and details for courses taken and marks obtained.





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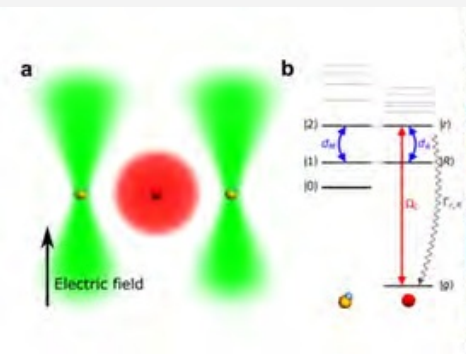
Prof. Mike Tarbutt
Professor of Experimental Physics
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Quantum networks of atoms and molecules

An array of laser-cooled polar molecules interacting with Rydberg atoms is a promising hybrid system for scalable quantum computation. Quantum information is stored in long-lived hyperfine or rotational states of molecules which interact indirectly through resonant dipole-dipole interactions with Rydberg atoms.

In this project you will:

- Join a team comprised of students, postdocs, and academics developing innovative quantum technologies
- Learn how to use precisely controlled lasers to cool atoms and molecules to ultracold temperatures
- Load the particles into traps formed by tightly focussed laser beams(optical tweezers)
- Rearrange the atoms and molecules into regular arrays and studytheir coherent interactions
- Implement a two-qubit gate between the molecules mediated by their strong interaction with a highly polar Rydberg atom
- Become an expert in vacuum and laser science, optics and imaging, 3D modelling, computer automation and interfacing, numerical modelling,and statistics and data analysis









Prof. Mike Tarbutt

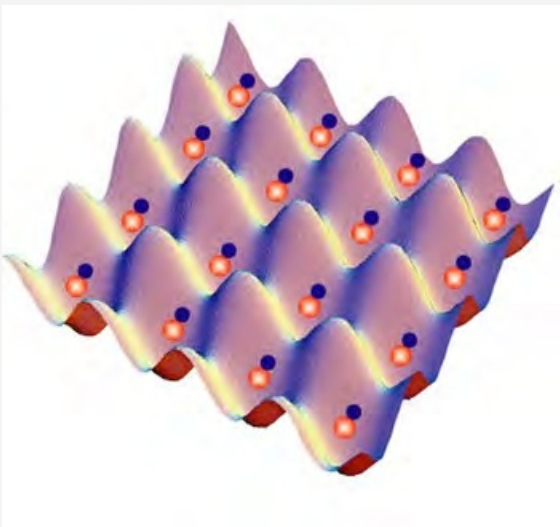
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Molecular lattice clock

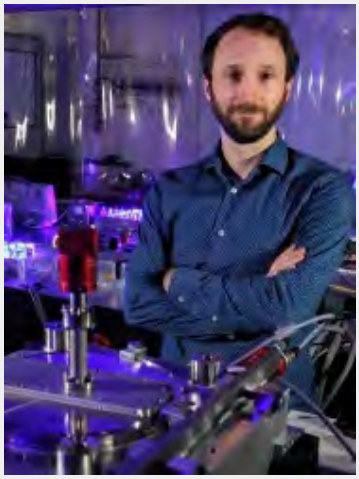
The aim of this project is to build a clock based on the vibrational frequency of ultracold molecules trapped in an optical lattice. The clock will be used to test the idea that the fundamental constants may be varying, as predicted by many extensions of the Standard Model. It willa lso serve as a frequency standard in the infra-red.

In this project you will:

- Join a small team of students, postdocs and academic staff
- Learn practical skills in lasers, optics, vacuum science, and electronics
- Build computer control hardware and software
- Evaluate and control systematic uncertainties in frequency metrology
- Develop and apply data analysis and statistical methods
- Work with collaborators from other institutions



Ultracold laser-cooled molecules in an optical lattice



Dr Stefan Truppe

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A quantum degenerate gas of stable, polar molecules

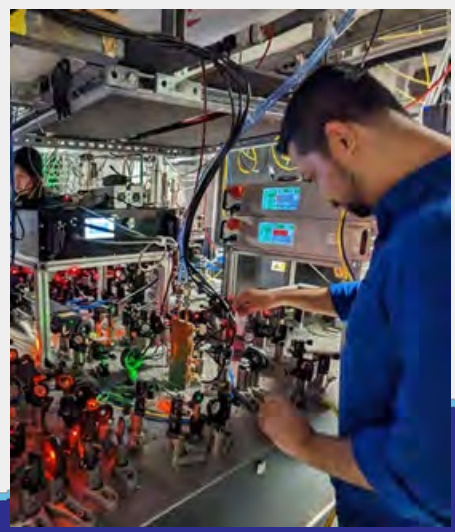
Ultracold molecules are the next frontier in ultracold quantum science. We develop new powerful lasers in the deep ultraviolet to manipulate stable gas-phase molecules and to cool them to ultracold temperatures in the microkelvin regime. Molecules cooled to such low temperatures offer many new possibilities in quantum information, simulation, and computation and for precise tests of fundamental physics.

In this project you will:

- Design and build lasers to produce high-power continuous radiation in the deep UV
- Stabilise and precisely control the frequency of these lasers
- Produce gas-phase, polar molecules in a high vacuum environment and cool them using cryogenic helium
- Use radiation pressure to slow a molecular beam and trap the molecules in a magneto-optical trap, where they can be cooled to microkelvin temperatures
- Study collisions in the quantum regime and perform precision measurements to test new physics
- Use the strong dipolar interactions between the molecules to encode quantum information and simulation protocols









Dr Frank Schindler

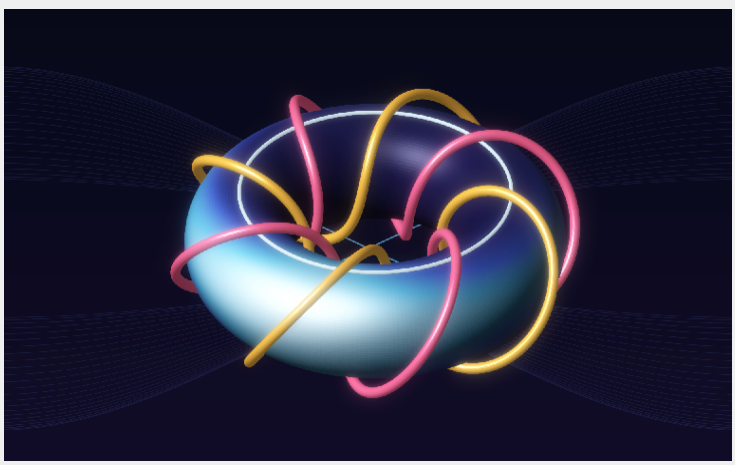
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Building bridges in the theory of topological phases of matter

Some quantum materials have properties that are completely robust to imperfections: perfectly quantised currents, edge states that cannot be destroyed, and emergent particles (anyons) that remember how they've been braided around each other. Theorists describe these topological phases in several powerful languages. Band topology covers electrons, symmetry-protected topological (SPT) phases cover interacting systems, and fusion and braiding algebras cover anyons. Yet these languages remain largely disconnected. When does a band invariant survive strong interactions? Can anyons themselves have a band structure?
In this project you will build bridges between these approaches, working towards a unified picture of topological matter. It connects to experiments on moiré materials and digital quantum computers, where such phases are now being realised.

In this project you will:

- Learn the modern theory of topological matter, from Berry phases to anyons.
- Develop new analytical frameworks linking band topology, SPT phases and topological order.
- Test your ideas numerically in concrete lattice models.



For more information please see https://frankschindler.github.io/phd.html.



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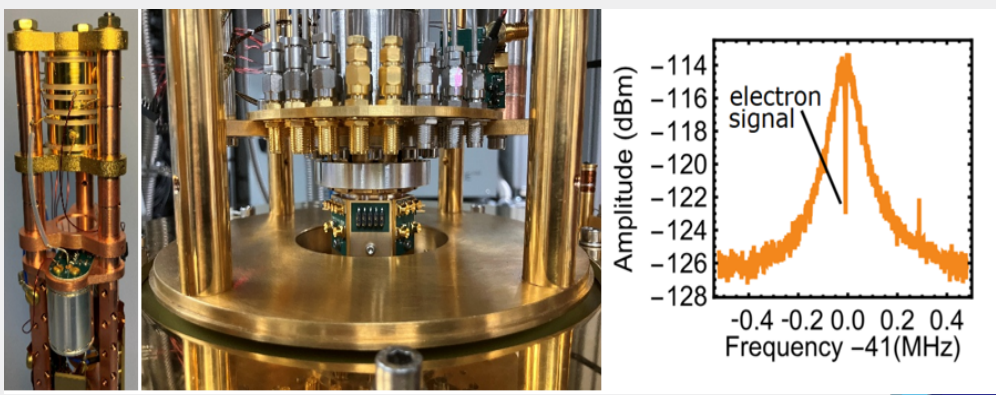
Astroparticle physics with a trapped electron quantum sensor

In this project you will use an electron in a Penning trap to do tabletop astroparticle physics, searching for hints of dark matter. The electron will act as a quantum sensor, and its quantum state will be monitored for changes caused by dark matter. These include both direct collisions with some types of dark matter and the absorption of single microwave photons from the decay of certain other types of dark matter particles like axions.

The primary focus of this project will be to design a next generation Penning trap, using some of the lessons learnt in our recent paper (https://link.aps.org/doi/10.1103/pg4b-jpg2), which will allow higher efficiency photon detection.

Amongst other things, you'll get to:

- Design and assemble a Penning trap electrode stack that can be cooled to 4 K
- Build ultra-sensitive detections systems to read out the trapped frequencies
- Make low noise electronics for use at cryogenic temperatures
- Learn all the skills of trapping individual particles including loading, cooling, trap optimisation and image current frequency detection
- Detect single microwave photons using a trapped electrons.



Frequently Asked Questions

How to apply?

Find out everything you need to know about your application journey onImperial's Application website.

What if I am interested in a number of projects?

If you are interested in a number of projects, state your preferences in the personal statement section of the application.

What's the deadline for submitting applications?

We do not have a deadline but students who are seeking studentships should aim to apply as early as possible. We typically allocate the available studentships by the end of March for a start date in October.

Can I apply for projects that are not fully funded?

Yes. The funding situation is very dynamic and we encourage you to mention your preference in the application.Scholarships are available for talented candidates.

Getting more information

For general information, please email Ms. Loli Sanchez on Loli.sanchez@imperial.ac.uk. For more information about research programmes and PG opportunities, please email Stefan Truppe s.truppe@imperial.ac.uk.

The Matter Research Community Website


SHERFIELD BUILDING