Imperial College London

PHD OPPORTUNITIES

THE LIGHT COMMUNITY

The Light Community

Head of Community
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Research mission

To carry out basic science using lasers and to investigate, utilise and control photonic and material states and processes down to the quantum level. We have about 27 full-time academic staff, 30 postdoctoral researchers and over 60 research students, making us one of the largest communities in the Physics Department at Imperial College London.

Research goals

- To investigate fundamental scientific questions using lasers, condensed phase, nanosystems and cavity optomechanical systems.
- To explore the interaction of laser radiation with matter at ultrahigh intensity and using ultrashort laser pulses– down to the attosecond domain.
- To develop the methods to use high intensity, ultrashort, Xray pulses from free electron lasers to measure electronic and structural dynamics in matter
- To develop and apply photonics-based tools for the life sciences, aiming to understand fundamental mechanisms in biology and to better diagnose and treat disease
- To understand and develop imaging technologies for fundamental research and real-world applications
- To develop theoretical schemes for Quantum Computing and Quantum Cryptography based on Quantum Optics.
- To develop advanced theoretical and computational techniques to simulate complex laser-induced dynamics, nonlinear optics, and ultrashort laser pulses.
- To utilize quantum mechanical properties to develop ultrahigh precision sensors
- To generate, manipulate and measure quantum states of light

Research Areas

The community has four main research areas:

- Attosecond Optical Science
- Biophotonics and Imaging
- Quantum Science and Technology
- Nonlinear Optics and Lasers

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

List of available projects

Light sheet fluorescence microscopy

Error detection and correction in photonic quantum computing

Filamentation of high-intensity light pulses in water

Ultra High-Intensity OPCPA Laser Systems and Light-Matter Autocorrelation

Measuring ultrafast electronic dynamics in organic semiconductors and photoswitching materials

Ultrafast and Strong field effects in the condensed phase

Light in time-varying metamaterials

Nanoscale graph lasers as neuromorphic computers

Sources and Diagnostics for Attosecond Quantum Science

Professor Christopher Dunsby

Professor of Biomedical Optics
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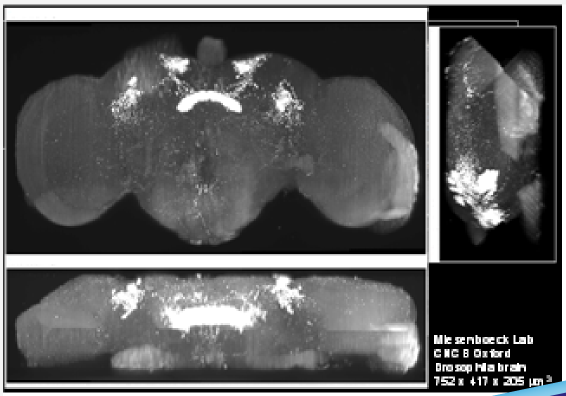
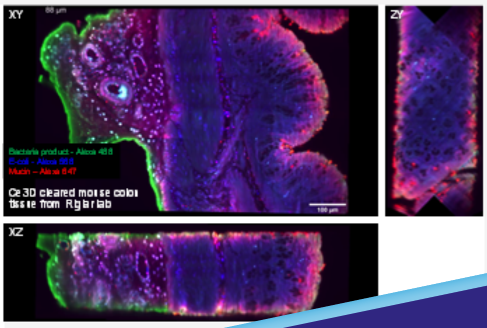
Light sheet fluorescence microscopy

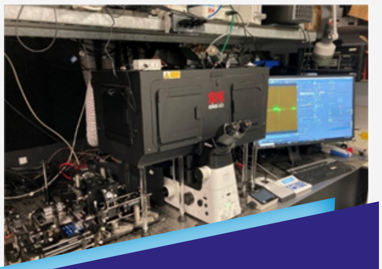
Light sheet fluorescence microscopy (LSFM) is a high-speed 3D fluorescence imaging method. However, conventional LSFM requires two microscope objectives placed at 90 degrees to one another to provide orthogonal illumination and detection and which restricts how the sample can be mounted. Oblique plane microscopy (OPM) is a (patented) technique developed in the Photonics Group at Imperial that uses a single high numerical aperture microscope objective to provide both the illumination light sheet and collection of fluorescence from the sample and can image in a wide range of standard sample mounting methods including multi-well-plate arrays.

This project will focus on the development of a dOPM system optimised for 3D imaging of arrays of optically cleared fixed tissue specimens and involve detailed optical design, alignment, testing and characterisation on Nikon and/or openFrame microscopes. The system will be applied to image arrays of optically cleared biological samples with collaborators in biology. Potential collaborators include studies of Drosophila brains (CNCB – Oxford), ovarian cancer tissue (McNeish Lab – Dept. Cancer, Imperial), Mouse colon (Riglar Lab. – Dept. of Infectious Disease, Imperial), lymphatic and blood vessels in mouse heart and small intestine (Birdsey Lab. – NHLI, Imperial), liver cancer needle biopsies (Goldin Lab. Dept. of Metabolism, Digestion and Reproduction, Imperial).

The cleared specimens will result in larger datasets and the associated challenge of data processing and analysis will require the application and development of automated image segmentation approaches, including the application and development of machine-learning based approaches.







Dr Raj Patel

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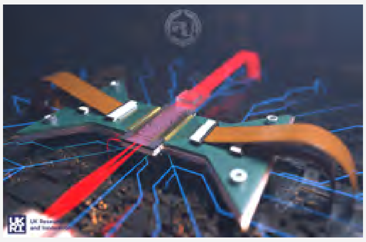
Error detection and correction in photonic quantum computing

Quantum computing holds great potential to enhance the performance of certain tasks such as database searching, optimisation, and the simulation of physical systems. Photonics provides a versatile platform for not only computation, but secure communications as well as sensing.

Large-scale, fully-error corrected, quantum computing devices capable of performing a range of tasks are a long-term goal. In the interim, noisy intermediate-scale quantum (NISQ) processors, designed to tackle important, dedicated, tasks have garnered much attention in recent years. Any useful, practical, quantum computer will require a means of handling errors.

This PhD project address error-detection and correction in both near-term and future photonic quantum computing devices. The student will:



- Utilise ultrafast lasers to generate quantum states of light carrying quantum information.
- Use bulk-optics, optical fibre, and integrated photonic circuits on a chip to perform operations to manipulate quantum information.
- Use cryogenic systems housing state-of-the-art single-photon and photon-number-resolving detectors.
- Study new circuit designs and data processing techniques to handle errors in a near-term quantum computing architecture known as Gaussian Boson Sampling which has recently been shown to exhibit a genuine quantum advantage over the world's fastest supercomputers.
- Use quantum interference and photon-number-resolving detection to engineer exotic quantum states of light suitable for detecting and correcting errors in fault-tolerant quantum computing, such as Schrodinger Cat states and Gottesman-Kitaev-Preskill states.
- Collaborate with both national and international partners in academia and industry, and disseminate results at conferences and in high-impact journals.

Professor Roland A. Smith

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Filamentation of high-intensity light pulses in water

Co funded by DSTL and the Energy Transfer Technology PhD Training Hub

(UK Nationality Required)

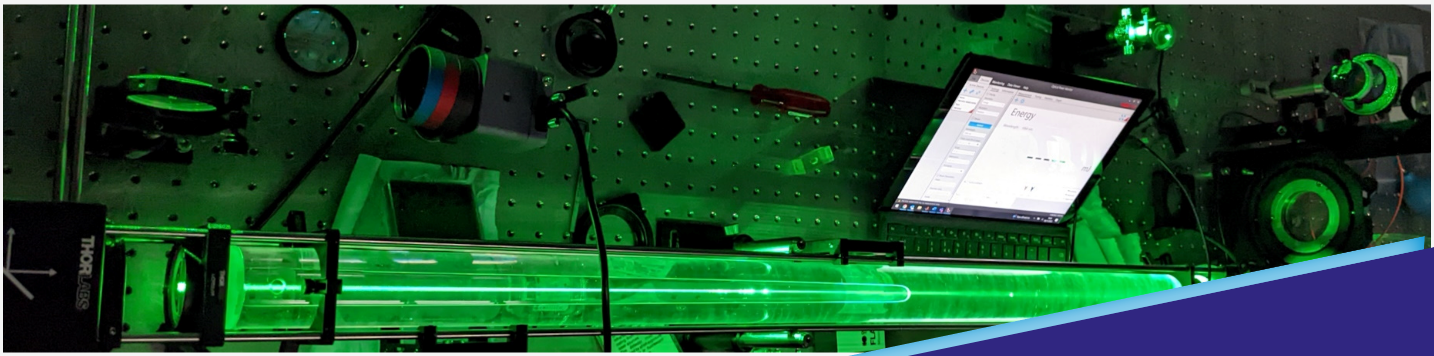
High power laser light propagating through a medium can instantaneously change the local refractive indeed, driving a focusing effect without needing a physical lens. This process can “run away” and self-generate hair-fine filaments of ultra-intense light.

Filamentation in air can produce km long ionization tracks, recently used to guide lightning bolts, but the underlying process in much less well understood in denser media such as water.

This project will investigate water filamentation in the green light optimal transmission window of water over long (1-10m) distances and characterise ionization and the generation of new wavelengths.

The project will include laboratory experiments driven by Imperial’s large multi-TW Cerberus laser system to deliver intense 0.5ps – 1ns “chirped” pulses which can self-compress by dispersion in water.

Experimental work will be linked to computer simulations to develop a predictive tool to model future applications in remote sensing driven by water filamentation.



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Dr Mary Matthews
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Ultra High-Intensity OPCPA Laser Systems and Light-Matter Autocorrelation

This project is a collaboration between Imperial College and the Rutherford Appleton Laboratory (RAL) to develop and exploit a new generation of ultra-high intensity lasers. RAL is currently upgrading the UK's Vulcan National Laser Facility to create one of the world's most powerful systems, aiming to deliver 20 Petawatts of peak power in a 20 femtosecond pulse. A key element of this laser is the use of Optical Parametric Chirped Pulse Amplification (OPCPA) in which a stretched light pulse is amplified several million times or more by instantaneous transfer of energy from one laser to another in a non-linear optical crystal. This is much more complex than a traditional laser, but allows for creation of the very high quality sub-picosecond light pulses needed to drive experiments in areas such as particle beam acceleration and x-ray imaging. A key element of this project will be the development and testing of parametric amplification test systems (particularly characterising their unwanted parametric fluorescence noise) and the creation and refinement of supporting numerical models. This will be linked to specific "end use" requirements at RAL (likely including some on-site work there), for very high-contrast / low noise laser pulses.

As part of this project we will also aim to use OPCPA for the 1st time to create a new measurement technique that can time resolve the details of a particle beam (or other process that perturbs the vacuum fluctuation background) with unprecedented detail, perhaps just a few femtoseconds. We believe that this could lead to a "light matter autocorrelation" technique with applications in next generation high-energy physics experiments.

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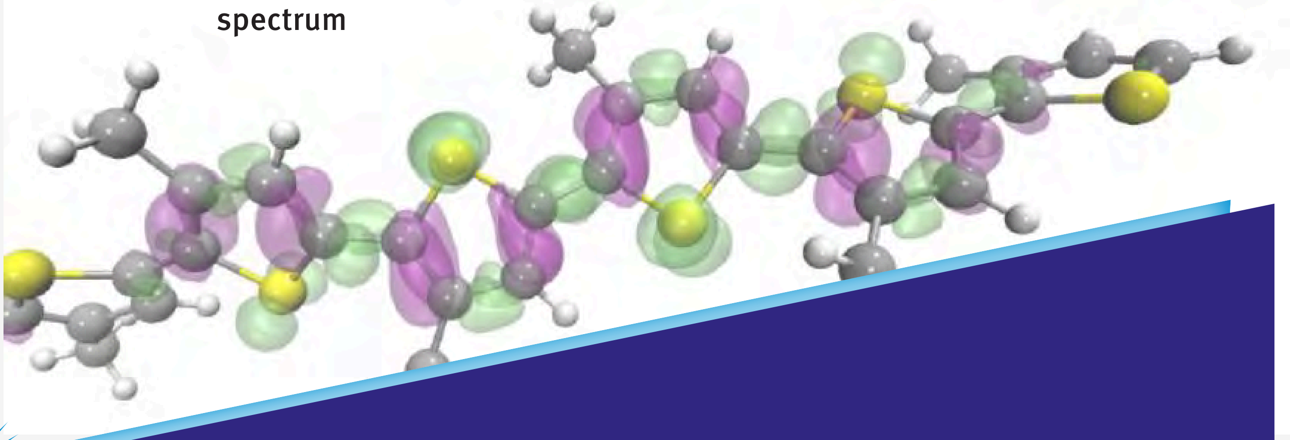
Measuring ultrafast electronic dynamics in organic semiconductors and photoswitching materials

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 oganometallic 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



Dr Mary Matthews

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Ultrafast and Strong field effects in the condensed phase

The interaction of strong electromagnetic fields with matter is at the heart of attosecond science and sources of coherent extreme UV light: a high intensity laser distorts the medium's potential, allowing an electron to tunnel out and gain kinetic energy. The oscillating field then returns the electron to its parent ion, releasing a high-energy photon on recombination. This phenomenon, called high harmonic generation (HHG), produces attosecond-duration harmonics of the driving field, reaching up to 1.5 keV in different media such as in gases, liquids and solids. This emission does not require a material resonance, making it a useful diagnostic and potential coherent source of XUV and VUV. The strong laser field also drives the electrons within the material at PHz rates, creating ultrafast currents which could lead to a new generation of PHz optoelectronic devices. Furthermore, HHG is a quantum process, and the emitted photons can be entangled to create a source of coherent broadband quantum photon states. We aim to study two aspects of HHG: 1) in liquids to develop a means to discriminate chiral liquids by creating chiral light and 2) in solids to deliver a new class of quantum devices and EUV sources.

The student will be part of the Extreme Light Consortium (XLC) in a team of students and postdocs working on ultrafast science and ultrafast spectroscopy. They will have mentoring and support from senior PhD students, postdocs and staff on a range of equipment, from ultrafast high intensity laser systems, vacuum systems, gas/liquid sample delivery, cleanroom, techniques and electron and optical microscopy. As well as developing research skills and knowledge of semiconductors and chiral liquids and ultrafast spectroscopy the student will be able to access the Imperial College Postdoctoral courses. Imperial College provides extensive support for PhD students through core courses, transferable skills and careers support networks.

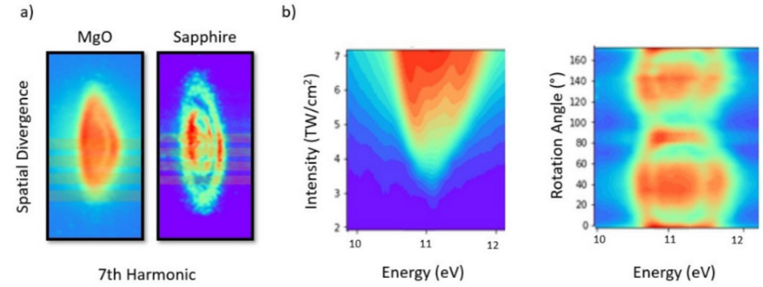

Fig. 1 a) Spatially and spectrally resolved fringes of the 7th harmonic from bulk Mgo and Sapphire b) spatially filtered off-axis 7th harmonic from MgO dependence on the laser frequency and rotation angle presenting the modulation and changing interference patterns.

Professor Riccardo Sapienza

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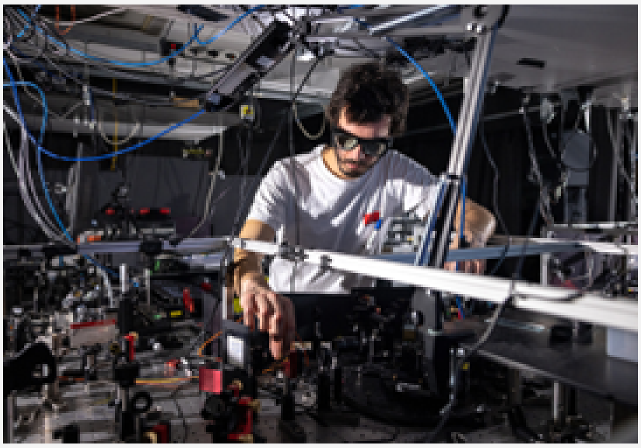
Light in time-varying metamaterials

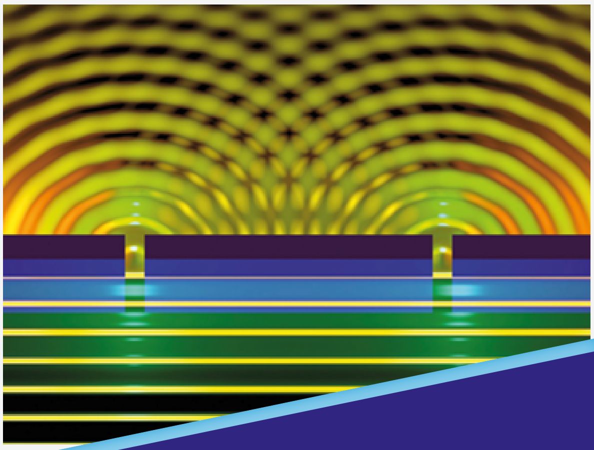
Metamaterials are artificial materials with properties that do not exist in natural materials. This both charts the physics of wave propagation in exotic media and is of utmost practical importance.

You will study time-varying metamaterials, whose optical properties varies on femtosecond time scales. The project, joint between Prof. Stefan Maier, Prof John Pendry and Prof. Riccardo Sapienza, builds on the latest advances in nanophotonics, metamaterials and nonlinear optics, which gives powerful tools to control light-matter interaction at the nanoscale. Exploiting the nonlinear response of semiconductors we will study temporal phenomena like the temporal Young slits diffraction, e.g. see one of our latest work (https://www.nature.com/articles/d41586-023-00968-4). This is part of a large project, an EPSRC funded Programme Grant “Next generation metamaterials: exploiting four dimensions – Meta4D”, so you will interact with researchers from many departments across 3 institutions.

We are seeking an enthusiastic PhD student to undertake experimental research. The project involves design, nanofabrication and optical studies of nanostructures and metamaterials. The successful candidate should have a degree in physics, or material science. Independent thinking and multidisciplinary attitude are sought.

The experiments involve state-of-the-art custom built ultrafast optical setups.





Professor Riccardo Sapienza

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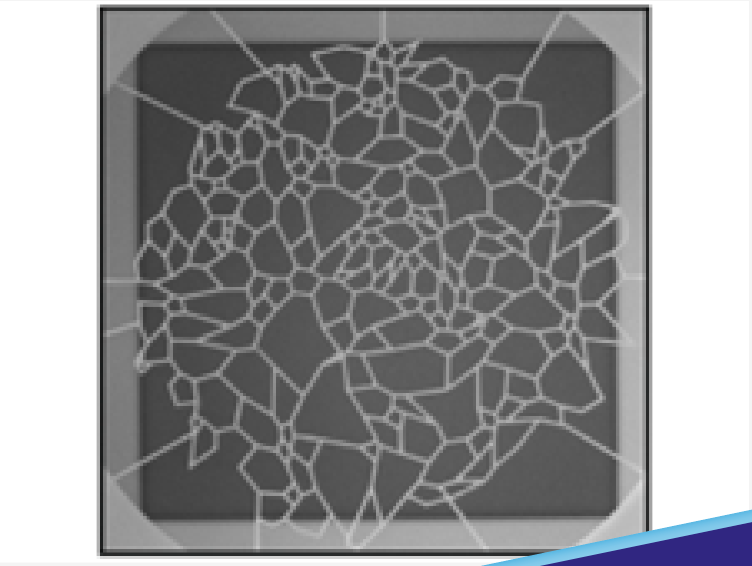
Nanoscale graph lasers as neuromorphic computers

You will develop unconventional laser to be integrated with silicon chip to power next generation optical computation technology. The project, at the interface between random lasing and advanced material science, builds on the latest advances in nanophotonics of disordered media, network theory and lasing, and aims at studying lasing in a mesh of nanoscale waveguide forming a physical graph. Preliminary work can be found here https://www.nature.com/articles/s41467-022-34073-3. You will then show that these lasers can be used to perform machine learning and image recognition.

We are seeking an enthusiastic PhD student to undertake experimental research. The project involves design, nanofabrication and optical studies. The successful candidate should have a degree in physics, or material science. Independent thinking and multidisciplinary attitude are sought.

The project is in collaboration with Kirsten Moselund, in EPFL and IBM Zurich and Jack Garter and Will Branford in Imperial College London.



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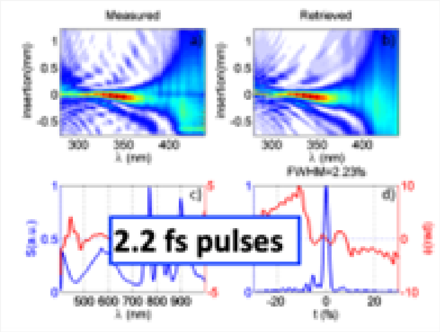
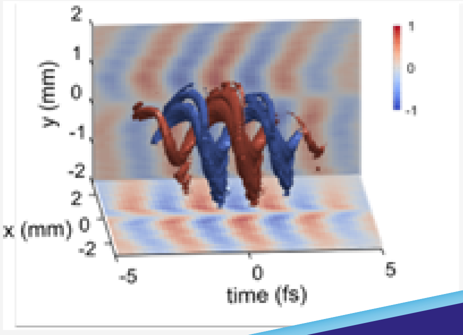
Sources and Diagnostics for Attosecond Quantum Science

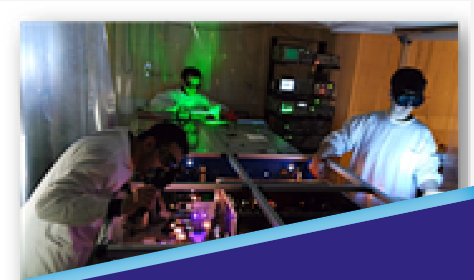
The proposed work is part of a recently submitted EU Doctoral Network (lead by Giuseppe Sansone, Albert-Ludwigs-University, Germany) aimed to promote and advance the merging of the fields of quantum optics and quantum information science with attosecond physics. This will be achieved through novel experimental campaigns aimed at highlighting the novel aspects that arise from the generation of quantum states of light characterized by a large number of photons and massively entangled light-matter states. This will require the development of solutions for optimising the laser sources used in the experiments, namely in the promising mid-infrared spectral range. These optimizations are crucial for meeting the requirements necessary for the reconstruction of the quantum states of light and the targets. Simultaneously, the network will focus on advancing the theoretical descriptions necessary for a comprehensive understanding and characterization of the quantum state of light associated with intense laser fields.

In this project you will:

- Design and develop new methods for the temporal and spatiotemporal characterisation and optimisation of novel light sources for attosecond quantum science
- Collaborate in joint experiments and campaigns aimed at demonstrating key principles in attosecond quantum science
- Actively engage with leading academic and industrial partners to foster collaborative relationships, gain insights from key players in the field, and access cutting-edge resources and expertise







Frequently Asked Questions

How to apply?

Find out everything you need to know about your application journey at https://www.imperial.ac.uk/study/apply/postgraduate-doctoral/application-process/

What if I am interested in a number of projects?

If you are interested in a number of projects within LIGHT you should state your preferences in the personal statement section so we can tell the appropriate people in the group of your application.

What's the deadline for submitting applications?

There's no hard deadline but students who are seeking studentships should aim to apply by early March as the studentships are normally decided before the end of the month.

I'm from outside the UK, what's my funding situation?

If you are from outside the UK you may need to arrange your own funding, for which the following link may be useful: https://www.imperial.ac.uk/students/fees-and-funding/postgraduate-funding/postgraduate-scholarships/

Getting more information

For general information please contact Marcia Salviato: m.salviato@imperial.ac.uk. For more information about research programmes and PG opportunities, please contact Prof. Florian Mintert: f.mintert@imperial.ac.uk

The Light Community website

https://www.imperial.ac.uk/physics/research/communities/light/


SHERFIELD BUILDING