Imperial College London

PHD OPPORTUNITIES

THE LIGHT COMMUNITY

The Light Community

Head of Community
Professor Myungshik Kim
m.kim@imperial.ac.uk
https://www.imperial.ac.uk/people/m.kim

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

Attosecond sciences in the condensed phase

Bose Einstein condensation of light in inorganic semiconductor open microcavities

Filamentation of high-intensity light pulses in water

Light in time-varying metamaterials

Light sheet fluorescence microscopy

Nanoscale graph lasers as neuromorphic computers

Saving lives by Imaging Cancer Specimens with Entangled Photons

Sub-cellular mass spectrometry imaging with shaped mid-infrared light

Dr Mary Matthews

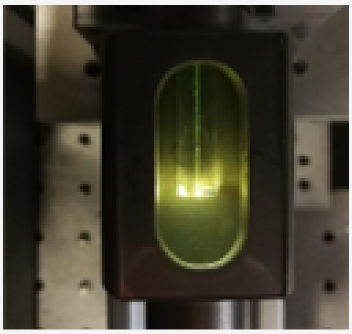
Lecturer in Ultrafast Science
Extreme Light Consortium
m.matthews@imperial.ac.uk

Attosecond sciences in the condensed phase

Both solids and liquids when illuminated with an intense ultrashort laser pulse will emit XUV light, with attoseconds duration. In the Extreme Light Consortium we have begun investigating methods to these generate attosecond and extreme UV, (XUV), pulses from different types of materials, with the dual aims of understanding how extreme UV light is produced in these materials and developing photonic devices. The emission is called high harmonic generation (HHG), as it is higher harmonics of the input pulse. HHG can extend up to 40eV in some solids and liquids.

Potential applications include a solid-state source of attosecond pulses, laser pulse diagnostics. However they also include spectroscopy “on-a-chip” and a means to discriminate chiral liquids. Chiral enantiomers are forms of molecules which are chemically and physically identical, but with left and right handed versions. These kinds of molecules which are ubiquitous in chemistry and biology and are important in drug development. Diagnostics are needed to help discriminate different enantiomers.

The student will look at testing a range of samples from nanostructures to create enhanced HHG emission from chiral liquids. The aim is to develop prototype sources with ways to discriminate chiral enantiomers. The student will explore what are the best nanostructures for HHG spectroscopy, how HHG can be used to discriminate chiral enantiomers. These topics then combine in the development of a microfluidics setup where in-situ HH generation can be used for HHG spectroscopy on a miniature chip.



The study will involve daily use of ultrafast lasers and the characterisation of ultrafast pulses and XUV emission. An interest in either solid state physics, nanostructure design, molecular chirality, microfluidics and nonlinear.

Applicants should hold a MSc or BSc in Physics, Chemistry or a closely related subject and have a strong interest in materials, molecular physics and experimental laser physics. The candidate will have access to state-of-the-art research laboratories and equipment and will work closely with the current XLC team.

Prof Rupert Oulton

Professor of Nanophotonics
r.oulton@imperial.ac.uk

Bose Einstein condensation of light in inorganic semiconductor open microcavities

The project investigates experimentally the condensation of light in open microcavities made of inorganic III-V semiconductor materials. Bose-Einstein condensation is the macroscopic occupancy of the ground state as a system of bosons is cooled down. Unlike cold atomic gases, confined photons in microcavities can have a very small “effective mass”, that enables condensation at room temperature. Photon condensation is distinct from laser action as it does not require a population inversion. Recent theory suggests that photon condensates exhibit unique quantum correlations enabling low-noise quantum sensing applications.

Photon condensation was first demonstrated using an optical cavity filled with an organic dye [1]. Our group has recently shown that the same behaviour is possible with inorganic semiconductors [2]. Remarkably, it looks like many laser systems especially semiconductor lasers can operate in this manner. This is important as organic materials are difficult to electrically inject and present limited prospects for compact laser application. The aim is to study the nonlinear properties of these devices to enable quantum states of light to be produced on demand from a single laser device. We will for example study squeezed states of light, as well as studying superfluid dynamics – so-called Liquid-Light. The material will be grown at the University of Sheffield.

[1] J. Klaers, J. Schmitt, F. Vewinger & M. Weitz, “Bose–Einstein condensation of photons in an optical microcavity” Nature 468, 545 (2010)

[2] R. C. Schofield et al “Bose–Einstein condensation of light in a semiconductor quantum well microcavity” Nature Photonics 18, 1083–1089 (2024)

Techniques, activities, and equipment used:

- Laser spectroscopy
- Pump-probe spectroscopy
- Theory and modelling of light emission and gain semiconductors.
- Electromagnetic simulation of nanophotonic structures.

Professor Roland A. Smith

Professor of Laser Physics
Plasma Physics & High Power Lasers
r.a.smith@mperial.ac.uk

Filamentation of high-intensity light pulses in water

Funded by 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.

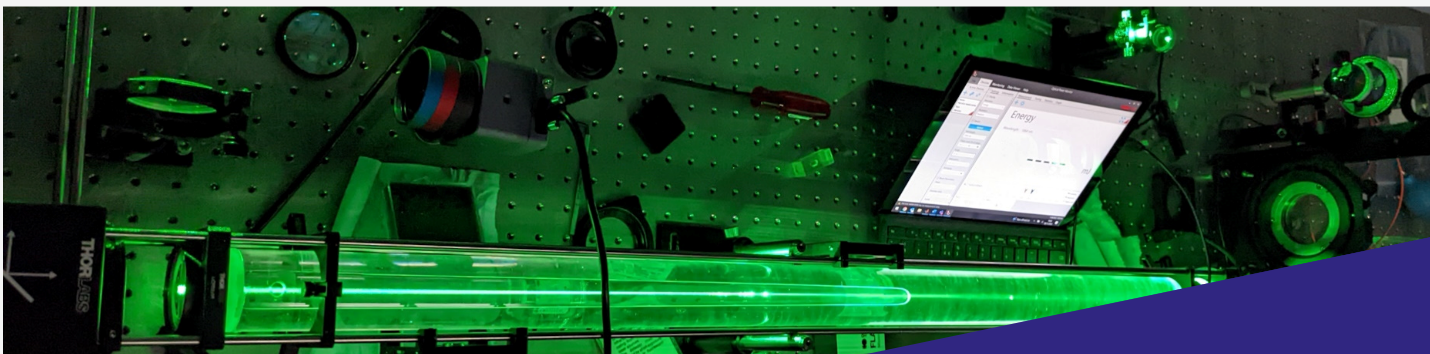
Filamentation in air can produce km long ionization tracks, recently used to guide lightning bolts, but the underlying process in much less well understood in denser (and more complex) media such as water.

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.

Experimental work will be linked to complex computer simulations with the aim of develop a predictive tool to model applications in remote sensing, but a key challenge is dealing with "missing physics" as our experiments to date have thrown up a number of unexpected oddities.



Professor Riccardo Sapienza

Professor of Physics
r.sapienza@imperial.ac.uk

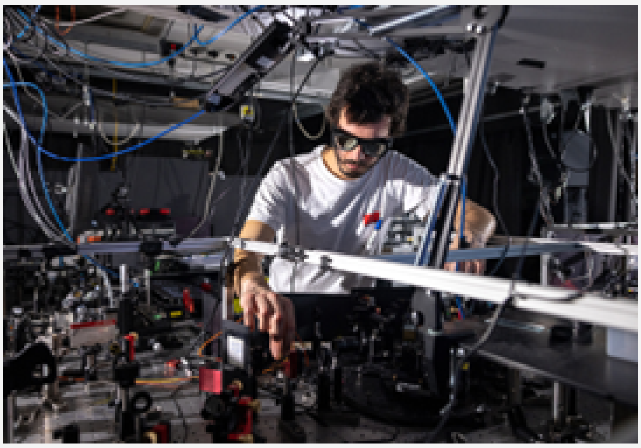
Light in time-varying metamaterials

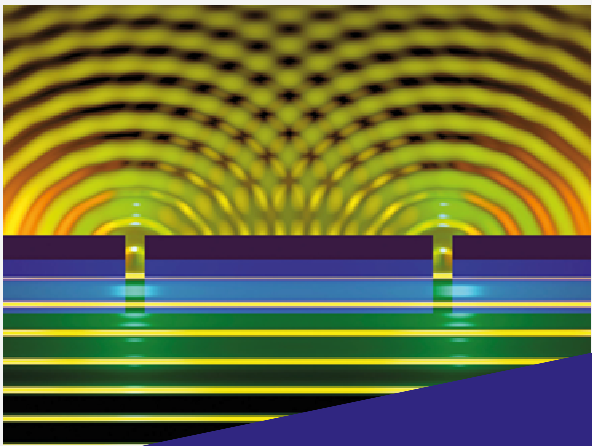
Metamaterials are artificial materials with properties that do not exist in natural materials. This both charts the physics of wave propagation in exotic media and is of utmost practical importance.

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.





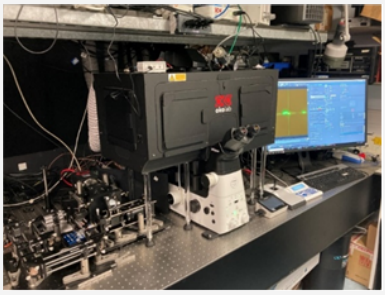
Professor Christopher Dunsby

Professor of Biomedical Optics
christopher.dunsby@imperial.ac.uk

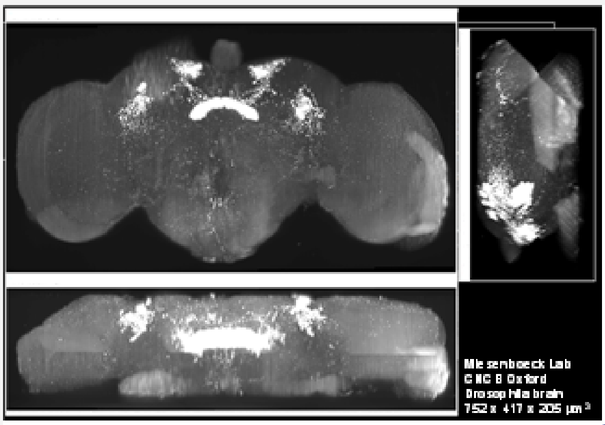
Light sheet fluorescence microscopy

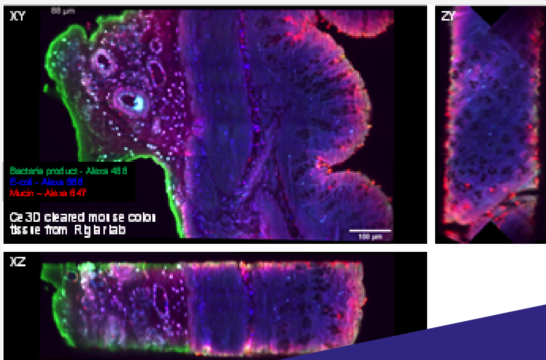
Light-sheet fluorescence microscopy (LSFM) is a high-speed 3D fluorescence imaging method that is used widely for imaging biomedical samples. However, conventional LSFM requires two microscope objectives placed at 90 degrees to one another to provide orthogonal illumination and detection and this restricts how the sample can be mounted. Oblique plane microscopy (OPM) is a (patented) technique developed in the Light Community 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 develop cutting-edge advanced OPM fluorescence microscope and related systems for imaging optically cleared fixed tissue specimens. The work will include detailed optical design and alignment, testing and characterisation on Nikon and/or openFrame microscopes. The system will be applied to image arrays of optically cleared biological samples with potential collaborations including 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) and liver cancer needle biopsies (Goldin Lab. Dept. of Metabolism, Digestion and Reproduction, Imperial).



The cleared specimens will result in large (TB) 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.





Professor Riccardo Sapienza

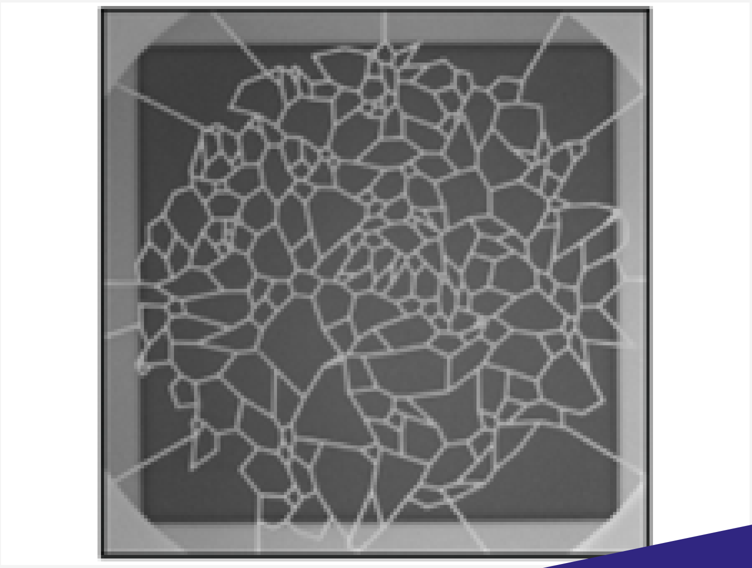
Professor of Physics
r.sapienza@imperial.ac.uk

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.



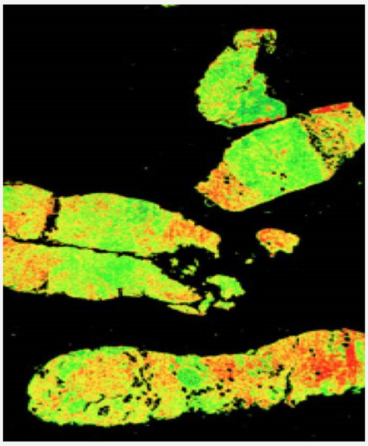
Professor Chris Phillips

Professor of Experimental Solid State Physics
chris.phillips@imperial.ac.uk

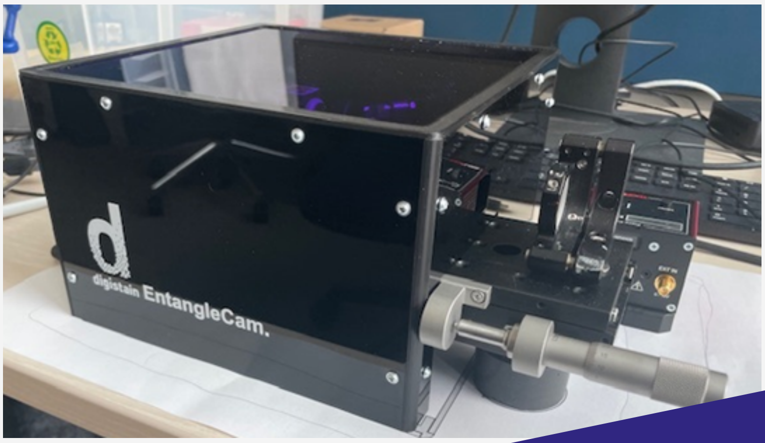
Saving lives by Imaging Cancer Specimens with Entangled Photons

Our team within the UK Quantum Imaging Hub is investigating the use of quantum correlated light sources for infrared imaging. This uses a method of Quantum imaging with undetected photons (QIUP)*, where an image is formed from photons that haven't interacted with the object in view at all! We use entangled photon pairs, an infrared one that interacts with the object of interest, (usually a sample of breast cancer tissue), and a visible one which can be detected with a standard camera. The entanglement means that when the infrared one interacts with the object the event is instantaneously known by its twin in the visible, a working example of what Einstein famously called "spooky action at a distance".

Apart from the intriguing fundamental aspect of this research, it has the practical advantage that high performance detectors in the visible, can be used to form images with other scientifically important, but technologically challenging, spectral regions – especially the mid infrared, which hosts the fingerprints of molecular vibrations. We use this part of the spectrum to measure the concentration in the Breast Cancer, giving a very reliable diagnosis to inform treatment decisions.



The project involves developing nonlinear optics techniques to produce photon pairs bridging the visible and mid infrared (3-12 um wavelength), where vibrational absorption bands allow the chemistry of the object to be inferred. The results will be combined from other IR imaging methods in the group, including sub-wavelength s-SNOM images of cells and graphene devices, and our "Digistain" IR based cancer detection technology. The UK government has taken a great interest in this work, and promises to have one of our " EntangleCam" instruments in every hospital by 2030. A independent consultant's investigation has decided that if we can achieve this we will save 1266 lives and £267m a year by avoiding unnecessary chemotherapy for breast cancer.



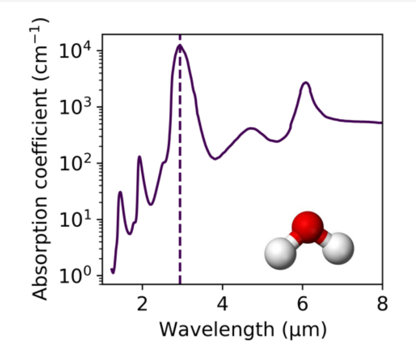
Dr Robert Murray

Senior Lecturer in Mid-Infrared Photonics
robert.murray10@imperial.ac.uk

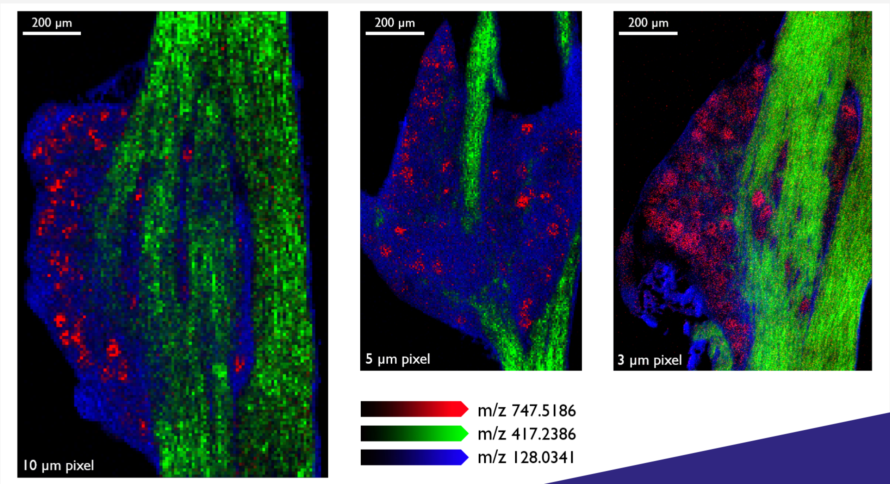
Sub-cellular mass spectrometry imaging with shaped mid-infrared light

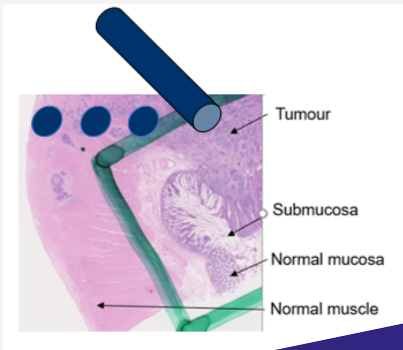
Mid-infrared (MIR) light sources (2.94 μm) can be used to precisely ablate biological tissue due to resonant absorption by water (O-H), for subsequent analysis using mass spectrometry (MS). Raster scanning the laser beam across the sample allows the construction of hyperspectral images consisting of thousands of different molecular channels, known as mass spectrometry imaging (MSI).

MSI techniques so far (at least those performed with lasers) have been limited in the spatial resolution that can be achieved. Achieving resolutions below ~10-20 μm has not been possible. Optical microscopy on the other hand, can readily achieve resolutions down to 100s of nm (and lower). Thus, there is a 'resolution gap' between optical and molecular imaging techniques (MSI). There is vital need to bridge this resolution gap, to allow co-registration of tissue morphology (optical microscopy) and the underlying biochemistry (molecular imaging). This will allow biologists and clinicians to better understand biological processes at the cellular level, crucial for advancing our understanding of disease.



This project will involve the development of mid-infrared light sources with fully customisable spatial and temporal properties using spatial light modulators. Such exquisite control over the amplitude and phase of the mid-infrared ablation lasers will allow us to selectively remove tissue at the sub-cellular level (< 1 μm precision), allowing us to achieve sub-cellular ambient MSI for the first time. The imaging platform developed will be tested in collaboration with biological and clinical partners from the Faculty of Medicine (ICL), Rosalind Franklin Institute and National Physical Laboratory.





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 multiple projects within LIGHT, please state your preferences in the personal statement section. This will allow us to inform the relevant individuals in the group about your application.

What's the deadline for submitting applications?
There is no hard deadline but students who are seeking studentships should aim to apply by March.

I'm from outside the UK, what's my funding situation?
If you are from outside the UK, you will most likely 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