NANOPHOTONICS

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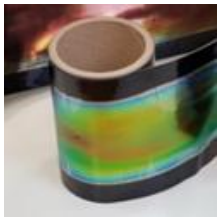
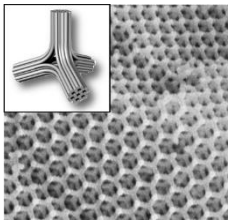
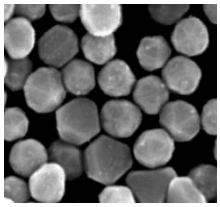
NanoOptics: Our centres in Ubiquitous Optical Healthcare Technologies (ubOHT), NanoOptics-to-NanoChemistry, Soft and 3D Metamaterials, and Light-controlled Nano-assembly make unusual sorts of nano-materials which combine novel optical properties built from structuring components on the nanometre scale, to investigating single molecules, with the (literal) flexibility of using soft materials. The physics of combining electromagnetism and quantum mechanics produces emergent surprises in new useful properties. Our collaborations with bio, polymer and soft matter groups involve many research disciplines around the university including Chemistry, Chemical Eng, Physics of Medicine, Institute for Manufacturing, involving partnerships with many international leaders.
To get an idea of current projects, check out recent papers (http://www.np.phy.cam.ac.uk/publications/)



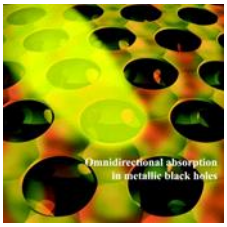
Scalable and reconfigurable 3D metamaterials: Metamaterials provide emergent properties by combining nano-scale building blocks to elicit completely novel behaviours not found in natural materials. Applications are for energy absorption and harvesting, mechanical intelligence, enhanced sensors, and much more. However few practical examples exist because of the difficulty of realistic scale-up. Projects here explore nano-assembly routes to create 3D metamaterials, using a variety of building blocks from noble metal nanoparticles, to DNA nanostructures and precision colloidal architectures. You would engage with a wider team across academic and industrial partners.



DNA Origami Nanomachines and Metamaterials: By knitting DNA strands to make a wide variety of rigid building blocks, and combining these with polymers which respond to light, we conceive of a new generation of nanomachines that can flap, walk, and wave. Our discoveries of new ways to actuate these DNA origami architectures opens up a wave of possible applications. This project will explore early pathways, and devise new ways to measure and exploit forces at the nanoscale, colloborating with the Keyser group and others across the UK and EU.

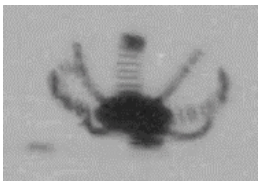


Low-cost healthcare sensing using light: Our new centre (ubOHT) is aiming to revolutionise healthcare by tracking hormones and neurotransmitters in biofluids. We developed a number of crucial advances that allow us to analyse urine in real time using surface-enhanced Raman scattering (SERS) to acquire fingerprints of different small molecules. Using the massive enhancement of light in metal nanogaps, signals can be billion-fold stronger, allowing rapid acquisition using low cost microfluidics and lasers. A range of projects are available to study how molecules compete to bind to the active hotspots, how they are transported on the nanoscale, and how the gold facets can be controlled at the atomic scale. Many interactions with industrial and clinical partners are available, with collaborators across the UK.



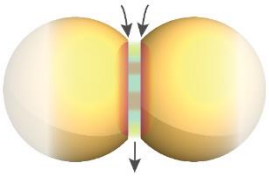
Ultrafast nonlinear spectroscopy of single nano-structures: Our group has pioneered ways to trap light inside gold 'plasmonic' metallic nanostructures producing enormous concentration of the optical fields down to $1nm^3$. Light coupling to dipoles inside our nanostructures, enhance coupling by up to 10 orders of magnitude. We now routinely watch the motion of single atoms and single bonds. This project involves ultrashort laser pulses to disturb the electrons inside such

nanostructures, and observe the ultrashort dynamics of individual atoms and molecules trapped in these nanocavities. The aim is to produce the lowest energy optoelectronic switches ever created, down to zepto-joules.

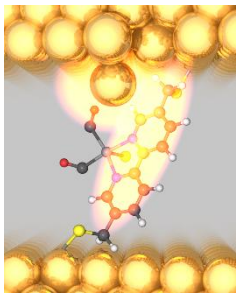


Light-controlled Microswimmers and Micro-cilia: The task of making microswimmers is challenging. We have developed a carbon nanotube (CNT)-thermoresponsive polymer (TRP) system in which CNT forests form the 'skeleton' and the embedded TRP are 'muscles' triggered through laser illumination. Their sub-ms actuation is fast (sub-ms), with forces large enough to power micro/nanomachines, capable of making autonomous interacting microswimmers, or micro-cilia that interact with light to move cargo across surfaces. You will trial a wide variety of different designs, developing improved ways to break the symmetry of the skeletons so they bend in response to light, aiming for fields of waving cilia that respond to different colours. Currently applications are futuristic, such as microsurgery in the body, with first steps vitally needed in this nascent field.

Active plasmonics nanodevices: We lead the world in the robust nano-assembly of individual metallic nano-architectures which trap light to the nm-scale, allowing us to study excitations such as electron-hole pairs or individual molecular bonds. This project will explore the use of active photo-responsive polymers in switching these optical devices on the sub-ns scale, opening access to dynamics of indivdual atoms, molecules and electrons, and their dynamics and control, as well as accessing quantum properties which we can exploit.



Plasmonic nanoreactors: Our group is leveraging their knowledge of nanoscale plasmonics to develop new self-assembled plasmonics nanoreactors. These utilize the million field enhancements, obtained in tight plasmonic nanogaps, to enhance photocatalytical processes. The aim of this project is to develop efficient optically driven and scalable nanotechnologies for converting othewise resistant materials such as plastics, biowaste and CO_2.



Tracking single molecule catalysis: by pairing single molecule SERS data to extensive DFT calculations a real-space image can be recreated of how a molecule was behaving in time. This allows us to track how molecules interact with their environment and undergo chemical processes with sub-millisecond integration times. The aim of this project is to use this methodology to track how a single organic catalysts performs catalytic operations, what are time limiting steps and how undesirable by-products are formed.

In all projects for a PhD in NanoPhotonics, you will develop new construction techniques combining self-assembly and soft polymer materials to create and then spectroscopically measure these nanomaterials. This will thus involve a large number of different techniques in Nano-science, before you build advanced optics rigs to create adaptively-controllable materials and devices. The new applications for such materials are widespread and you would get involved in considering how novel physics can impact different areas. We work with collaborators around the world, for instance in theory, and you would visit and interact with a number of key people.