# NANOPHOTONICS

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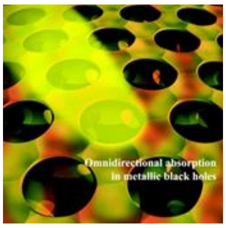
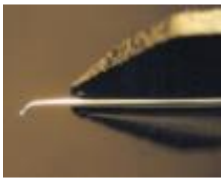
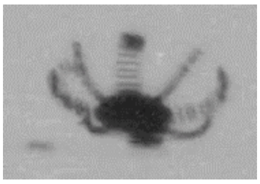
<u>NanoOptics:</u> Our centres in NanoOptics-to-NanoChemistry, Soft NanoPhotonics and Light-controlled Nano-assembly make unusual sorts of nano-materials which combine novel optical properties built from structuring components on the nanometre scale, to investigating single molecules, with the (literal) flexibility of using soft materials. The physics of combining electromagnetism and quantum mechanics produces emergent surprises in new and useful properties. Our collaborations with Scherman (polymers), Keyser (soft matter) groups involve many research disciplines around the University including Chemistry, Chemical Eng., Physics of Medicine, Institute for Manufacturing, with Hess (Imperial), Aizpurua (Spain) and other international leaders.
To get an idea of current projects, check out recent papers (http://www.np.phy.cam.ac.uk/publications/)




<u>Ultrafast nonlinear spectroscopy of single nano-structures</u>: 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.



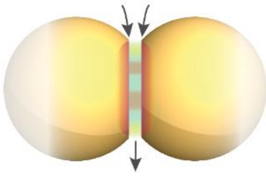
<u>The fundamental basis of nanoscale friction and how lubricant molecules work</u>: The aim of this project is to develop new prospects to use plasmonics to understand the molecular basis for friction and wear, using Raman scattering for in-situ study of nanolayers in the gaps. Our plasmonic nanogaps will be used to give intense vibrational spectra from surfactant molecules used in lubrication of engines and motors, which are vital for the modern low-carbon society. However their understanding is at an early stage, and few techniques exist to probe metal-molecule interactions during frictional wear. You will build a new experiment to track the molecular orientation and strain in real time, collaborating with our colleagues in Chemical Engineering and industrial partners.



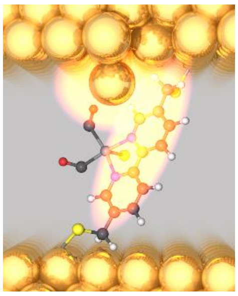
<u>Light-controlled Microswimmers and Micro-cilia</u>: The task of making microswimmers is challenging. We have developed a carbon nanotube (CNT)-thermoresponsive polymer (TRP) system in which CNT forests form the 'skeleton' and the embedded TRP are 'muscles' triggered through laser illumination. Their 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.