

# Nanoplasmonics

In the Faculty of Natural Sciences

Nanoplasmonics is a new research field marrying photonics with nanotechnology. It investigates the localisation of light and light/matter interactions on the nanoscale. Research in this area has accelerated at an immense rate in the last couple of years, thanks to advances in computation, nanofabrication, and the development of new experimental techniques to image light fields of dimensions smaller than the wavelength. Nanoplasmonics is at the verge of developing into a very promising technology platform for next-generation applications in information technologies, energy, high-density data storage, life sciences and security. The nanoplasmonics group, led by Professor Stefan Maier, operate at the forefront of plasmonics research, and are collaborating with a wide range of key groups both across Imperial College London, within the UK and internationally.

## Plasmonics research

The term 'plasmonics' refers to the science and technology dealing with manipulation of electromagnetic signals by coherent coupling of photons to free electron oscillations at the interface of a conductor, such as gold or silver. Nanostructures out of these materials then act as efficient nanoantennas, converting incident light into highly localized electromagnetic fields on the nanoscale. This breaking of the diffraction limit of optics underpins a new area of nanotechnology – nanophotonics.

The opportunity to confine and guide light in the form of surface plasmon waves on nanostructured metallic interfaces is attractive for the development of integrated photonic chips where the information can be processed all-optically without the need of electronic-to-optical and optical-to-electronic conversion, for example. Performance of optoelectronic devices, such as light emitting diodes, photodetectors and solar cells, can also be improved by integrating them with plasmonic nanostructures. Another blossoming field is biochemical sensing, where the enhanced light fields facilitated by metallic nanostructures are exploited for the detection of small traces of molecules.

Nanoplasmonics is a very interdisciplinary field, applicable to all areas of science and technology where control over light, or more generally electromagnetic radiation, is a prominent ingredient. It spans from the fundamental sciences such as nanoscale quantum optics and the development of ultrasmall laser cavities to tool-building, for example novel nanotags for cellular imaging, diagnosis and laser therapy.



Blackett Laboratory, South Kensington Campus

Photo: Christian Richter

## Large Projects and Collaborations

### Centre for Plasmonics and Metamaterials

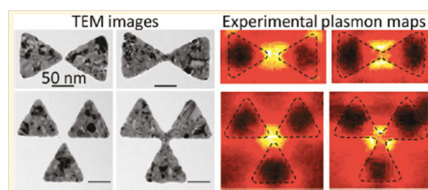
The Centre for Plasmonics & Metamaterials is a new cross-faculty grouping at Imperial covering a broad range of research in plasmonics and metamaterials. We are working on both fundamental research, through theory and proof-of-concept experimental studies, and on application-oriented work towards highly disruptive technologies for energy, communication and computing, as well as healthcare. The Centre also runs a one-year Masters course in Plasmonics & Metamaterials.

### EPSRC Active Plasmonics programme

This UK research programme on nanoplasmonics is a multidisciplinary collaborative project between Imperial College London (Profs Maier, Bradley, Kim, Alford and Dr Stavrinou), King's College London, and Queen's University Belfast. The research programme, funded by the Engineering and Physical Sciences Research Council and also supported by INTEL, Seagate, Ericsson, Oxonica, IMEC and the National Physics Laboratory, concerns the development of next-generation optical communication infrastructure.

### Leverhulme Project on Metamaterials and the Control of Electromagnetic Fields

This project, funded by the Leverhulme Trust and headed by Profs Sir John Pendry and Stefan Maier, has as its goal the establishment of Metamaterials as a new research discipline, and has funded three new faculty positions, amongst them Leverhulme Chair Prof Ortwin Hess. Nanoplasmonics here serves as an enabling technology for the realisation of metamaterials in the optical part of the electromagnetic spectrum.



Electron microscope (left) and plasmon field distribution (right) images of nanoantennas.

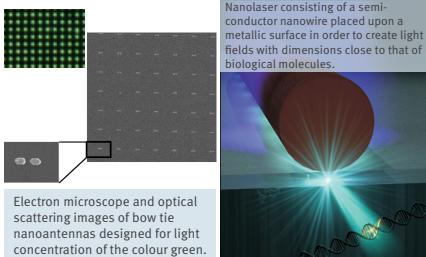
NANOPLASMONICS

## Nanocavities

### Fundamentals and applications in energy concentration and biosensing

Metallic nanostructures have the unique ability to concentrate light on the nanoscale, thus they enable a powerful marriage between photonics and nanotechnology. This concentration of electromagnetic energy is similar to that of well-known cell phone antennas, but occurs at optical frequencies. When light falls on a metal nanostructure, it can set the conduction electrons within the metal in motion, and for specific frequencies electromagnetic resonances can arise. These so called localised surface plasmon resonances depend on the shape, size, and the immediate dielectric surrounding of the nanostructure. On resonance, light is tightly confined to the surface of the nanostructure, until it gets eventually absorbed inside the metal, or scattered back into photons. This effect is all around us - in its most spectacular form in stained glass.

Using modern nanofabrication methods such as electron beam lithography or focused ion beam milling, we can now create metallic nanostructures with very defined plasmon resonances. This lays the groundwork for a whole set of promising applications, be it in biosensing, the development of nanolasers, or structures for enhancing the emission of quantum dots or the efficiency of solar cells.



## Nanolasers

Plasmonic lasers focus optical energy in both time and space to generate extremely intense light at the nanoscale. Dr Rupert Oulton, an EPSRC Career Advancement Fellow and Leverhulme Lecturer in Plasmonics and Metamaterials, is currently developing such laser devices. Light at length scales of just ten billionths of a metre and lasting for just one trillionth of a second drastically alters the strength of light-matter interactions to vastly improve the sensitivity of conventional spectroscopies and the data capacity of optical communications.

Nanoplasmonics research at Imperial is supported by a range of sponsors, including:

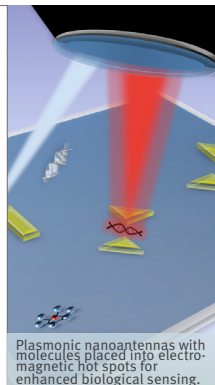


The Leverhulme Trust



## Top recognitions for nanoplasmonics work

In 2010 the pioneering nanoplasmonics work headed by Prof Stefan Maier was awarded with two distinguished prizes – the **international Sackler Prize in the Physics Sciences**, awarded by Tel Aviv University, and the **Paterson Medal of the Institute of Physics**.



## Plasmonics for Biological Sensing

The field of plasmonics uses collective electronic resonances in metal nanostructures to compress light fields into tiny volumes, often much less than an optical wavelength. Such structures can be designed to concentrate light to enable extremely sensitive chemical detection, down to just a handful of biomolecules, via a dramatic amplification of their optical absorption characteristics. Similar approaches are being pursued at the other end of the spectrum, where we use designer “spoof plasmon” surfaces to confine THz radiation close to the surface where it can be strongly absorbed. A well-known example of devices relying on localised plasmon resonances are glucose-sensors for diabetics.

SERS, surface enhanced Raman Spectroscopy, exploits the same plasmonic field enhancement effect to achieve enhancement of vibrational coupling of molecules to light by many orders of magnitude. Imperial researchers led by Prof Cohen developed the use of coupled plasmons between colloidal gold nanostructures to move towards a method capable of detecting disease-specific enzymes with unprecedented levels of sensitivity.

## For more information contact

Professor Stefan Maier  
Co-Director of Centre for Plasmonics & Metamaterials  
Imperial College London,  
South Kensington Campus,  
London SW7 2AZ.

Email: [s.maier@imperial.ac.uk](mailto:s.maier@imperial.ac.uk)  
Telephone: +44 (0)20 7594 6063

Website: [www.imperial.ac.uk/people/s.maier](http://www.imperial.ac.uk/people/s.maier)  
[www.imperial.ac.uk/plasmonmeta](http://www.imperial.ac.uk/plasmonmeta)  
[www.imperial.ac.uk/naturalsciences](http://www.imperial.ac.uk/naturalsciences)