Nanoplasmonics: control of light at the nanoscale

- Noble-metal nanoparticles with sizes smaller than the wavelength of visible light show strong resonances for light scattering and absorption, due to the excitation of localized surface plasmons. At resonance, light resonantly drives collective oscillation of the conduction electrons of the metal nanoparticle, which therefore acts as a radiating dipole. Its resonance frequency is strongly dependent on particle shape and dielectric environment, which enables tuning of its "color" throughout the visible and into the near-infrared (IR) regime of the spectrum, while keeping particle size well below 100 nm.

- The most prominent application of this effect has been all around us during history, in the form of colored glass, incorporating metal nanoparticle dopants. More modern applications, increasingly at a single-nanoparticle level, lie in the tagging of biomolecules, enhancement of light emission from nanoscale photon sources, and biomolecular sensing [3,4]. All of these exploit the fact that at their dipolar resonance frequencies, metal nanoparticles enable nano-concentration of light below the diffraction limit around the particle surface, and feature resonantly enhanced absorption and scattering cross-sections.

- Some equipment of the LCN is key for the study and fabrication of the structures needed in nanoplasmonics: high-resolution TEM unravels the properties of plasmonic modes in complex structures. E-beam lithography / Focussed Ion Beam milling are necessary to produce metallic structures with properties in the visible range. High resolution SEM imaging is required to ensure that the samples under investigation have the desired dimensions and morphology.

1. Imaging of localised plasmon resonances

   The TITAN TEM microscope at the LCN allows for a mapping of plasmon modes/fields with an unprecedented resolution – of the order of the nanometer, using Electron Energy Loss Spectroscopy (EELS). The example above shows how a bow-tie nanoantenna made out of gold concentrates the electromagnetic energy in the gap [1,2]. It is one of the very few techniques allowing for excitation and observation of modes called "dark", that can not be excited easily with light.

2. Plasmonic nanoantennas

   Nano-antennas are expected to increase our control on light at the nanoscale. They allow for the increase of quantum yield of emitters in their vicinity (top left), as well as helping to control their efficiency or direction of emission [3,4].

   Bottom left: images of the light scattered by three arrays of different nano-antennas, for two different polarisation of the incident light (indicated by the red arrows).

3. Engineering of plasmon modes

   Control on the spectral properties of plasmonic cavities can be achieved by using the concept of hybridisation: two plasmonic cavities in close proximity interact. The "plasmonic molecule" formed has properties that can be tuned to produce for instance modes with low radiation losses [5,6], or sharp transmission windows in regions that would be scattering otherwise, thanks to Fano resonances [5,7].

Acknowledgements

Key Publications


Contact

Stefan A. Maier
Professor of Nanophotonics
Co-Director, Centre for Plasmonics and Metamaterials
Imperial College London
http://www3.imperial.ac.uk/people/s.maier
S.Maier@imperial.ac.uk