

Warwick Chemistry Departmental Seminar



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4.00 pm, C521, 5th floor, Chemistry

‘Biological quantum optical systems’

Photosynthetic systems achieve remarkable quantum efficiencies, and exhibit exciton diffusion lengths that are long compared to those found in semiconducting polymers. Light harvesting antenna complexes (LHCs) are pigment-protein complexes in which precisely engineered architectures array pigment molecules (chlorophylls and carotenoids) in 3D. It has recently been discovered that electronic coherences between pigment molecules ensure efficient capture of photons and help to regulate resonant energy transfer to neighbouring LHCs in photosynthetic membrane structures. These systems provide abundant inspiration for the design of new kinds of biologically-inspired molecular photonic materials.

Recently we have discovered that excitonic states in LHCs are strongly coupled to localised surface plasmon resonance (LSPR) modes at the surfaces of gold nanostructures. This strong coupling yields hybrid states that combine the properties of light (excitonic transitions in the protein) and matter (surface electronic oscillations in the metal). Using simple spectroscopic apparatus, we discover pronounced changes in extinction spectra of coupled systems as a function of protein structure, transition dipole moment and exciton energy. Because strong plasmon-exciton coupling is a quantum optical phenomenon, the LSPR couples to an array of pigment molecules. The coupling energy thus varies with the density and organisation of excitons at the metal surface. Using synthetic maquette proteins, consisting of tetrahelical peptide “candelabra” structures with one or two binding sites for a synthetic chlorin, we have examined the potential to achieve couplings between non-local pigment molecules. In two-chlorin maquettes, where the chlorins are collinear in the field direction, the LSPR is found to couple to a chlorin Q_x J-dimer state not found in the solution-phase spectrum. In contrast, in one-chlorin proteins the LSPR couples to the Q_y transition. These data demonstrate that using synthetic biological approaches it is possible to manipulate and control plasmon-exciton coupling. We also find that there is evidence for extended evanescent coupling in arrays of gold nanostructures coupled to LHCs. Our data suggest that strong plasmon-exciton coupling facilitates extended coherence, over distances of 100s of nm. A consequence of this is that strong coupling may also be used to achieve long-range coherent transport of excitation, potentially important for the development of a new generation of molecular photonic materials for use in solar energy capture. Early attempts to replicate the behaviour found in LHCs using synthetic polymers will be described.

Biography

Prof. Leggett obtained a BSc in Chemistry from UMIST in 1987. His PhD from the same institution, obtained in 1990, was followed by consecutive appointments as Research Associate at Universities of Washington and Nottingham. In 1994 he was appointed as lecturer at the University of Nottingham 1994-98. He became a Lecturer at UMIST in 1998, where he was subsequently promoted to senior lecturer and reader. In 2002 he was appointed as Professor of nanoscale analytical chemistry at the University of Sheffield.