Nanophotonics is the study of light-matter interaction on the nanoscale, where nanoscale is a millionth of a millimetre. It is a truly twenty-first century field of scientific investigation, which has only become possible due to the recent advances in nanomaterials, nanofabrication and measurement techniques. The exciting and multidisciplinary field deals with the generation, propagation, manipulation and detection of light with nanoscale structures. The reduced length scale gives rise to opportunities for miniaturization of optical devices to sizes comparable to the components in electronic circuits. Photonic integrated circuits offer advantages such as higher speed and lower power consumption.

In the past photonics has primarily focussed on the propagating components of light, known as the far-field, but nanophotonics provides an unprecedented opportunity to study and exploit the near-field components of the electromagnetic radiation which remain tightly confined to the structure.

Metal nanostructures act as nano-antenna and provide large enhancement of the near-field, responsible for surface enhanced Raman scattering and enhanced fluorescence. Metal based nanophotonics is known as the field of plasmonics. The near-field properties are determined by the choice of the nanoscale material, dimensions and shape, as well as the choice of surrounding medium of the structures. Plasmonic structures can be tailored to have resonances at specific colours in the spectrum.

Applications: bio-sensing, light harvesting, imaging, ICT – My own research is focussed on the optical properties of coupled nanomaterial systems. One key topic has been near-field energy transfer in quantum dots. These nanoscale light emitters and this energy transfer mechanism are important for applications in bio-sensing, light emitting devices and light harvesting. Previously, I investigated the energy transfer mechanism and the conditions under which theory could be quantitatively applied to quantum dots, taking account of their specific properties.

My team, the Bradley Group, was the first in the world to demonstrate plasmon-enhanced energy transfer between quantum dots, showing increased interaction distance, energy transfer efficiency and rate. We, subsequently, showed that this could be extended to other hybrid nanomaterial systems and devices. Work on implementation in a range of optical devices is on-going.

Another exciting area of research is to discover ways to achieve dynamic tuning of plasmonic properties. A current limitation of plasmonic structures is that once fabricated their properties cannot be tuned. Through a Science Foundation Ireland funded project I am investigating coupling plasmonic structures with a phase change material, vanadium dioxide, to provide electrical control of the near-field interaction. Vanadium dioxide transitions from a semiconducting to metallic phase under certain conditions. This is expected to present new physics and to generate new concepts for nano-optic components with novel functionalities and improved performance.

Other challenges in the field are around discovering new materials with superior properties, such as lower losses, and identifying the best routes to translate the new science and capabilities to the wide range of possible applications across sensing, imaging, and information communication technologies.

Louise Bradley received her BSc from University College Dublin and MSc and PhD from Trinity College Dublin. She joined Trinity’s School of Physics as a Lecturer in 2001 and is now Professor in Physics. She was elected Fellow of Trinity College in 2009. She has published over 145 scientific papers, including almost 100 peer-reviewed journal articles. Her research focuses on the physics of light-matter interaction on the nanoscale and how these processes can be harnessed for information communication technologies, light harvesting and sensing applications. She has been awarded funding from Science Foundation Ireland, Enterprise Ireland and the Irish Research Council.

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We are developing an understanding of how to manipulate the interaction between light and matter on the nanoscale, as well as identifying how this can be used for new technologies.

Two metal metasurface. Schematic of a unit cell: Square arrays (300 nm pitch) of gold nanodiscs (100 nm high and 150 nm in diameter) on a back-reflector substrate consisting of a polymer thin film on top of a 100 nm thick silver (Ag) layer on silicon.

Reflectance spectrum for a 100 nm thick polymer layer showing near-zero reflectance dip at 585 nm.

Electric and magnetic field distributions at 585 nm along the vertical cross section (x-z plane) through one unit cell of hybrid structure. The near-zero reflection arises due to efficient light trapping in the polymer layer.
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