Ultrafast PhD projects

2-colour 2-dimensional spectroscopy: resolving the mechanisms of coherent coupling in condensed matter systems.

Two-dimensional spectroscopy is a technique that enables the identification of quantum states that are coherently coupled, and their dynamics. Through the use of such techniques in the optical regime it is being realised that these intrinsically quantum mechanical processes play an important role in nature, including photosynthesis. In two-dimensional nmr many variations on this technique have been developed (for which the Nobel prize was awarded in 1993). The analogue of many of these techniques in the optical domain is 2-colour 2D spectroscopy. Until recently, all experimental realisations of optical 2D spectroscopy have used single colour excitation due to experimental complexities. We have developed a method that utilises a data-processing technique known as phase-retrieval and allows the realisation of two-colour 2D spectroscopy. This project will enhance and utilise this technique in order to gain deep insight into coherent energy transport dynamics in coherently coupled quantum systems, including chains of coupled semiconductor quantum dots and quantum wells.

Exploring the role of quantum coherence in photosynthesis.

Recent work has identified the presence of long-lived coherences amongst different molecules within some light-harvesting complexes involved in photosynthesis. Using the techniques developed here at Swinburne, we are able to study directly these quantum mechanical processes in detail. This project will explore the role of quantum coherence in photosynthesis by studying the dynamics of both coherent and classical energy transfer, within the isolated molecules and between the molecules within light-harvesting complexes. The ultimate aim is to develop an in depth understanding of the mechanisms responsible for the efficient energy transfer in photosynthesis.

Coherent dynamics in semiconductor nanostructures.

Semiconductor nanostructures, such as quantum dots (QDs) and quantum wells (QWs), have been the subject of intense research over the past 2 decades because of their intrinsic quantum mechanical properties. These systems have been of such interest because they can give great insight to the quantum mechanical processes that also apply in atoms and molecules, and also because of their realised and potential role in device applications, from lasers and detectors to quantum computation and quantum cryptography. Interest in this area continues as the sample making techniques become more sophisticated allowing intricate sample designs to possess the properties of interest. In this project the coherent dynamics within and between coupled quantum dots and/or wells will be investigated using novel two-colour experimental techniques. This will shed light on the mechanisms of coherent coupling, and the role played by coherent phonons, and many-body effects within the semiconductor lattice.