DODD-WALLS CENTRE
for Photonic and Quantum Technologies

Marsden Success for Dodd-Walls Centre Members 2018

Computing with walls of light

Associate Professor SX Coen (PI) & Dr M Erkintalo (AI) University of Auckland $935,000

In optical fibres, lightwaves with different properties can be segregated in domains separated by robust ""walls of light"" known as polarization domain walls. We will build an optical fibre ring in which polarization domain walls can circulate endlessly, fed by a constant influx of energy in the form of a continuous-wave laser beam. As the walls and domains interact, both naturally and through engineered pathways, the evolution of the lightbeam over many transits in the ring will mimic the behaviour of spins in solid-state physics. This will open up opportunities to study behaviours of matter otherwise not accessible, including an anomalous phase transition characterized by the emergence of an ordered structure out of an increasing level of noise, and never observed before: a substance crystallizing in hotter temperature. Interacting spins have also been shown to map to complex combinatorial problems of modern society, including artificial intelligence, analysis of social networks, or new drug searches. These problems are intractable for traditional computers, but a chain of polarization domain walls would naturally tend to the solution, realizing a so-called Ising machine. As such, our project paves the way for a new era of analog photonic computers with endless potential applications.

Hot Entanglement with Cold Atoms

Dr MF Andersen (PI) & Dr A Bradley (AI) University of Otago $935,000

The physical phenomenon known as “Quantum Entanglement” has undergone a remarkable voyage since it was first predicted by Quantum Mechanics. Albert Einstein initially considered it “spooky”, but today we know it as an observed fact, and it even forms a key resource in future technologies, such as quantum computers. However, quantum entanglement is often fragile and is easily lost if not kept in an ultra-cold environment. This presently hampers its transition from laboratory experiments to real life applications.

We will show how the very processes that often destroy entanglement can be exploited for its generation thereby giving a new thermally robust source of entanglement for future quantum technologies. Powered by astounding progress in scientists' ability to control atoms, we will assemble individual atomic pairs held by laser beams, and watch through our single-atom sensitive optical microscope as the atoms entangle when they collide.

Comparing our experiments to state-of-the-art numerical and theoretical models will provide unprecedented insight into processes that generate and destroy quantum entanglement. We will separate the atoms and see how they remain invisibly interconnected, and how they can be used for sensors who's precision surpass the fundamental limit of standard technologies.

SPASER – Towards Practical Nanolaser Devices

Dr B Ding (PI) University of Otago Fast-Start $300,000

A SPASER (Surface Plasmon Laser), regarded as the "smallest laser", has dimensions much smaller than the wavelength of light that is emitted, which is key to future high-density optical computers, biological imaging/sensing and other important applications. To create a spaser the excitation of localised surface plasmons in metallic nanoparticles is proposed to concentrate optical modes into sub-wavelength volumes which, when coherently stimulating emission from ambient emitters, leads to lasing effects at the nano-scale.

To date, there has been no demonstration of "real" spasers – direct evidence of lasing from spasers based on single nanoparticle resonators is still lacking. The main problem preventing spasers' realisation is that current spaser designs cannot provide sufficient gain levels to compensate damping loss in real-world experimental systems.

In this project, utilising the integration of rare-earth doped nanocrystals and our recently developed asymmetric core-shell plasmonic resonators, we will develop high-gain spaser systems based on single-nanoparticle resonators. The high doping concentration of rare-earth ions will provide sufficient gain to establish population inversion in the system, resulting in real spasing actions. This will provide nanoscale, stable and embeddable nano-laser sources for applications ranging from sensing and biomedicine to imaging and information technology.

Next-Generation Small Molecule Acceptors for use in Organic Solar Cells

Associate Professor G Waterhouse (AI) The University of Auckland Fast-Start $300,000

This project aims to develop new acceptor materials for organic solar cells (OSCs) in order to evaluate non-traditional design principles. In an OSC, absorption of light triggers electron transfer from a donor molecule to an acceptor molecule, forming a pair of charges. In particular, small molecule acceptors (SMAs) have great potential for development, because recent observations suggest that two long-held OSC design principles do not apply to them.

First, when SMAs are used, much smaller donor/acceptor orbital energy offsets can drive electron transfer than previously thought. This means that more of the absorbed solar energy can be converted into electricity. Second, it has typically been assumed that strong electronic coupling between donor and acceptor molecules is desirable, because strong coupling increases the rate of electron transfer. However, the rate of charge recombination also increases with electronic coupling. It was recently proposed that, in small molecule systems, decreasing coupling may increase the difference between the rate of electron transfer and the rate of charge recombination, thereby increasing overall charge generation efficiency. We will prepare new SMAs with a range of orbital energies and coupling strengths to assess the validity of this hypothesis using a combination of device measurements and ultrafast spectroscopy.