Quantum sensing for biology with optically addressable spin defects

UCL Lead department: London Centre for Nanotechnology (LCN)/Medical Physics and Biomedical Engineering

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Project Summary:

Background:
Quantum sensors leverage quantum mechanical effects to probe their external environment. Nitrogen-vacancy (NV) centres in diamond are optically addressable single spins that are sensitive to magnetic noise, charge, electromagnetic fields, temperature, and pressure, promising impactful sensing methods for numerous biological applications. In addition to sensitivity, their nanometre size and fast dynamics convey high spatial and temporal resolution. NVs in diamond nanoparticles can be functionalised and introduced into biological samples for localised, in-situ measurements with optical readout. Advances in the field include nanoscale thermometry, magnetic nanoparticle detection, T1 relaxometry for detection of free radicals, spin-enhanced diagnostics, measurement of neuron action potential, and nuclear magnetic resonance.

Project Aims:
This project aims to develop quantum sensing techniques for NVs and other spin defects in diamond and other materials. The focus will be on techniques with potential biological applications, and might include ensembles of randomly orientated nanodiamonds, silicon vacancies in diamond, and/or divacancies in silicon carbide. There are a range of possible projects exploiting different sensing modes: magnetic resonance, optical spectrometry, relaxation, coherence time, lifetime; and biological applications including: biophysical measurements (in vitro and in vivo), understanding interfaces between biomaterials and cells, and accurate diagnostics and monitoring. Project specifics will be adapted to the interests of the student – please contact me (ben.miller@ucl.ac.uk) to discuss.

What you will be doing:
This will involve manipulating and measuring spin defects using a variety of radiofrequency, microwave, and optical techniques, including designing and building instrumentation and optics, experimental design and programming (Python/MATLAB). In addition to sensing, materials characterisation will be important, as well as surface chemistry and various biological techniques. The work will be primarily experimental, supported by theory and computational modelling, and will involve extensive cross-disciplinary collaboration with groups at UCL and externally (UK, USA, India), and industry.

Background reading:
Nature **587**, 588–593 (2020); *Nat Rev Phys* **5**, 157–169 (2023); *Appl. Phys. Lett.* 10 July 2023; 123 (2): 020501