Rotation of a levitating nanodiamond containing a spin qubit

Supervisor: Gavin W Morley

Background

Single nitrogen-vacancy (NV^-) centres in diamond have isolated electronic and nuclear spins which can store quantum information at room temperature for over one second. We have built an exciting new experiment to study nanodiamonds that are levitated by a focused laser beam. Our theoretical proposals (together with the groups of Sougato Bose and Peter Barker in UCL and Myungshik Kim at Imperial College) suggest that we could put these diamonds into a quantum superposition in which they try out being in two places at once [1-3]. This could permit tests of quantum mechanics and may lead to future quantum sensors.

The green dot is a levitated nano-diamond in our optical tweezers.

We had found that our nanodiamonds heat up to destruction when we pump out the air that was taking away the energy absorbed from the trapping laser [4]. However, we have solved this problem with nanodiamonds that are 1000 times purer, so absorb less of the trapping light [5]. Our lab in Warwick also benefits from several other NV^- experiments for quantum technology focused on nanoscale and bulk magnetometry both at room temperature and in helium cryostats.

The goal of this project is to adapt our levitated nanodiamond experiment for detecting rotational oscillations of the nanodiamond. To achieve this you will begin by setting up optical detectors which can see the higher rotational vibration frequency of around 1 MHz instead of our current work with the 100 kHz translational motion. High vacuum is required to increase the quality factor of these vibrations, and to reach this you will implement a "feedback cooling" scheme that has been used in several labs worldwide. You will add in a small homogeneous magnetic field so that the rotational motion of the nanodiamond couples to the electron spin of the NV^- [6]. You will then have the chance to explore whether the diamond's rotational state can be in a quantum superposition of clockwise and counter-clockwise. This would be significant for our understanding of quantum mechanics as the diamond would be the most massive object that has ever been put into a superposition state by several orders of magnitude.

Full funding is available from the Royal Society for 4 years at standard research council rates (stipend plus fees). You would start on your project in the lab from day one without doing an initial Masters course. For informal enquiries, please contact gavin.morley@warwick.ac.uk.

[1] M. Scala *et al.*, Physical Review Letters **111**, 180403 (2013).

[2] C. Wan *et al.*, Physical Review Letters **117**, 143003 (2016).

[3] S. Bose *et al.*, in press at Physical Review Letters, arXiv:1707.06050 (2017).

[4] A. T. M. A. Rahman *et al.*, Scientific Reports **6**, 21633 (2016).

[5] A. C. Frangeskou *et al.*, arXiv:1608.04724 (2016).

[6] Y. Ma *et al.*, Physical Review A **96**, 023827 (2017).