Magnetic markers for illumination-free imaging using a quantum diamond microscope

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Phototoxicity is a major problem for live cell imaging, and photodamage and photobleaching can affect the integrity of inferences made of biological significance[1,2]. This is particularly the case when fluorescent markers are used, which require illumination. We have developed a magnetic field microscope to image the location of magnetic markers, at room temperature, without requiring illumination of the marker. This provides a new method of tracking movement in light-sensitive environments.

The magnetic field microscope utilises the quantum properties of negatively-charged nitrogen-vacancy (NV) centres in diamond. NV centres fluoresce in the red, and the rate of fluorescence indicates the NV centre spin state. By manipulating the NV centres with microwave pulses, and then detecting the change in the spin state, the magnetic field strength can be detected. To image the magnetic properties in 2D, we engineered a layer of near-surface NV centres into a single-crystal diamond and imaged the NV fluorescence with a wide-field microscope coupled to an sCMOS camera[3]. Using our technique, vividly displaying the magnetic properties of multiple individual particles in a sample, simultaneously, becomes possible. In this way, we have demonstrated the technique's ability to display the variability of the magnetic properties of a sample. This highlights its potential application in the development of new particles, to assist in addressing a key problem in magnetic particle manufacture - creating particles of heterogenous size and shape.

Pinpointing the location of a marker in a sample, in the case of tracking movement, will require image acquisition at a speed commensurate to the movement under analysis. We have demonstrated that NV sensing in a fast image acquisition mode is capable of producing images to reliably locate particles in timescales suited to tracking cellular motility, with a spatial resolution better than 200 nm in less than a second of acquisition time, see Fig. 1.

Magnetic markers are biocompatible and can be phagocytosed by cells. In addition to the labelling of cells, illumination-free magnetic markers could be used in cell motility assays, such as traction force screening [4], replacing fluorescent markers and thus enabling the testing of photosensitive drugs.

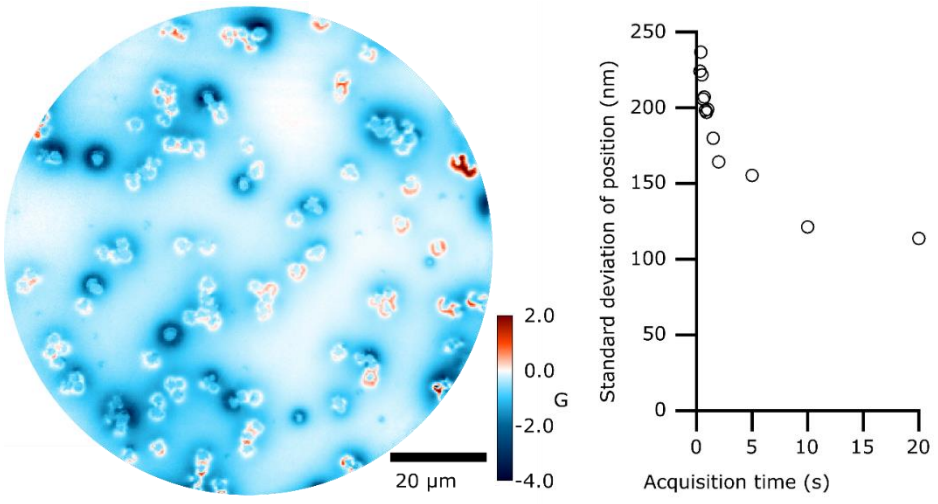

Figure 1: Illumination-free imaging of magnetic beads. Left, Magnetic image of single magnetic beads placed on the diamond imaging chip. Right, Accuracy of the bead position versus acquistion time.

References:

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