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Dynamical monitoring of magnetic markers using quantum diamond magnetometry

Louise F. Frellsen[1*], Adam M. Wojciechowski, Mikkel F. Hansen, Alexander Huck[1], Ulrik L. Andersen[1]
[1]Center for Macroscopic Quantum States (bigQ), Department of Physics, Technical University of Denmark, 2800 Kgs. Lyngby, Denmark
*Email: louifr@fysik.dtu.dk

The nitrogen-vacancy (NV) center in diamond crystal has shown great promise as a magnetic field sensor [1]. The method is of particular interest for biological systems, because of its high sensitivity at ambient conditions and the biocompatibility of the diamond carrier.

Tagging of biological samples using magnetic nanoparticles (MNPs) is an important tool for both manipulation and detection of biotargets. NV center based magnetometry has proven capable of resolving single magnetically marked cells [2]. Furthermore the technique allows for scalability to large areas and the analysis of macroscopic sample. This makes the system promising for incorporation in flow cytometry and eventually lab-on-a-chip systems. Meanwhile, the current detection times are in the order of seconds for specially treated diamonds and ranging into hours for untreated samples to obtain high sensitivity.
Here we present a set-up with the option of detecting magnetic particles at high framerates, providing videos of magnetic particles and introducing the opportunity of monitoring motile bacteria or cells in flow.

The magnetic sensing capabilities of the NV centers stem from its energy level structure. The electron spin states are coherently probed using microwaves. The states are optically initialized and read out through laser excitation and monitoring the intensity of the emitted fluorescence, which is sensitive to magnetic fields. The set-up has been characterized, showing a uniform sensitivity of approximately 160 nT/√(Hz)/pixel over a 40 µm x 40 µm field of view working at a frame rate of 60 FPS. Single 2.8 µm beads have been detected and the ability to monitor the movement of beads has been verified for both mechanical movement and varying electric fields.

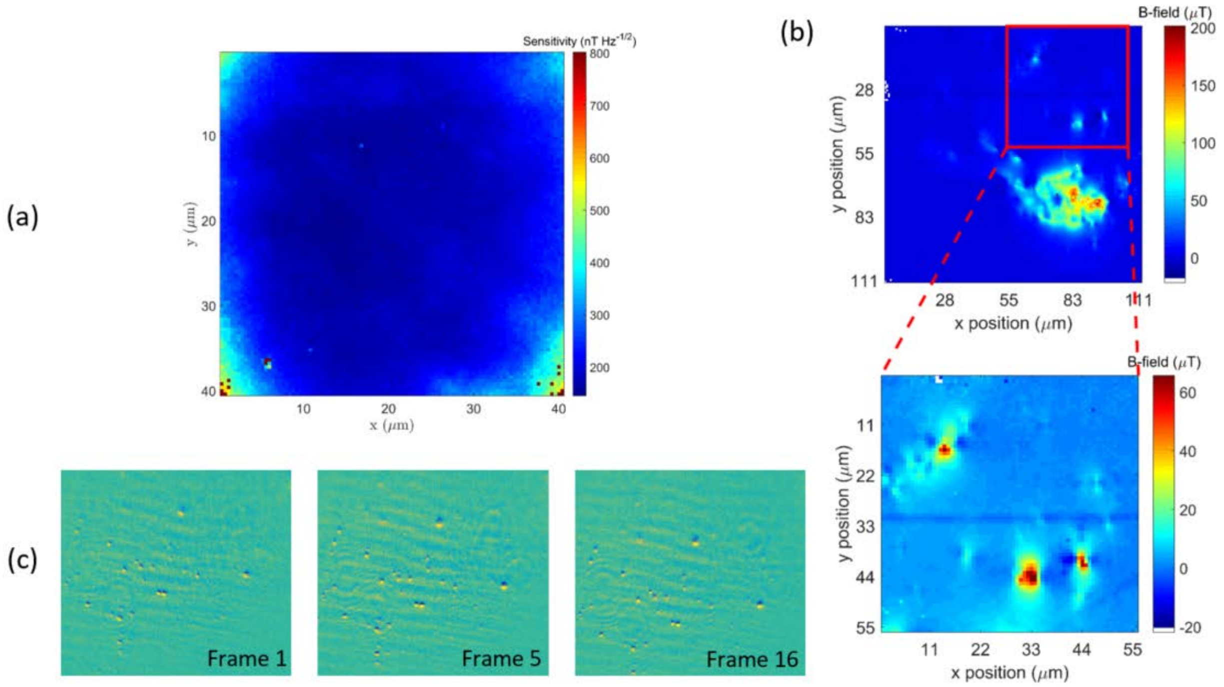

Figure (a) Measurement of the spatial uniformity of the magnetic sensitivity in the optical field of view. (b) Image of magnetically detected beads on the surface of the diamond. The close-up of lone beads and smaller clusters show the expected dipole field distribution. (c) A few frames from dynamical measurements of a number of beads on the diamond surface manually moved with the stage.

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