MAR13-2012-020054

Abstract for an Invited Paper
for the MAR13 Meeting of
the American Physical Society

Mobile quantum sensing with spins in optically trapped nanodiamonds[1]

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The nitrogen-vacancy (NV) color center in diamond has emerged as a powerful, optically addressable, spin-based probe of electromagnetic fields and temperature. For nanoscale sensing applications, the NV center's atom-like nature enables the close-range interactions necessary for both high spatial resolution and the detection of fields generated by proximal nuclei, electrons, or molecules. Using a custom-designed optical tweezers apparatus, we demonstrate three-dimensional position control of nanodiamonds in solution with simultaneous optical measurement of electron spin resonance (ESR)[3]. Despite the motion and random orientation of NV centers suspended in the optical trap, we observe distinct peaks in the ESR spectra from the ground-state spin transitions. Accounting for the random dynamics of the trapped nanodiamonds, we model the ESR spectra observed in an applied magnetic field and estimate the dc magnetic sensitivity based on the ESR line shapes to be $\sim 50\ \mu\mathrm{T}/\sqrt{Hz}$. We utilize the optically trapped nanodiamonds to characterize the magnetic field generated by current-carrying wires and ferromagnetic structures in microfluidic circuits. These measurements provide a pathway to spin-based sensing in fluidic environments and biophysical systems that are inaccessible to existing scanning probe techniques, such as the interiors of living cells.

[1]This work is supported by AFOSR and DARPA.
[2]In collaboration with Viva R. Horowitz, Benjamín J. Alemán, Paolo Andrich, David J. Christle, and Andrew N. Cleland.
[3]V.R. Horowitz, B.J. Alemán, D.J. Christle, A.N. Cleland, and D.D. Awschalom, *Proc. Natl. Acad. Sci. USA*, **109**, 13493 (2012).