Towards compact quantum diamond nuclear magnetic resonance spectrometers

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Nuclear magnetic resonance (NMR) spectroscopy is an indispensable technique in the analysis of molecular structure via the acquisition of chemical shift and spin-spin coupling spectra. NMR spectrometers are based on the detection of oscillating magnetic fields that are generated by nuclear spin precession in the presence of strong magnetic fields. Conventional NMR devices require costly superconducting magnets to generate external magnetic fields, offer limited spatial resolution, and exhibit suboptimal scaling for micro-nanoscale analytes.

Quantum sensors based on nitrogen-vacancy (NV) atomic defects in diamonds are capable of measuring magnetic fields with high sensitivity and high spatial resolution under ambient conditions [1, 2]. Recent developments in diamond-based sensors promise an alternative platform for NMR spectroscopy, dramatically reducing infrastructure costs and maintenance by eliminating the use of superconducting magnets, whilst achieving an unprecedented sensitivity and spectral resolution [3–6].

In this talk, I will detail a number of novel hardware solutions that enable the realisation of a compact high-resolution diamond-based NMR spectrometer exceeding the instrumentation compatibility of conventional NMR spectrometers. Our spectrometer consists of a thin layer of NV centres in a diamond crystal, a green laser to initialise and readout the spin state of an ensemble of NV centres, and a microwave delivery system for the spin manipulation. We measure NMR signals via their modulation of the NV spin-state dependent red photoluminescence intensity using a time-resolved quantum heterodyne detection scheme. Finally, I will discuss an application of this system as a novel and practical analytical method for in-situ monitoring of chemical reactions.

[1] L.T. Hall et al., *Nature Communications* **7**, 10211 (2016).

[2] D.A. Simpson et al., *Nature Communications* **8**, 458 (2017).

[3] S. Schmitt et al., *Science* **356**, 832–837 (2017).

[4] J.D.A. Wood et al., *Nature Communications* **8**, 15950 (2017).

[5] D.R. Glenn, et al., *Nature* **555**, 351–354 (2018).

[6] J. Smits et al., *Science Advances* **5**, 7 (2019).