## Wide-field multispectral super-resolution imaging using spin-dependent fluorescence in nanodiamonds

*Englund group*

*Nanoletters 2013*

* Addresses challenge of localising emitters for super resolution imaging.
* Use magnetic resonance techniques to change brightness of emitter, allowing for suppression of one emitter relative to neighbors.
* Paper therefore focused on single emitter regime

## Proton magnetic resonance imaging using a nitrogen–vacancy spin sensor

*Awschalom group*

*Nature nano 2014*

* Sensing protons in PMMA using a single NV centre.
* Look for dip in NV coherence when tau matches precession frequency

## Nanoscale NMR spectroscopy and imaging of multiple nuclear species

*Walsworth group*

*Nature nano 2015*

* Nanoscale, optically detected NMR spectroscopy and MRI of multiple nuclear species (1H, 19F, 31P) using shallow NV centres in diamond.
* Scanning confocal microscope interrogating single NV centres (sensitive to ∼100 polarized nuclear spins)
* Wide-field microscope using a CCD camera to image fluorescence from a high-density NV ensemble in a thin layer near the diamond surface, which is optimal for NMR spectroscopy and imaging over a >10 μm field of view and with sub-micrometre resolution.

## **Optical magnetic detection of single-neuron action potentials using quantum defects in diamond**

*Walsworth and Lukin*

*2016*

* Broadband sensing using an ensemble. Total internal refraction.

## Efficient Readout of a Single Spin State in Diamond via Spin-to-Charge Conversion

*Lukin*

*PRL 2015*

* Fun paper – use ionisation to NV0 to then measure spin state at room temp
* Can get much more accurate measurement as greater contrast

## High-Sensitivity Magnetometry Based on Quantum Beats in Diamond Nitrogen-Vacancy Centers

*PRL 2103*

*Beausoleil*

Use microwaves resonant with both transitions to avoid any problems due to temperature sensitivity etc.

## Nuclear magnetic resonance detection and spectroscopy of single proteins using quantum logic

*Lukin and Walsworth*

*Science 2016*

Cool paper, they use a single very shallow spin for NMR. Use standard XY pulse sequences. One nice aspect is that they transfer the state to the Nitrogen nuclear spin using RF, so that they can readout the state multiple times.

## Fourier magnetic imaging with nanoscale resolution and compressed sensing speed-up using electronic spins in diamond

## Atomic-Scale Nuclear Spin Imaging Using Quantum-Assisted Sensors in Diamond

*Lukin*

*PRX 2015*

* Single NV spin NMR proposal.
* Uses N spin as quantum memory, measures polarisation leakage to nearby nuclear spins that are on resonance.
* Uses magnetic field of NV as further filter

# Comments on future challenges from papers

Nanoscale NMR spectroscopy and imaging of multiple nuclear species

* Future challenges for NV NMR and MRI include improving the sensitivity at the single nuclear spin level, and achieving both atomic-scale spatial resolution and hertz-scale spectral resolution sufficient to observe chemical shifts in single bio-molecules at low magnetic fields.
* Possible approaches to these problems include reliable creation of very shallow NV centres with good optical and spin properties, using Fourier k-space imaging techniques with pulsed magnetic field gradients of ∼1 G nm−1 (refs 19,36) and exploiting quantum-assisted techniques such as ‘reporter’ electron spins on the diamond surface coherently coupled to a shallow NV. and ancilla nuclear spins as a quantum memory.

Optical magnetic detection of single-neuron action potentials using quantum defects in diamond

* NV-diamond magnetic sensing could be combined with optical stimulation methods to provide individual-neuron- targeted excitation and noninvasive AP detection
* Improving the magnetic field sensitivity to enable real-time, single AP event detection from individual mammalian neurons, which are expected to generate peak AP magnetic fields ~1 nT at the NV sensor layer
* Incorporating magnetic imaging. Integrating wide-field parallel magnetic (paper - Optical magnetic imaging of living cells, paper - Single-cell magnetic imaging using a quantum diamond microscope), and superresolution magnetic imaging, as well as tomographic methods for extending the depth-of-field (computational).
* The sensitivity challenge can be addressed by using optimized diamonds with higher NV density and longer spin-dephasing times T2∗, and by implementing pulsed-Ramsey and quantum-beat (paper - High-Sensitivity Magnetometry Based on Quantum Beats in Diamond Nitrogen-Vacancy Centers) measurement protocols
* Investigate quantum-assisted techniques, which should enable measurements approaching fundamental quantum limits. Our present NV-diamond instrument has a photon-shot-noise-limited magnetic field sensitivity ~3000 times worse than the quantum spin-projection limit, highlighting the potential for large sensitivity gains. For example, we recently demonstrated that spin-to-charge-state readout for NV centers provides enhanced magnetic field sensitivity that is only a factor of 3 above the spin-projection limit (paper - Efficient Readout of a Single Spin State in Diamond via Spin-to-Charge Conversion).