ENDOR-Qdyne: A Nanoscale NMR Spectroscopy Protocol Applicable to High Magnetic Fields

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Nuclear magnetic resonance (NMR) spectroscopy poses one the most widely used spectroscopic techniques of modern times, with applications ranging from the serialized analysis of chemical structures at the molecular level to tissue imaging in clinical applications. However, the inherent insensitivity of conventional NMR spectroscopy prevents its use in the studies of nanoscopic systems. By increasing the sensitivity by several orders of magnitude, Nanoscale NMR spectroscopy based on the nitrogen vacancy (NV) center in diamond as quantum sensor has emerged as a promising research subject [1]. Although recent developments of innovative NMR detection schemes, such as the quantum-heterodyne (Qdyne) detection protocol, enable high spectral resolutions, these schemes are inherently not applicable at high magnetic fields, to further improve the resolution and measurement times [2]. Here we present a high-field compatible extension of the Qdyne measurement scheme by combining it with electron-nuclear-double-resonance (ENDOR) sequences. [3] This approach paves the way for the application of NV-NMR spectroscopy in nano-scale studies of biomolecules and materials attached to the diamond surface.

References

[1] T. Staudacher *et al.*, Science, 6119 (2013) 561.
[2] J. M. Boss *et al.*, Science, 6340 (2017) 837.
[3] J. Meinel *et al.*, Comm. Phys., 302 (2023).

Figures

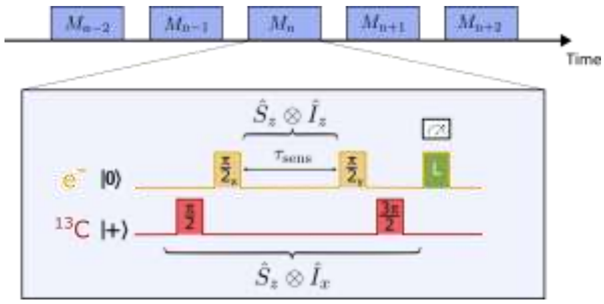

Figure 1: Pulse sequence of the ENDOR-Qdyne protocol. The transverse polarization of the target spin (red) is transferred to longitudinal axis via a RF pulse. This polarization is then read out by the sensor electron spin (yellow) with a Ramsey-type sequence, before the target spin is transferred back to xy-plane with a second RF pulse.

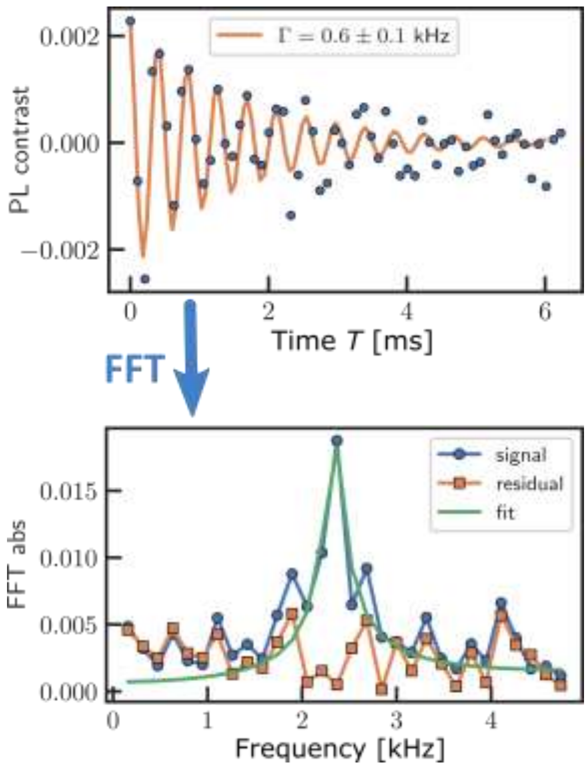

Figure 2: Detected down-converted NMR signal of a ^{13}C spin. The oscillating time trace reveals the Larmor precession of the target spin in the xy plane. The frequency spectrum is obtained through Fourier transformation of the time trace of the oscillation.