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Title: Nuclear Quadrupole Resonance (NQR) for stand-off detection of contraband

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Nuclear Quadrupole Resonance (NQR) for stand-off detection of contraband

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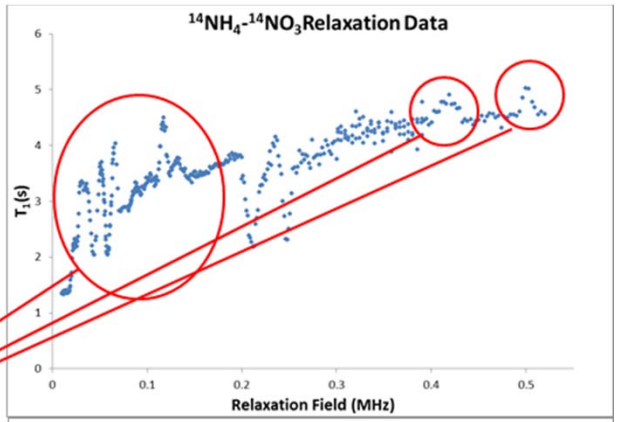
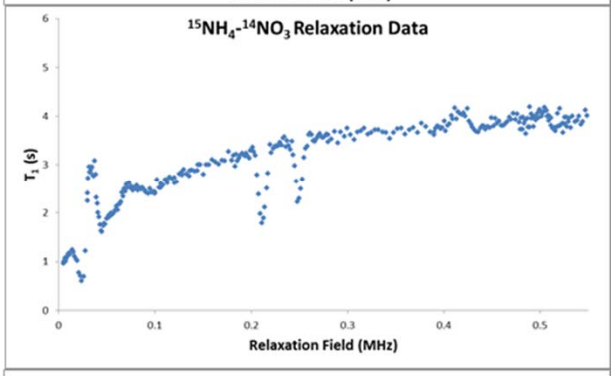
NQR is based on an interaction between the nuclear quadrupole moment of a spin ≥ 1 nucleus (commonly 14N) and the gradient of the electric field from electrons. This causes energy level splitting similar to NMR but with no requirement of an external field. NQR is highly sensitive to chemical structure. Most explosives and drugs have NQR signals (typically in the 1-6 MHz range), thus it is an excellent candidate for detection of concealed contraband (i.e. IEDs, smuggling) but it does have issues with low SNR and long detection times.

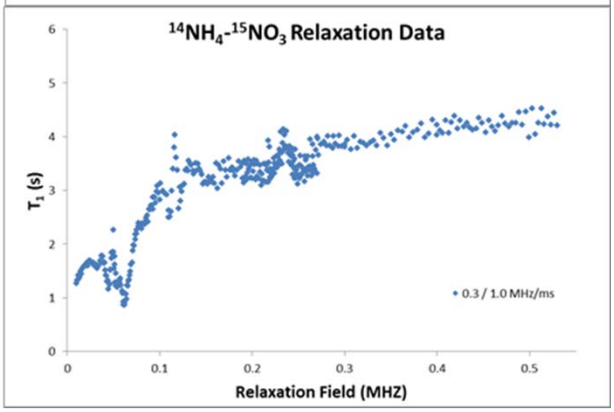
We are improving the sensitivity of NQR via methods of polarization enhancement. When a spin 1 nucleus is near a spin ½ nucleus, and Larmor and NQR frequencies overlap, the spin populations become linked. This produces two effects; (*1) the relaxation rate (T1) of the spin ½ nuclei are typically altered, and measuring T1 vs. magnetic field can reveal NQR frequencies; (2) Sweeping an applied field through a double resonance condition can transfer polarization to spin 1 nucleus, enhancing NQR signal.* Both methods leverage our expertise in pulsed magnetic fields and ultra-low field MRI. We recently turned LDRD funding into a DARPA project to detect contraband concealed in high water content opaque media.

We have demonstrated "exotic" cross-relaxation via (1). Totally new relaxation mechanisms have been discovered. Manuscript in prep.

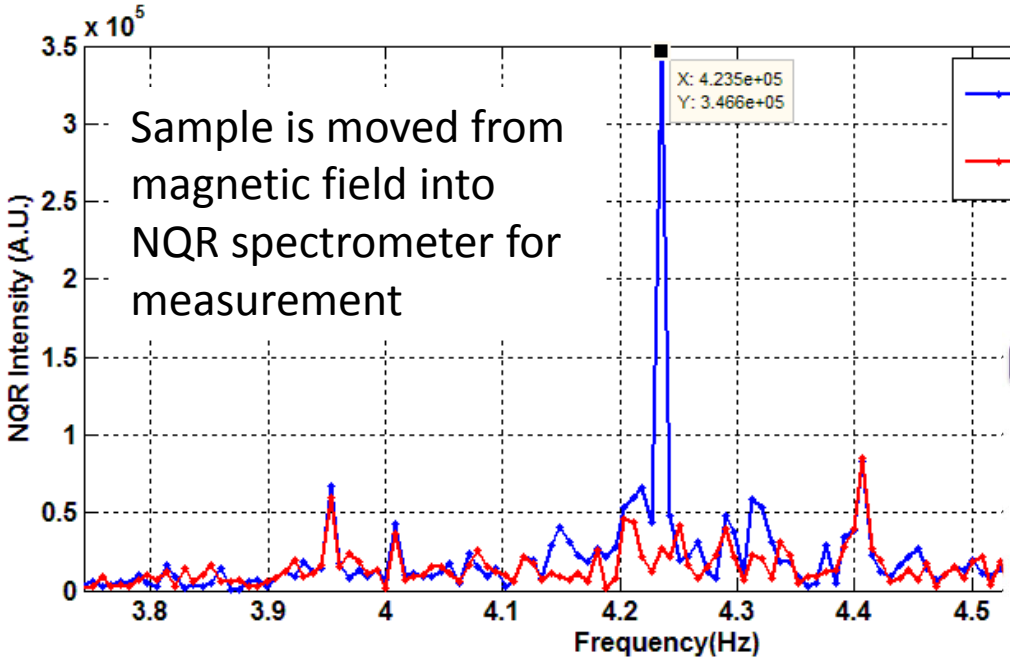
- T1 vs. magnetic field for 3 ammonium nitrate isotope combinations
- Expect dips in T1 curve at NQR frequency and at ½ the NQR frequency
- We see peaks in T1 – theoretically possible, but never before observed (red circles)
- Presence of peaks and dips give contradictory information about 14N T1– peaks indicate long, dips indicate short
- Theory needs improving
  - Level crossing effects?
  - Nonadiabatic effects?



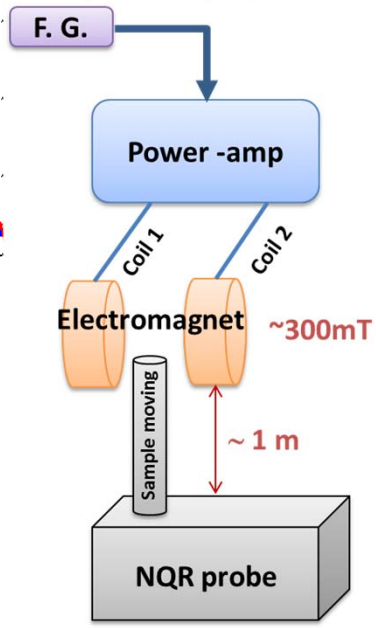




First NQR signature for ammonium nitrate (AN) detected with and without polarization enhancement in our own spectrometer



Sample is moved from magnetic field into NQR spectrometer for measurement



Without polarization enhancement we still see signal but 10X smaller!