Quantum Defects in Diamond:
Identifying Nitrogen Isotopes of Nitrogen-Vacancy Centers in Diamond

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Overview

- **Background**
  - NV Centers
  - Ion Implantation

- **Three tests:**
  - Continuous wave optically detected magnetic resonance (CW ODMR)
  - Rabi oscillations
  - Pulsed optically detected magnetic resonance (Pulsed ODMR)

- **Next Steps:**
  - Run tests for single NV samples implanted with $^{15}\text{N}$
  - Compare with photoluminescence excitation spectra for each NV center
Defects in Diamond: Nitrogen-Vacancy Centers

A nitrogen-vacancy (NV) center is a point defect in diamond

- Preserves quantum coherence at room temperature

- Ability to resolve the spin state of a single NV using optical pumping and microwave absorption
  
  [1]
  ○ Study the hyperfine interaction
  ○ Match the number of nuclear interactions with the isotopes’ respective spins

Ion Implantation

Ion implantation: Method of bombarding the diamond sample [with $^{15}$N] to form NV centers

- Pros: Precise control over location of NV centers
- Cons: May damage diamond lattice [2]

Our project aims to find whether there is a distinct correlation between the NV’s method of growth and their amount of spectral diffusion.

Find desired single NV center

Is this NV center $^{15}$N or $^{14}$N?

Is it a good NV?
Motivation: To identify single nitrogen-vacancy (NV) centers in diamond and determine whether they are naturally grown $^{14}$N NV centers or if they are a product of $^{15}$N ion implantation. Compare results with photoluminescence excitation (PLE) spectra of each NV center to study if ion implanted NV centers display greater spectral diffusion.

Figure: Srivatsa Chakravarthi
Experimental Setup
Continuous Wave Optically Detected Magnetic Resonance (CW ODMR)

**Purpose:** Allows us to determine the spin state of the NV center by studying the emitted optical photons.

This is utilized in order to determine the resonant frequency needed to rotate the spin state from the $m_s = 0$ ground state to the excited $m_s = \pm 1$ state.
CW ODMR

ODMR scan. Int time per data point = 0.5 s

Spin-spin, external magnetic field, \(^{14}\)N hyperfine

Levels:
- \(|m_s=0\rangle\)
- \(|m_s=\pm 1\rangle\)
- \(2g_{\text{W}}B\)

Energy transitions:
- 2.8 MHz
- 4.6 MHz
- 5.1 MHz

RF (MHz) vs. total counts
Rabi Oscillations

Pulse Sequence

\[ |0\rangle \]

\[ |x\rangle \rightarrow |y\rangle \rightarrow |0\rangle \]

Laser

RF

\[ m_s = 0 \rightarrow m_s = \pm 1 \]
Rabi Oscillation
Pulsed Optically Detected Magnetic Resonance (Pulsed ODMR)

V. M. Acosta, et. al. Physical Review B 80,115202 (2009)
Pulsed ODMR
Next Steps

Repeat this process for desired single NV samples:

- Locate the desired single NV center on the sample
- Identify isotope using three tests
- Compare with previously taken photoluminescence excitation (PLE) spectra to study the correlation between isotope and amount of spectral diffusion
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