All Optical Magnetic Field Sensor

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Introduction

- Magnetic Field Sensors are used in biomedical applications such as NMR and MRI
- Current detector technology require circuitry at or in close proximity to the detection site
- By detecting the magnetic field optically, circuitry can be moved away from the detection site
- Nitrogen vacancy (NV) defects in diamond exhibit magnetic field dependent fluorescence providing a method for optical magnetic field detection

Theory

- A single substitutional nitrogen and an adjacent vacancy produce a NV defect center in diamond.
- NV centers are highly stable isolated spin systems
- Optical excitations are spin conserving
- Relaxation transitions are spin dependent, with spin 0 states resulting in optical emission and spin ±1 states undergoing non-radiative transition to the spin 0 ground state
- In the presence of a magnetic field, energy level mixing results in more transitions through the non-radiative pathway
- The resulting reduction in fluorescence provides a means of measuring local magnetic field strength optically

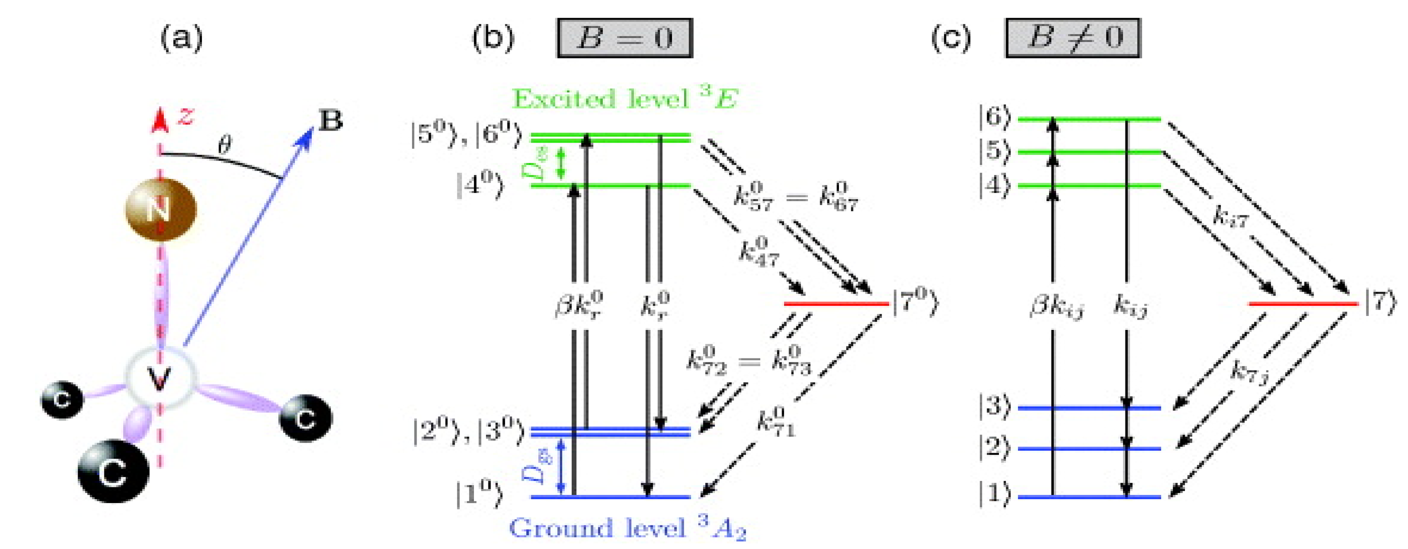

Figure 1: 7 state model jablonski diagram of unperturbed system along with the energy level splitting in the presence of a magnetic field. Tetienne, J.-P., et al. (2012). Magnetic-field-dependent photodynamics of single NV defects in diamond: an application to qualitative all-optical magnetic imaging. New Journal of Physics, 14(10), 103033.

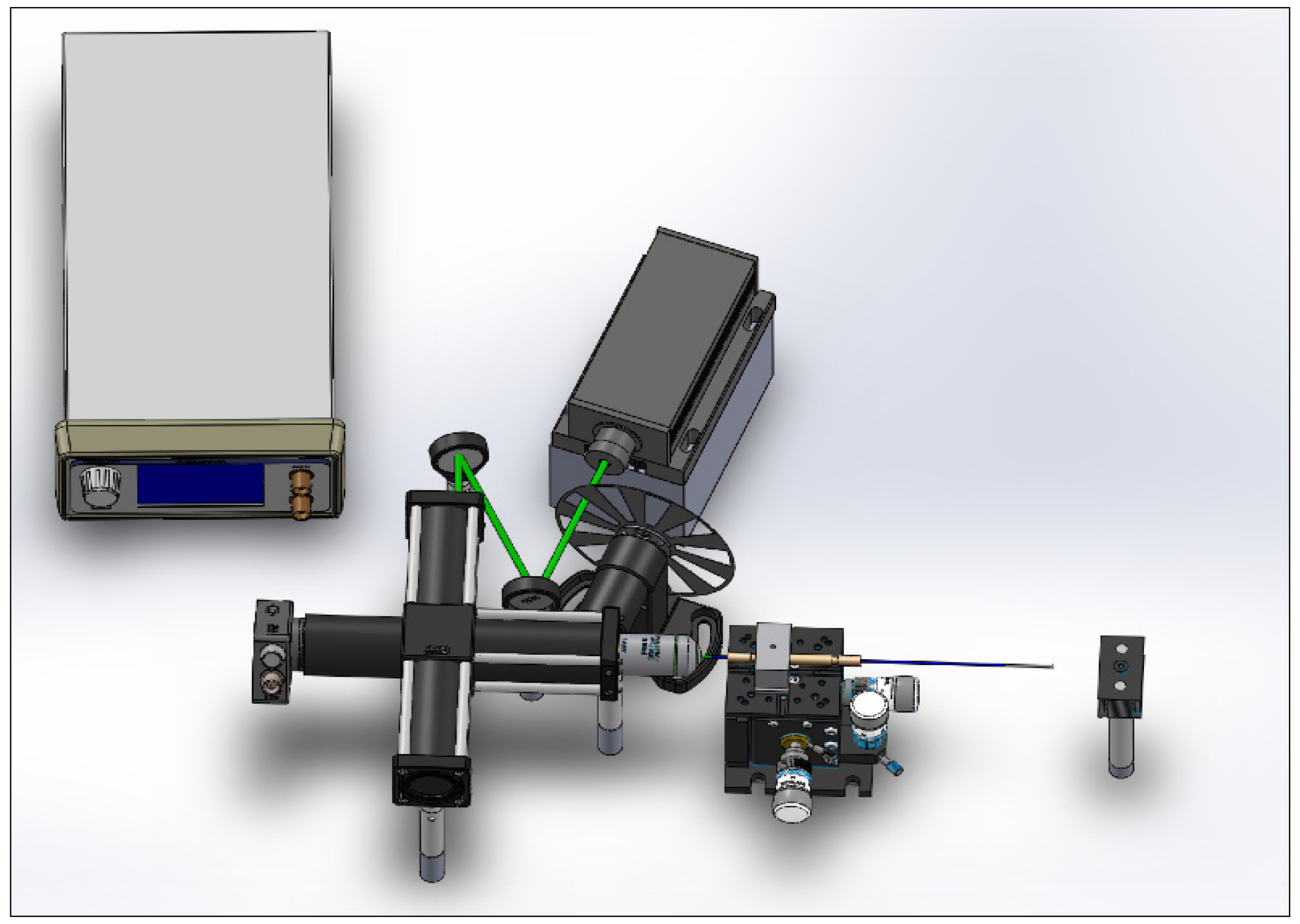

Figure 2: Solidworks depiction of optical magnetic field sensor

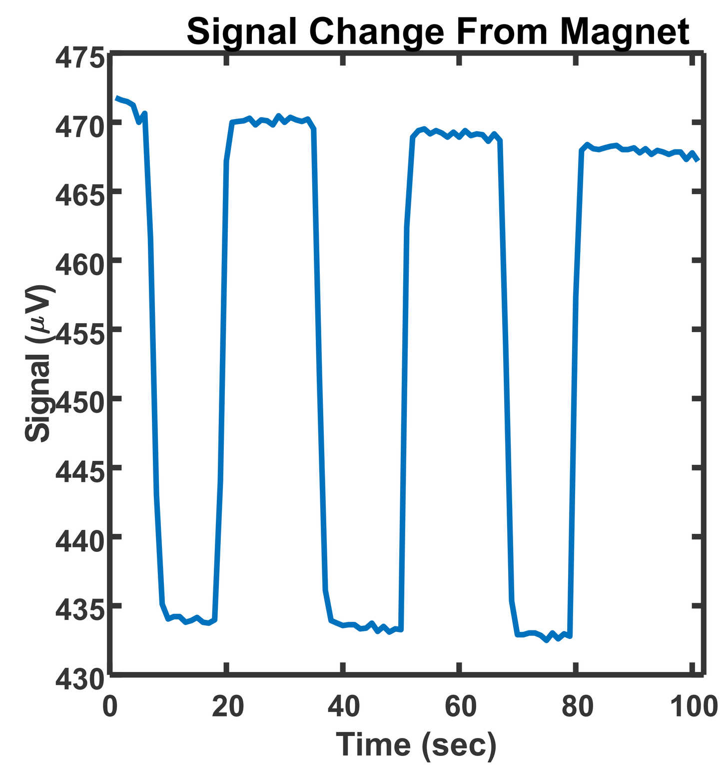

Figure 3: Example fluorescence signal. The signal drop corresponds to placing a magnet next to the sensor.

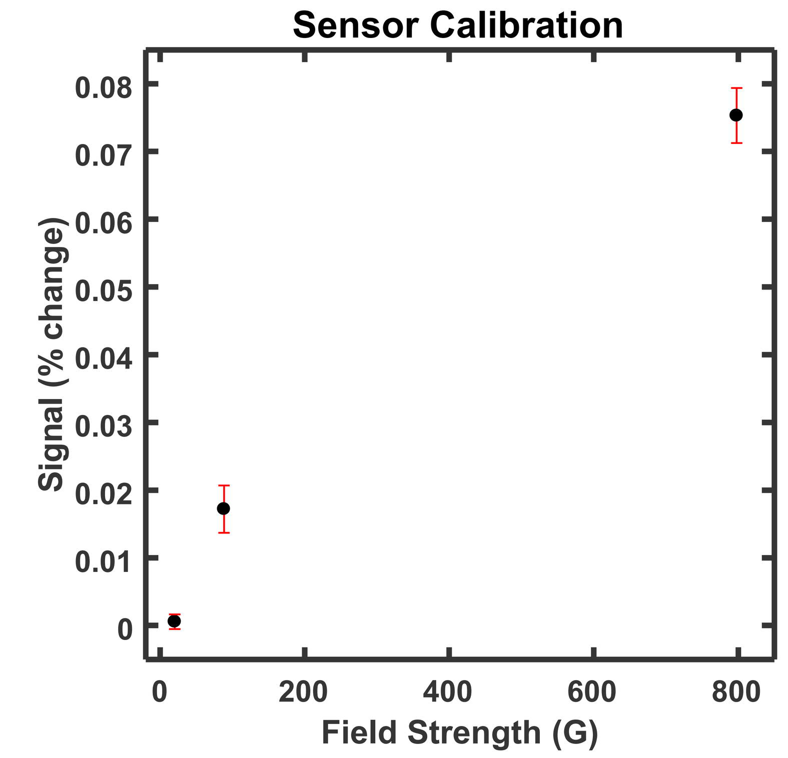

Figure 4: Percent change in fluorescence signal as a function of the magnetic field strength

Citations

The National Science Foundation has generously supported this study through the award DMR-1461275 REU Site: Research Experiences for Undergraduates in Renewable Energy

Method

- 532 nm laser excitation source modulated at 379 Hz by optical chopper
- Dichroic beam splitter directs excitation light into objective which focuses excitation light into fiber
- Fiber tip is coated in poly-L-lysine and NV filled nanodiamonds
- Some emission light couples into the fiber passes through the dichroic and emission filters and is collected by photodiode
- Signal from photodiode is then measured by the lock in amplifier
- Neodymium magnet was used as a magnetic field source
- The field strength was calibrated with a Gauss meter

Results

- The magnet reduces the fluorescence intensity resulting in a signal change of ~ 10%
- As the magnetic field gets stronger there is a greater change in fluorescence intensity

Conclusion

After a number of tests and iterations, we have a working sensor that is capable of sensing magnetic fields. Further work is needed to fully calibrate the sensor and determine its range of sensitivity.