Project Summary

1 Overview

Manipulation of the charge state of nitrogen—vacancy (NV) centers in diamond has proven to be a powerful tool in spectroscopy, microscopy, and quantum sensing. Photoionization spectroscopy could be used to finally solve the debate about the magnitude and temperature dependence of the energy gap between the metastable singlet state and other features within the band structure of the NV center. The photocurrent generated by photoionization of the NV center has been proposed to have superior magnetic resonance contrast compared to optically detected magnetic resonance measurement regimes, and could be used to enhance the sensitivity of existing minimally invasive fiber-optic quantum sensing probes. As a part of the proposed research, we plan to use photoionization of the NV center to implement various measurement techniques involving manipulation of the NV charge state in order to explore the wavelength of the NV- single-photon singlet state ionization threshold and to measure of the temperature dependence of the singlet-triplet energy gap. We also plan to utilize these diamond probes to fabricate a fiber-optic photoelectric detected magnetic resonance (PDMR) with have improved sensitivity to temperature and magnetic field when compared to previous fiber quantum sensors employing optically detected magnetic resonance (ODMR).

2 Intellectual Merit

The proposed experimental plan will resolve important open questions about the singlet state energy level structure by exploring the previously unknown temperature dependence of the energy difference between the ground state triplet and the metastable singlet energy levels in the NV center, as well as will create compact fiber-optic PDMR quantum sensors with leading-edge sensitivity and lower laser power profiles for use in sensitive biological environments.

3 Broader Impact

Using existing bulk NV diamond (NVD) technology, ultra-high sensitivity magnetometers and thermometers with nanometer resolution are possible. These probes can be used for in detailed study of sub-micron magnetic field and temperature distributions relevant to real-time spatially resolved magnetic imaging of individual neuron action potentials and sensitive subcellular thermometry necessary for the characterization of in vivo intracellular reaction kinetics. By measuring the dependence of the NV singlet-triplet energy gap on temperature, fundamental new insights into the phonon dynamics of the singlet-triplet intersystem crossing that underpins the quantum sensing capabilities of the NV center will be gained.