Electronic structure and charge stability of nickel vacancy centers in diamond.

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Color centers in diamond have emerged as leading qubit candidates and have been used in several proof-of-principle experiments. So far, research in this field has largely focused on the nitrogen vacancy (NV) and group-IV vacancy (SiV, GeV, SnV, and PbV) centers; however, they each face several orthogonal challenges, with the NV's lack of symmetry limiting its optical properties and the group-IV vacancies electronic structure resulting in short coherence times. Recently, we have identified the nickel vacancy (NiV) to be a highly promising inversion-symmetric and electronically favorable defect to overcome these remaining limitations. Here, we report first steps towards making the NiV accessible for applications in quantum information processing. We demonstrate creation of NiV^- centers in both type IIa and IIb diamond via ion-implantation and high-temperature high-pressure annealing. We use confocal magneto-optical fluorescence spectroscopy at temperatures down to 1.7K and up to 9T to further characterize the NiV's optical properties (Figure 1a), transition linewidths, and fluorescence lifetimes. Our studies confirm the predicted electronic and spin properties and are consistent with our own group theoretical model as well as with recent density functional theoretical calculations. Moreover, we report lifetime-limited optical transitions, paving the way for efficient photonic entanglement generation. Lastly, we investigate the NiV's charge state stability for various excitation conditions, diamond substrate types, and implantation doses. We observe a strong excitation wavelength dependence of the count rates, a termination of fluorescence under resonant excitation (Figure 1b) in absence of an off-resonant repump laser, as well as a strong bunching with up to millisecond timescales in photon autocorrelation measurements, all hinting towards charge state instabilities. While this highlights remaining challenges for the NiV that still need to be addressed, our studies broadly confirm the center's great potential as a near-term alternative to group-IV color centers.

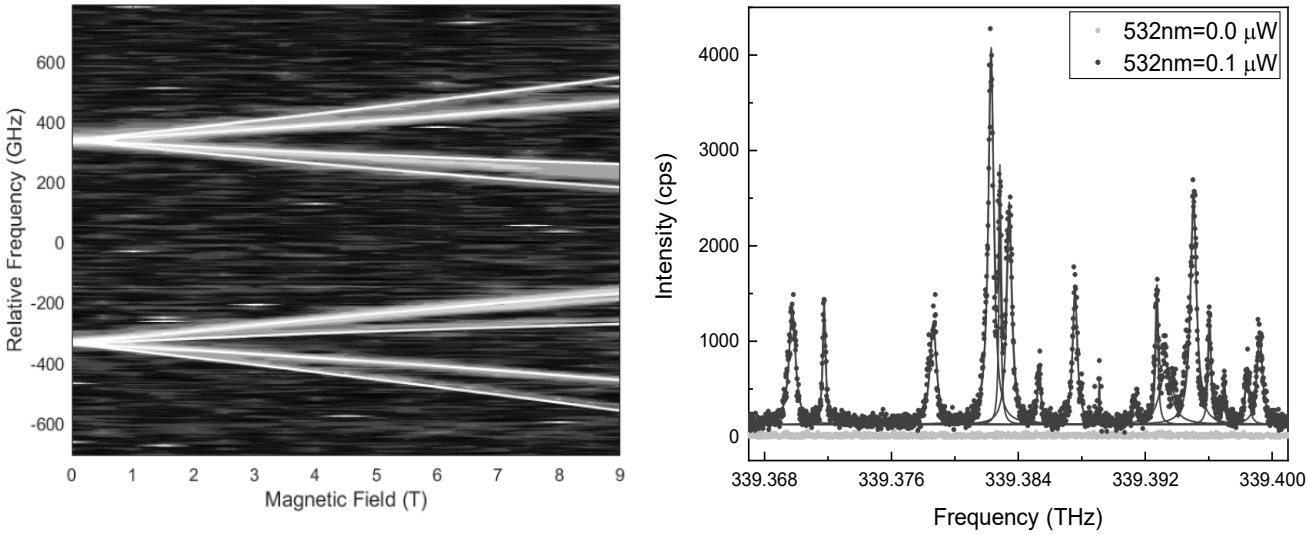

Figure 1 a) Spectral fine structure splitting of a NiV^- ensemble (contour plot, color coding indicates intensity. White solid lines are calculated transitions based on our group theoretical model. Data was taken at 1.8 K in Faraday configuration (7mW at 740nm). b) Resonant excitation of NiV^- ensemble sample with and without green repump laser (12μW scanned across 883nm).