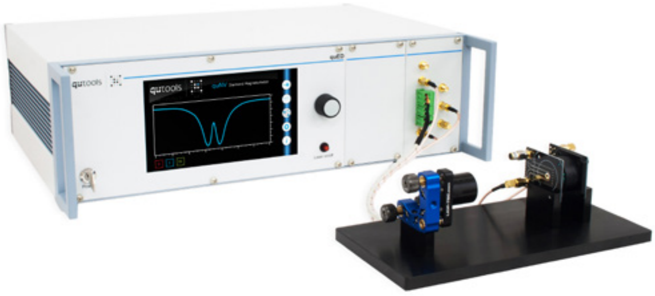
quNV

Quantum Sensing by Diamond Magnetometer



Science Kit

This Quantum Diamond Magnetometer and its experiments will introduce students to the concepts of quantum sensing. This design is based on recent achievements of scientific research and demonstrates quantum sensing in a simple and user friendly system for student lab courses at colleges and universities.

Experiments

- NV Center Fluorescence
- Optically Detected Magnetic Resonance (ODMR)
- Spin Relaxation Time
- Magnetic Field Sensing

Key Features

Probe:	HPHT Diamond
Excitation:	520 nm CW Diode Laser
Microwave:	4 GHz RF Sweep Generator
Detection:	Photodiode, Control & Read-Out Unit

Nitrogen-Vacancy Centers

Carbon forms in one of the allotropes a cubic lattice, called diamond. Within the diamond lattice numerous types of defects can exist. One of these defects is the nitrogen-vacancy (NV) center. It is formed by a substitutional nitrogen atom associated with a neighboring vacancy in the diamond crystal structure.

The NV center can be excited by light in the green spectrum. The excited state decays back to the ground state either directly or via an intermediate shelving state with different fluorescence intensity.

The decay path depends on the electron spin of the NV center. This allows optical readout and initialization at room temperature. Further the electron spin can be manipulated by microwave radiation. Applying magnetic and electric fields the energy levels of the spins can be shifted. Hence, a vast amount of experiments and measurement applications are possible.

The NV center can be used as a quantum sensor for very sensitive magnetic field measurements.

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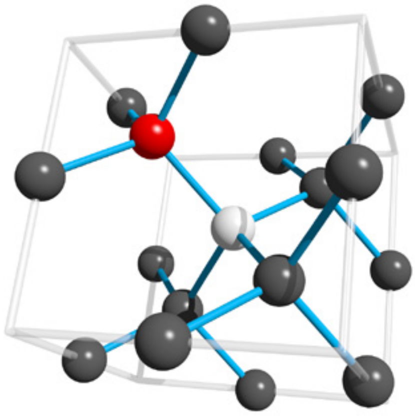
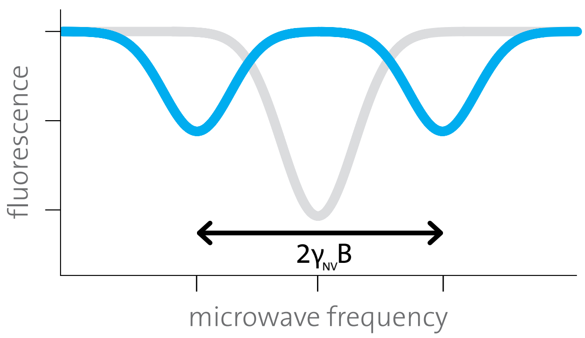
NV Center Applications

The dynamics of the NV center allow applications like spin initialization and state readout. Therefore, the center is suitable for quantum sensing applications like magnetic field sensing, spin relaxation time measurements and optically detected magnetic resonance - ODMR.

Due to their scalability, long coherence times and ability for interaction with photons, NV centers are of high interest for research in quantum information processing. Qubits can be defined as spin states of single electron or nuclear spins.



NV centers consist of a nitrogen atom (red) next to a vacancy (white) in a carbon (grey) cubic lattice.



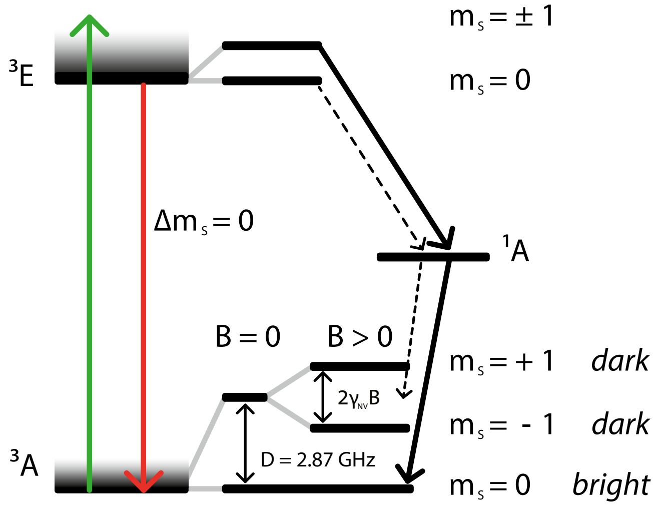
The grey curve shows the decrease of fluorescence at the resonance frequency. The m_s= ±1 ground level of the NV center splits up linearly by applying a magnetic field (blue) and indicate the shift in the resonance frequencies.

Electron Spin Manipulation

Applying microwave radiation with 2.87 GHz to the NV center drives the transition between m_s= 0 and ±1 in its electronic ground state. Additional excitation with laser light in the green spectrum populates m_s= ±1 in the electronic excited state.

This state has a significant possibility of intersystem crossing from ^{3}E to the shelving state ^{1}A with a long lifetime. From there it decays with high probability back to the m_s= 0 ground state. Due to the longer lifetime, the fluorescence gets quenched by applying microwave radiation at the frequency D, resonant to the transition between the spin levels. Hence, the fluorescence of a NV center is brighter when it is in the m_s= 0 state.

Applying a magnetic field B, the m_s= ±1 levels of the ground state split up linearly according to the Zeeman effect. Thus, the microwave resonance frequency also shifts. This allows measurements of magnetic fields with high sensitivity and high spatial resolution.



Energy-level scheme of the NV center. A green laser excites the NV center to the ^{3}E state, from where it either decays to ^{3}A or undergoes intersystem crossing to the metastable state ^{1}A, before decaying to the m_s = 0 ground state.

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