

Dipolar interactions in dense ensembles of Nitrogen-Vacancy centers

Clément Pellet-Mary, Maxime Perdriat, Gabriel Hétet

Nano-optics group



SORBONNE
UNIVERSITÉ



Université
de Paris



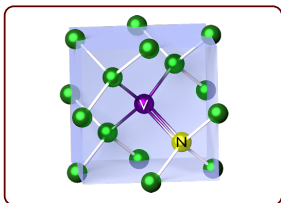
QUANTERA



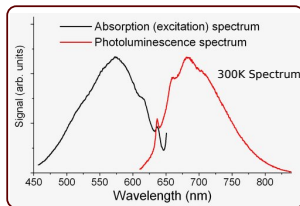
institut
universitaire
de France

Preamble : the NV center

Crystalline structure

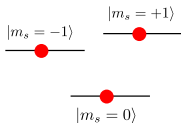


Optical properties



Spin properties

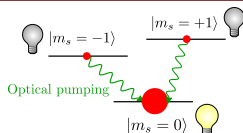
$S = 1$ in the electronic ground state



Unpolarized at 300 K :
 $\rho_{00} \approx 1/3 \approx \rho_{+1+1} \approx \rho_{-1-1}$

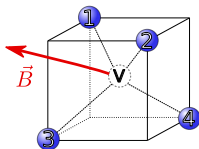


Interplay between spin and light

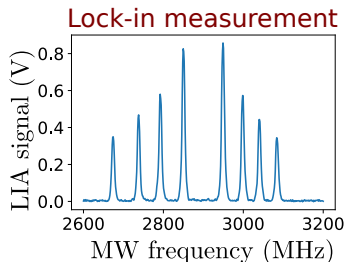
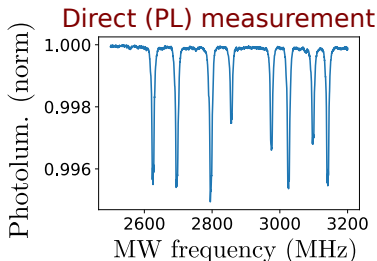
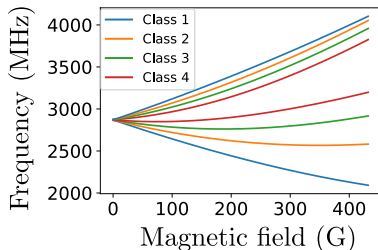


- Optical pumping in the $|m_s = 0\rangle$ state
- $|m_s = 0\rangle$ state brighter than $|m_s = \pm 1\rangle$

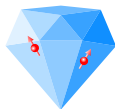
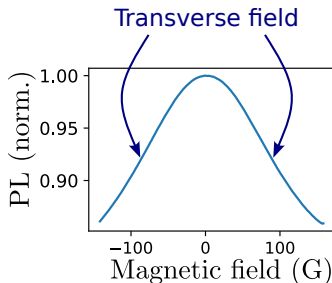
Preamble : the 4 classes of NV centers



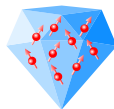
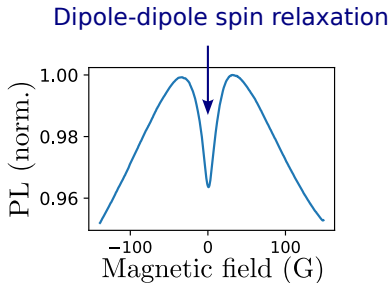
4 different projections of \vec{B}
over the 4 possible NV axes
→ 4 classes of resonances



Subject of this presentation



Low NV density
[NV] \leq 100 ppb



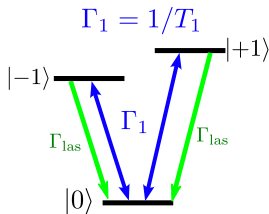
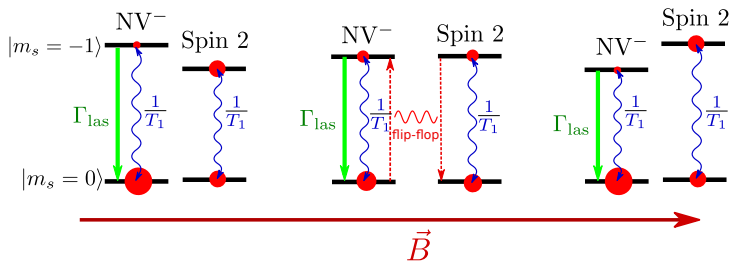
High NV density
[NV] \geq 1 ppm

- Better understand the dipole-dipole interaction in dense NV ensembles
- Exploit the PL feature for magnetometry

Outline

- 1 Cross-relaxation with NV centers
- 2 The NV-fluctuator model and experimental verification

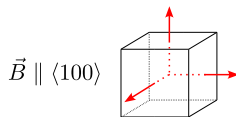
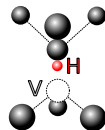
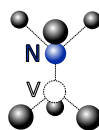
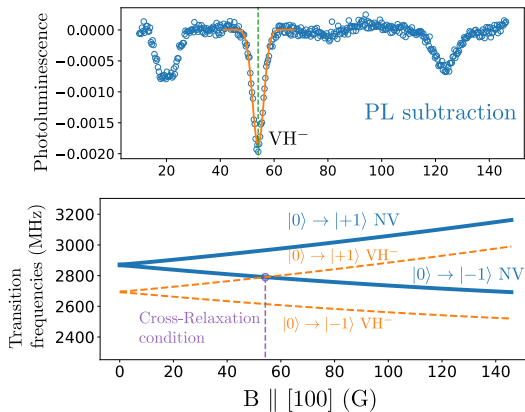
Principle of cross-relaxation with NV centers



$$\text{Rate equation: } \rho_{00} = \frac{\Gamma_1 + \Gamma_{\text{las}}}{3\Gamma_1 + \Gamma_{\text{las}}}$$

$$\Gamma_1 \nearrow \Rightarrow PL \searrow$$

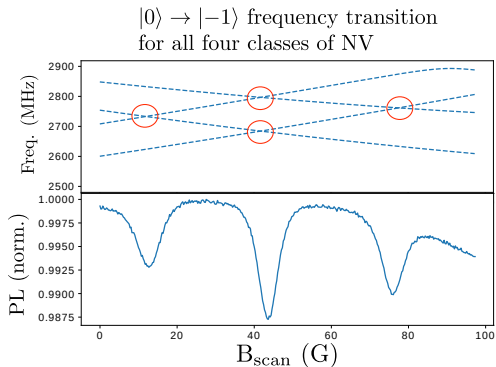
Example: Cross-relaxation between NV centers and VH^-



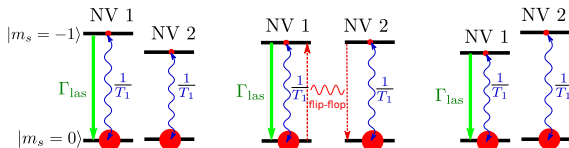
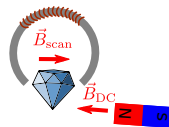
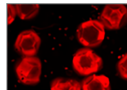
Optical detection of paramagnetic defects in diamond grown by chemical vapor deposition

C. Pellet-Mary, P. Huillery, M. Perdriat, A. Tallaïre, and G. Hétet
 Phys. Rev. B **103**, L100411 – Published 24 March 2021

Cross-relaxation between NV centers and NV centers

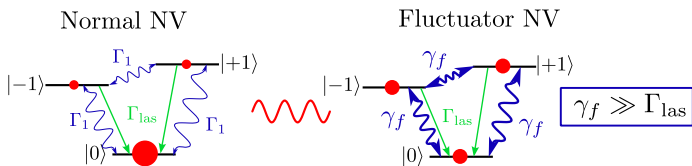


samples : Adamas 15/150 μm
fluorescent microdiamond
[N] = 100~200 PPM
[NV] \sim 3 PPM



No cross-relaxation
for equally polarized
spins

Presentation of the fluctuator model



Fluctuators are NV centers with a fast intrinsic depolarization mechanism

Localized noise sources with the spectral response of an NV center

Precedents in:

- P-doped Si
- solid-state NMR
- FRET

Possible microscopic explanation:

- charge tunneling
- modulation of J-coupling

Choi, Joonhee, et al. Physical review letters 118.9 (2017): 093601.

Predictions of the fluctuator model

- Γ_1 increases when classes overlap spectrally (increase in the resonant fluctuator density).
- The dipole induced depolarization has a stretched exponential profile:

$$\rho_{00}(t) \propto \exp\left(-\sqrt{\frac{t}{T_1}}\right)$$

- The Fluctuators spectral response is broadened by their decay rate γ_f (lifetime limit).