Probing dark spins with NV centers in CVD-grown diamond

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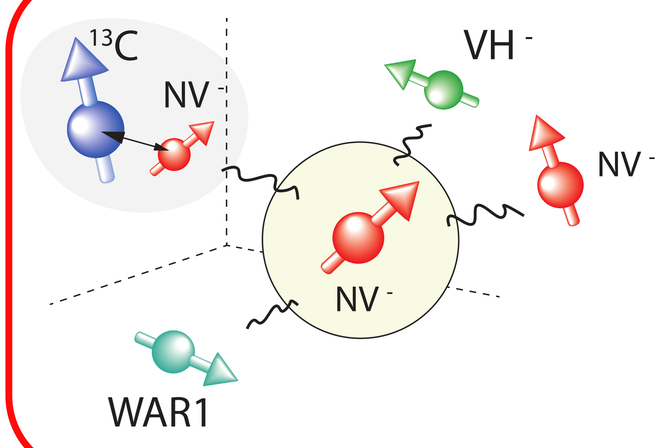
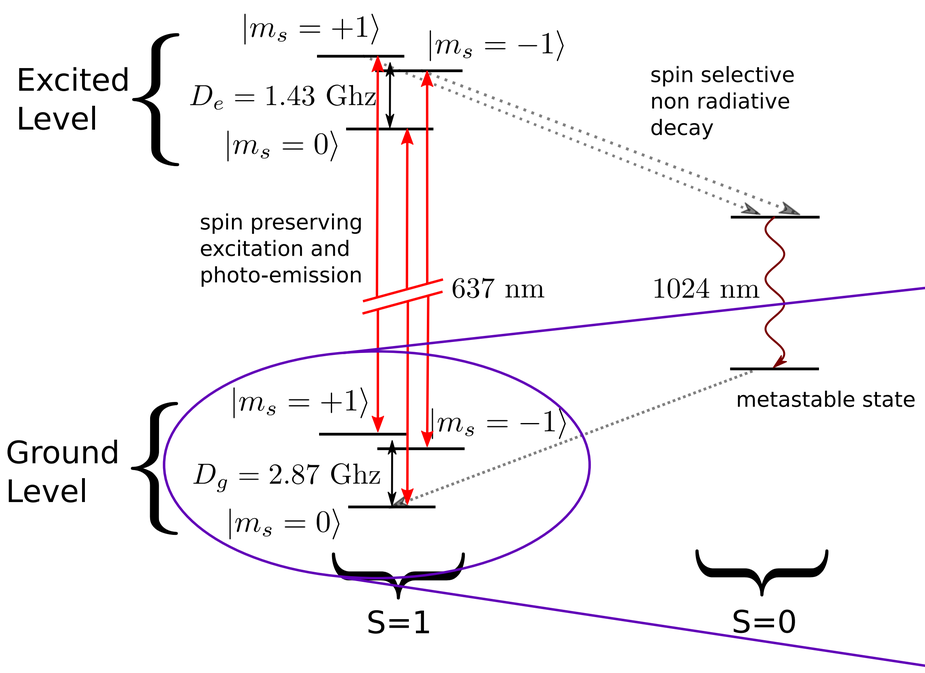
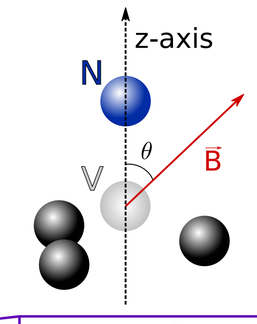


Abstract : The Nitrogen Vacancy (NV^-) electron spin has the remarkable property of being both polarizable and readable optically at room temperature. This property makes it a strong candidate to probe tiny magnetic field at the atomic level. Here we present our results where we managed to detect other spin impurities in a Chemical Vapour Deposition (CVD)-grown diamond, at the ppb range, thanks to resonant coupling with NV centers. We also present observations on the NV-NV dipolar interaction and its potential use in magnetometry.

NV^- electronic structure



NV^- center theory

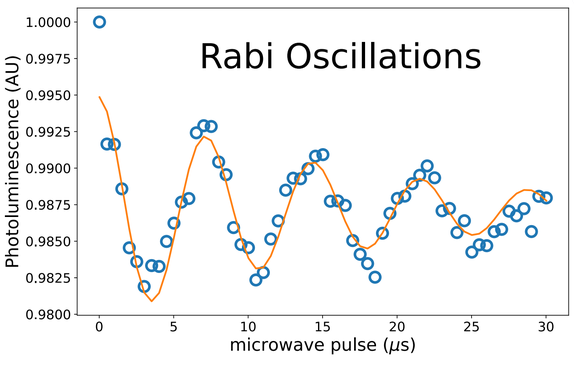


Ground level spin Hamiltonian

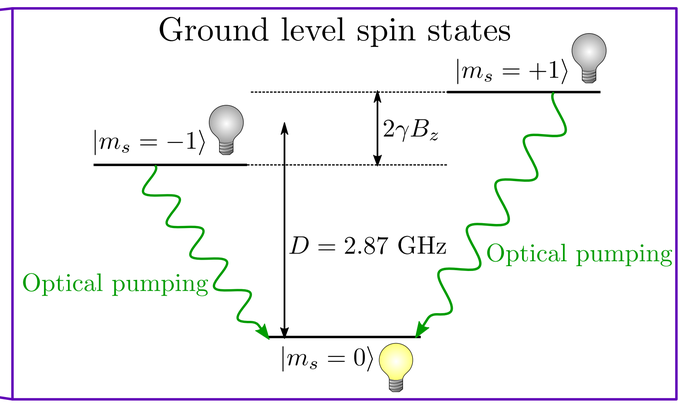
$$\hat{\mathcal{H}}_s = DS_z^2 + \gamma_e \mathbf{B}\cdot\hat{\mathbf{S}}$$

$D = 2.87\,\text{GHz}$ and $\gamma_e = 2.8\,\text{MHz/G}$

$$\mathcal{H}_s = \begin{pmatrix} D-\gamma_e B\cos\theta & \gamma_e B\sin\theta & 0 \\ \gamma_e B\sin\theta & 0 & \gamma_e B\sin\theta \\ 0 & \gamma_e B\sin\theta & D+\gamma_e B\cos\theta \end{pmatrix}$$



Ground level spin states

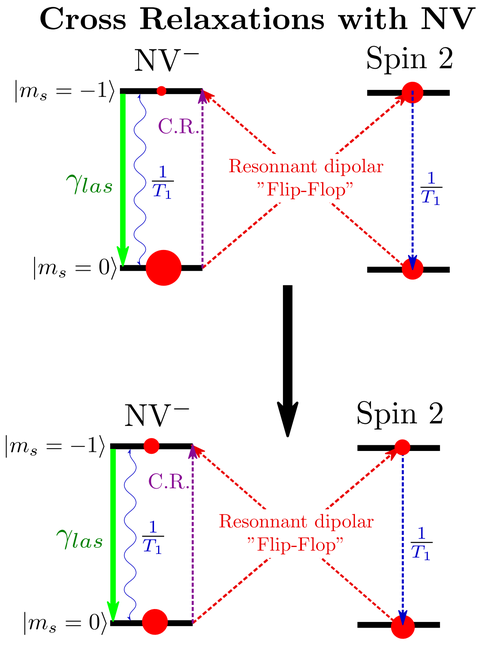


- $|0\rangle$ state brighter than $|\pm1\rangle$ state by ~ 30 %
- polarization in $|0\rangle$ state of ~ 80 % (equivalent to ~ 65 μK)

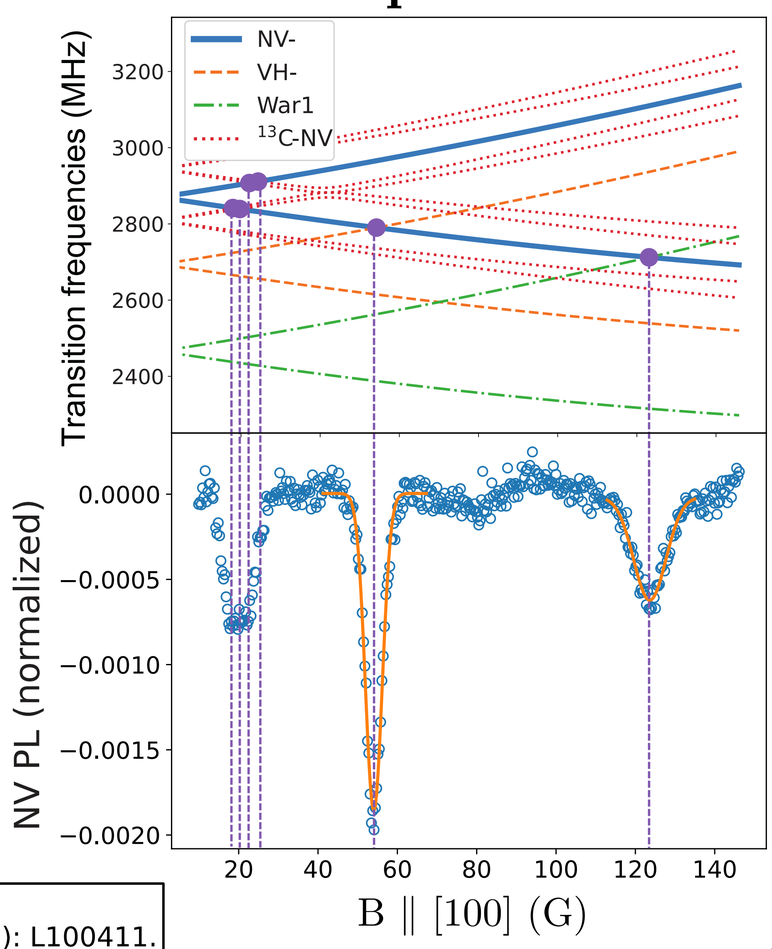
- Longitudinal lifetime $T_1 \sim 5$ ms (phonons)
- Dephasing time $T_2^* \sim 1$ μs (magnetic noise)

Detection of dark spins

Cross Relaxations with NV

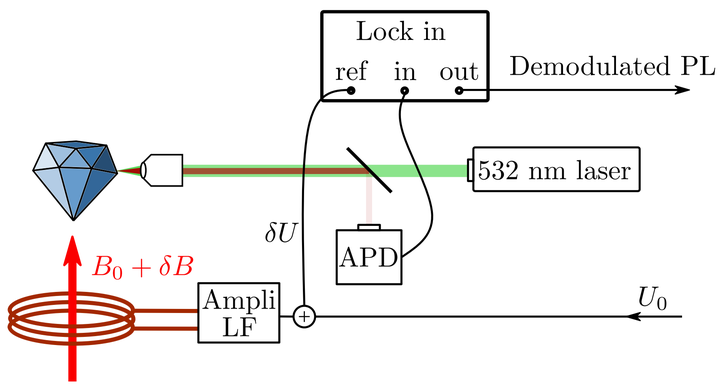


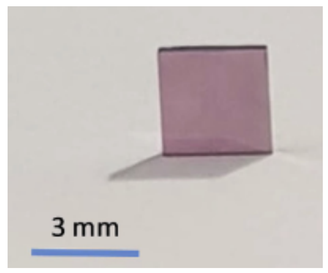
Dépolarization of NV's spin induced by an unpolarized dark spin



Pellet-Mary, Clément, et al. *Physical Review B* 103.10 (2021): L100411.

Experimental setup

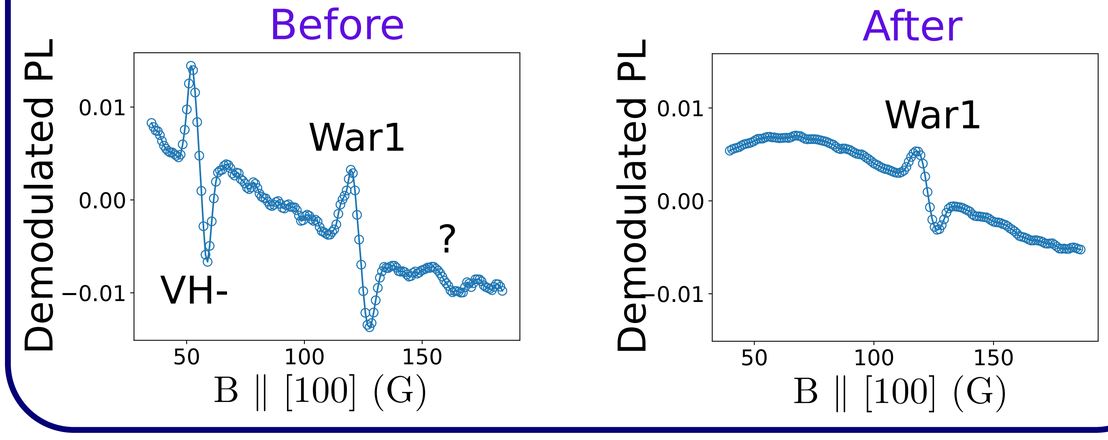




CVD sample (IRCP/LSPM)

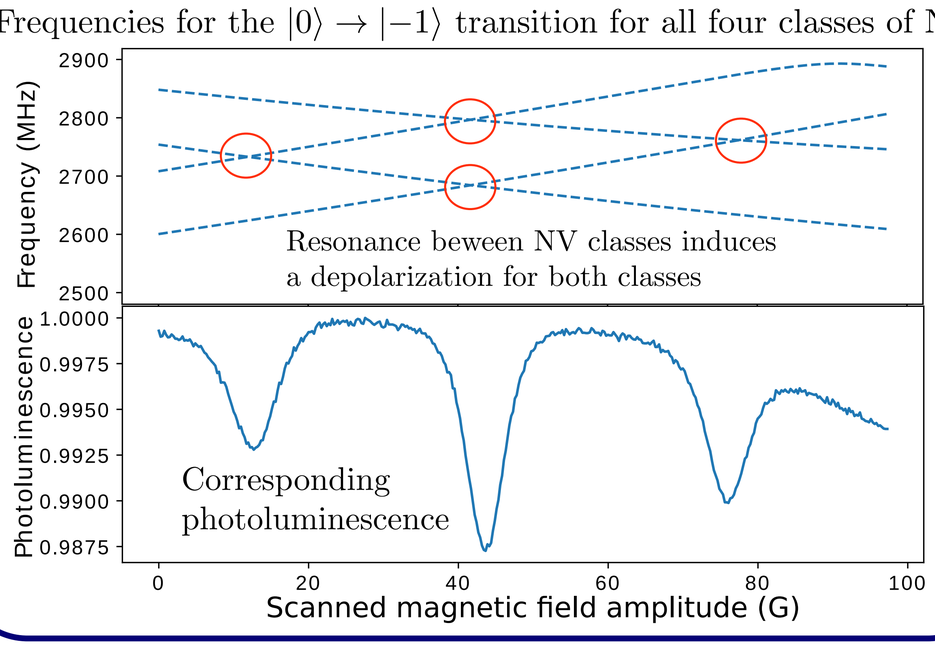
- 5 ppm NV^-
- 600 ns T_2^*

Effect of annealing at 1200° C

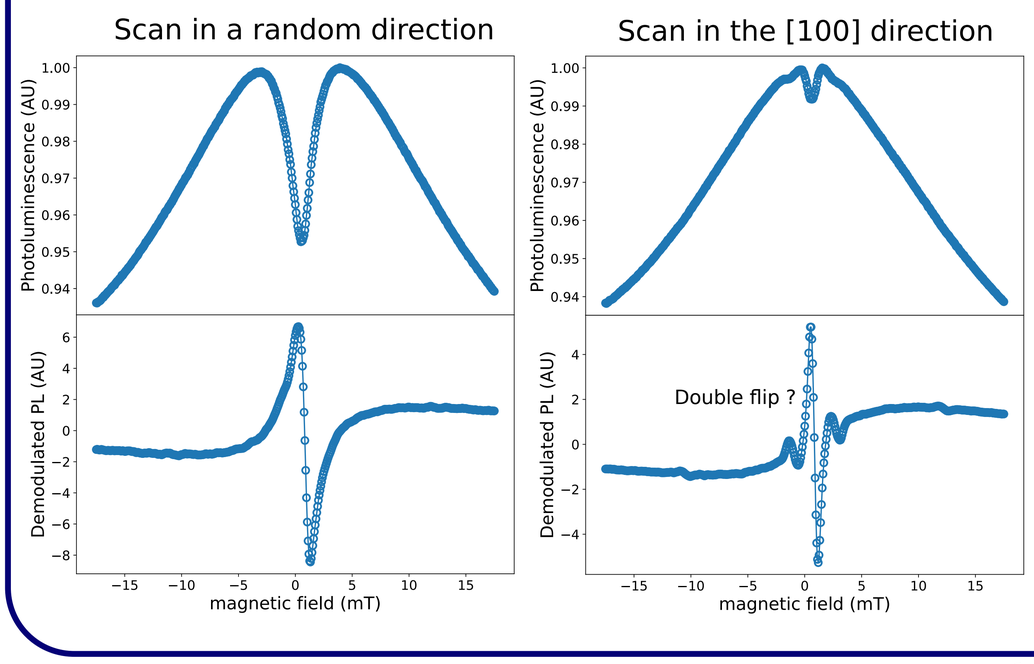


NV-NV cross-relaxations

Frequencies for the $|0\rangle \rightarrow |-1\rangle$ transition for all four classes of NV



NV-NV zero-field magnetometry



Sample :
15 μm HPHT
$\sim$ 5 PPM NV
(Adamas)

Sensitivity in 0B :
$\sim 100\ \text{nT}/\sqrt{\text{Hz}}$

- Microwave-free
- Orientation-free (powder,polycristalline)

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