

MA 32.6: Magnetic imaging with spin defects in hexagonal boron nitride

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slides available at <https://magimag.eu>

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Jiahao Li, James Edgar

Institut Néel, Grenoble, France

Johann Coraux, Nicolas Rougemaille

LPCNO, Toulouse, France

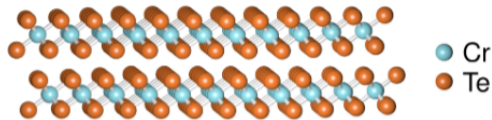
Cédric Robert, Jules Fraunie, Pierre Renucci, Xavier Marie



Imaging magnetic van der Waals materials

Collaboration: Institut Néel, Grenoble (A. Purbawati, J. Coraux, N. Rougemaille)

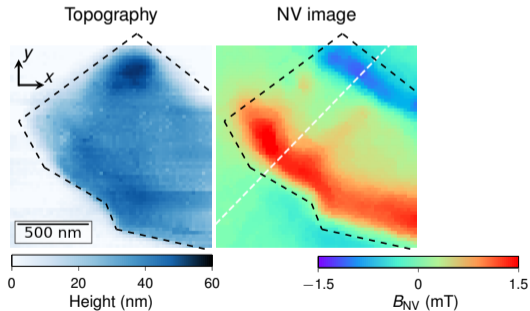
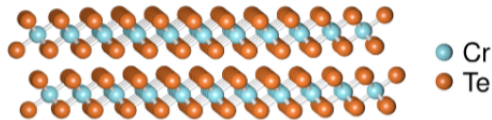
Scanning NV center magnetometry on CrTe₂
2D ferromagnet at room temperature
with in-plane magnetization



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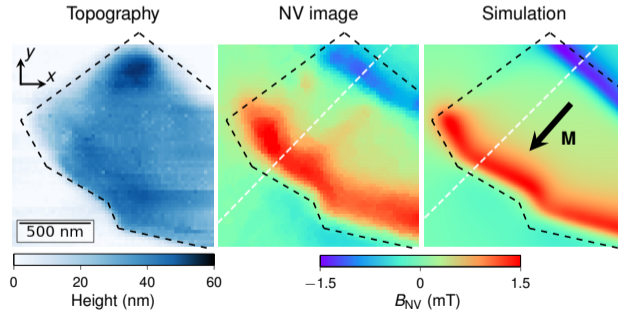
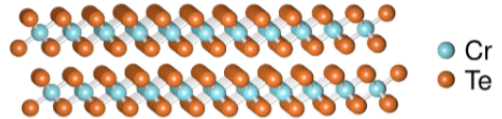


F. Fabre et al. *Phys. Rev. Mater.* 5 (2021), 034008

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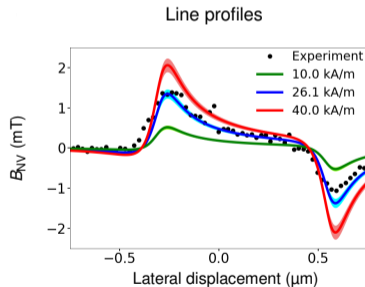
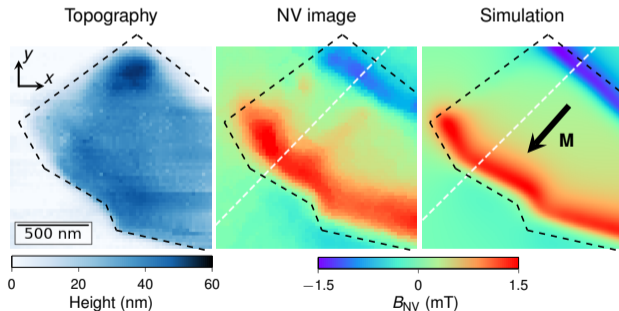
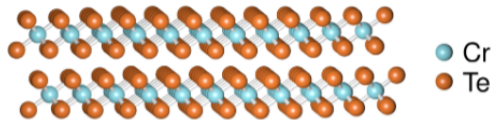


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CrTe_2 is not stable in air → encapsulation with h-BN

F. Fabre et al. *Phys. Rev. Mater.* 5 (2021), 034008

Defects in h-BN

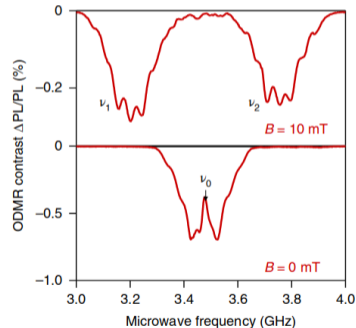
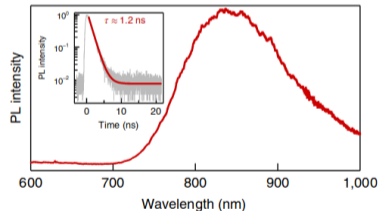
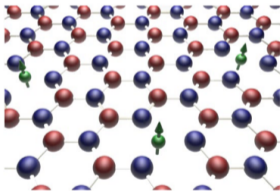
- h-BN is a wide bandgap material (about 6 eV)
- Single photon emitters were known in h-BN

 T. T. Tran *et al.* *Nature Nanotechnology* 11 (2016), 37

Defects in h-BN

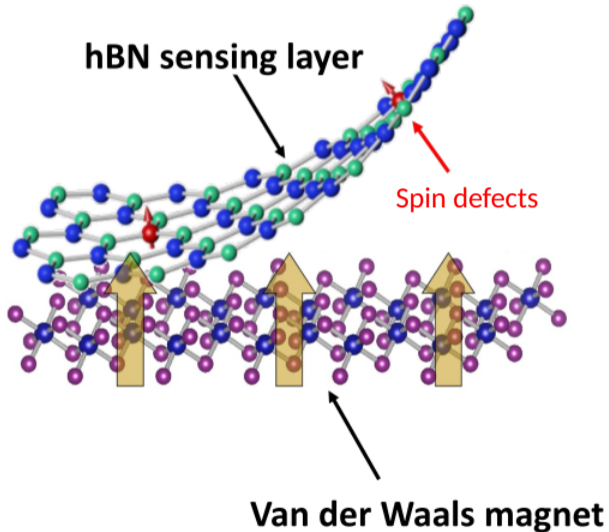
- h-BN is a wide bandgap material (about 6 eV)
- Single photon emitters were known in h-BN
- A **spin defect** was identified in 2020

T. T. Tran et al. *Nature Nanotechnology* 11 (2016), 37



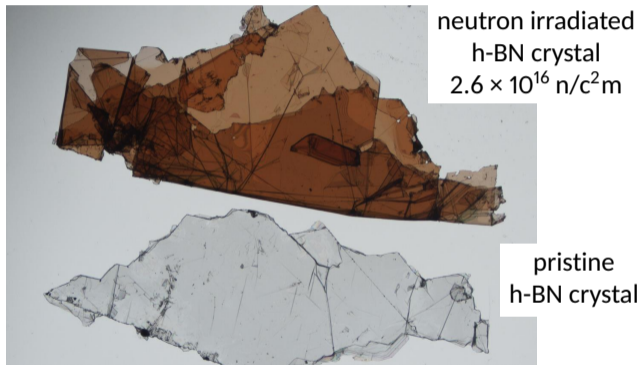
A. Gottscholl et al. *Nat. Mater.* 19 (2020), 540

Objective: a quantum sensing foil integrated in the van der Waals heterostructure



Creating ensembles of boron vacancies in h-BN

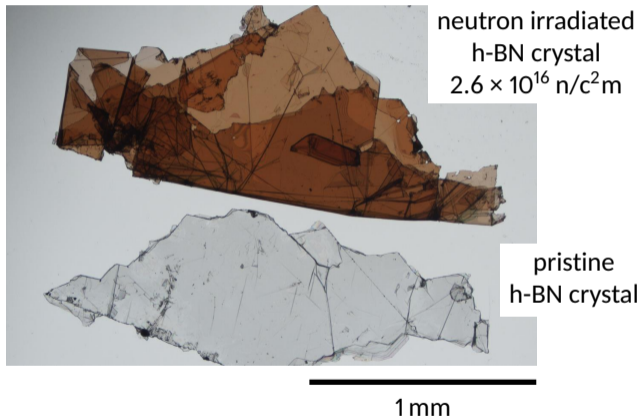
Collaboration: Kansas State University (J. Li, J. Edgar)



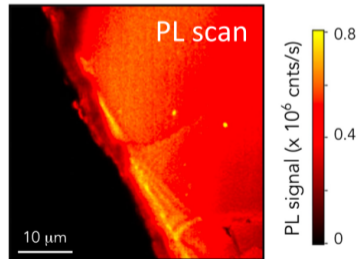
 S. Liu et al. *Chem. of Mater.* 30 (2018), 6222

Creating ensembles of boron vacancies in h-BN

Collaboration: Kansas State University (J. Li, J. Edgar)



- Excitation at 532 nm
- Ambient conditions

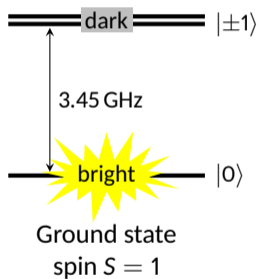


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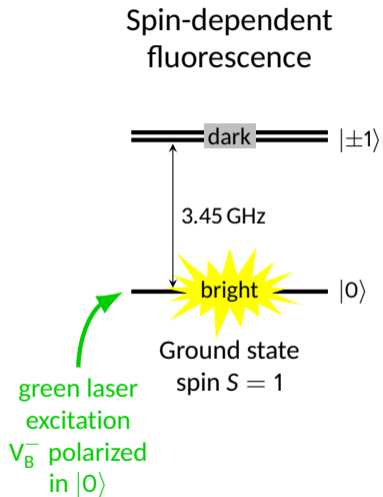
A. Haykal et al. *Nat. Commun.* 13 (2022), 4347

Measuring magnetic fields with V_B^-

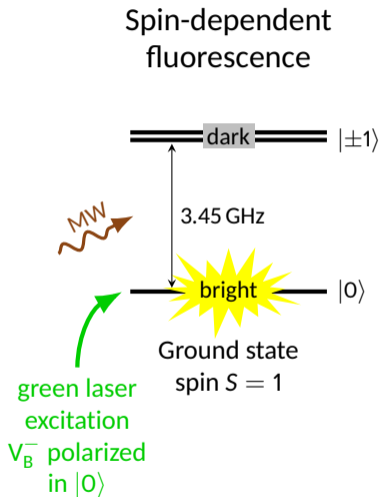
Spin-dependent
fluorescence



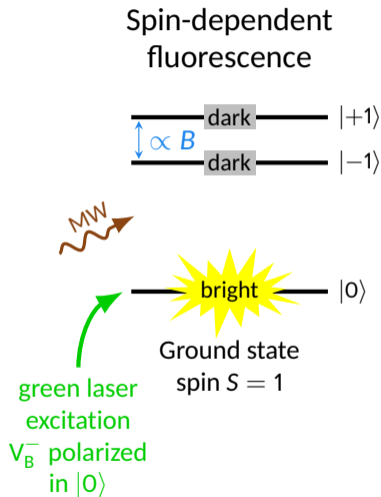
Measuring magnetic fields with V_B^-



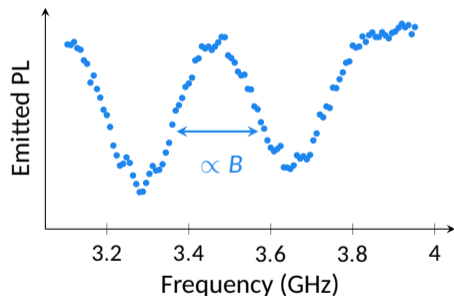
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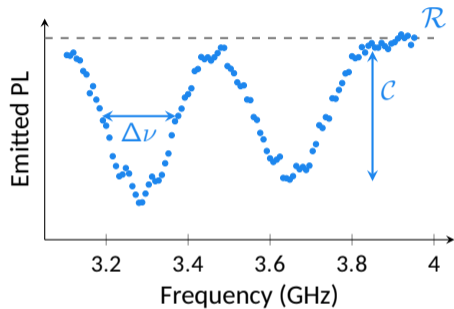
Measuring magnetic fields with V_B^-



Optically detected magnetic resonance



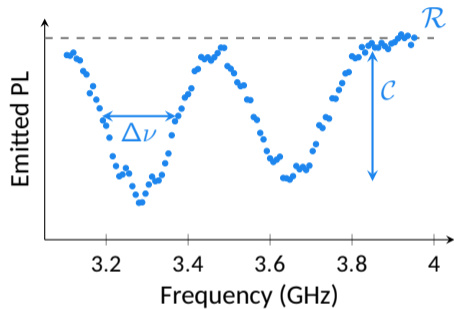
Magnetic field sensitivity



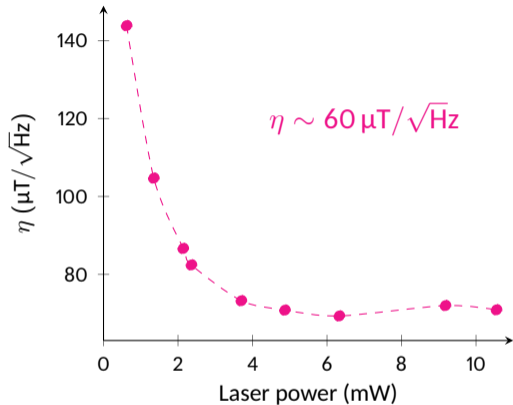
$$\eta \sim 0.7 \frac{1}{\gamma_e} \frac{\Delta\nu}{C\sqrt{R}}$$

 P. Kumar et al. *Phys. Rev. Appl.* 18 (2022), L061002

Magnetic field sensitivity



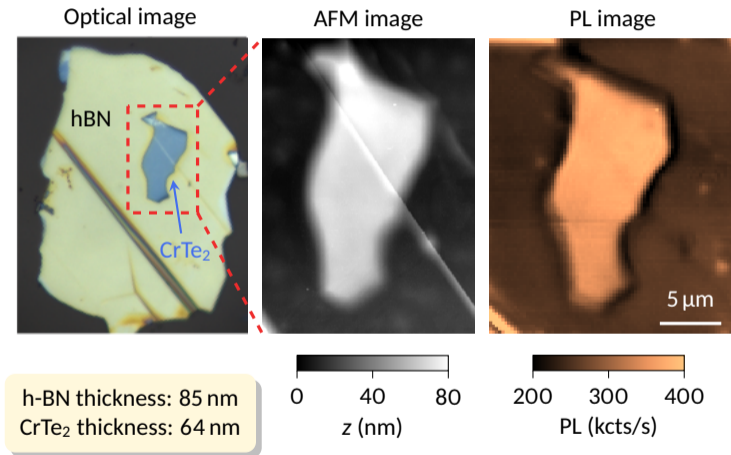
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P. Kumar et al. *Phys. Rev. Appl.* 18 (2022), L061002

Imaging a CrTe₂ flake

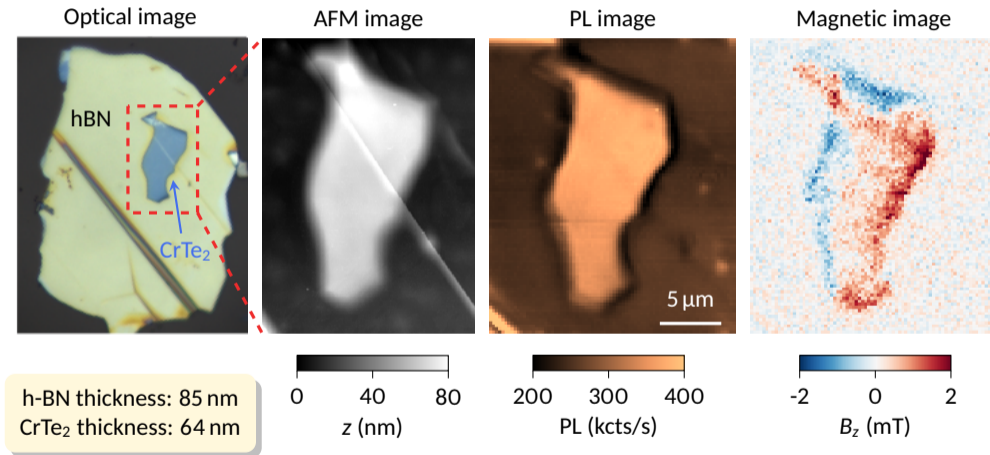
Collaboration: Institut Néel, Grenoble and LPCNO, Toulouse



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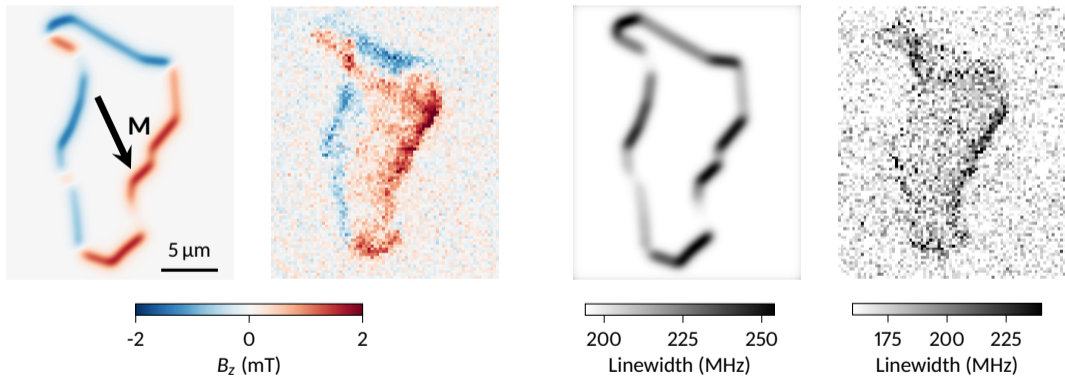


P. Kumar et al. *Phys. Rev. Appl.* 18 (2022), L061002

Comparison with simulations

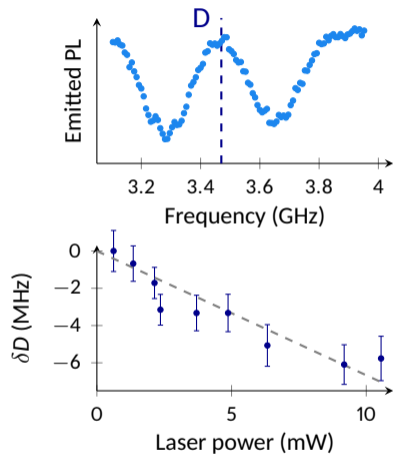
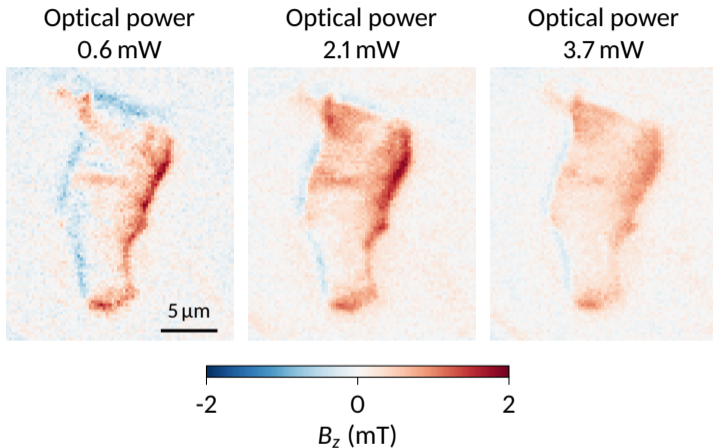
Two averaging procedures are necessary:

- Vertically, over the h-BN film thickness
- Laterally, over the gaussian profile of the laser beam



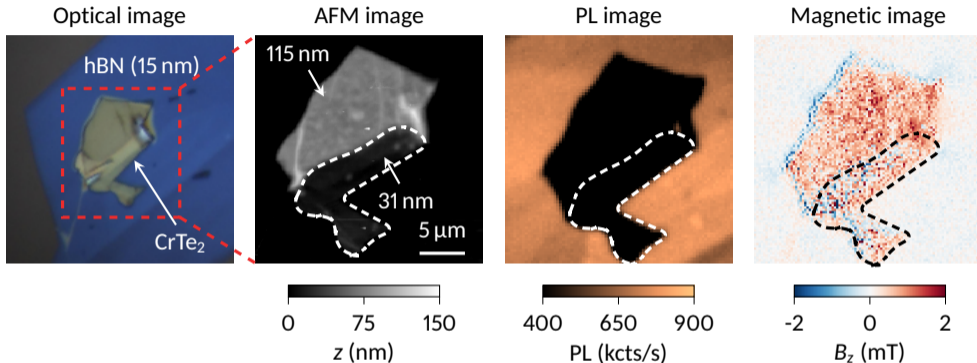
→ Being really quantitative is difficult, using thinner flakes would help!

Effect of heating



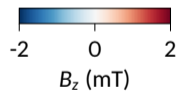
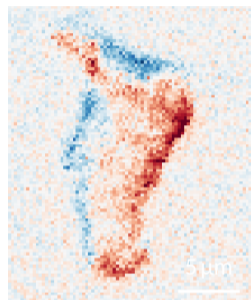
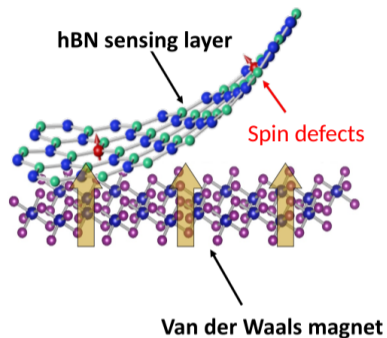
P. Kumar et al. *Phys. Rev. Appl.* 18 (2022), L061002

Using thinner flakes



- PL quenching effect at the metallic surface of CrTe_2
- Need for larger laser excitation power
- Heating of the magnetic material, crossing T_C

Summary



 P. Kumar *et al.* *Phys. Rev. Appl.* 18 (2022), L061002

 A. J. Healey *et al.* *Nat. Phys.* 19 (2023), 87

 M. Huang *et al.* *Nat. Commun.* 13 (2022), 5369

The team S2QT in Montpellier



We are looking for students and postdocs!