Imaging spin textures in synthetic antiferromagnets with quantum single spin relaxometry

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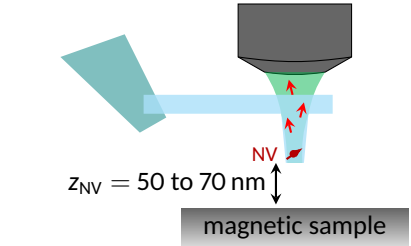
Centre de Nanosciences et de Nanotechnologies (C2N), Palaiseau, France

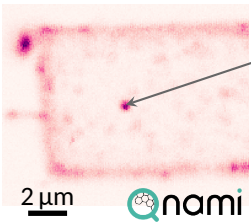
Paris, 10/12/2019

slides available at https://magimag.eu

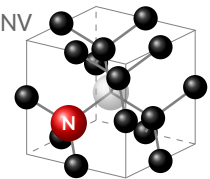
Scanning NV magnetometry



Photoluminescence scan
top view of the tip



single NV



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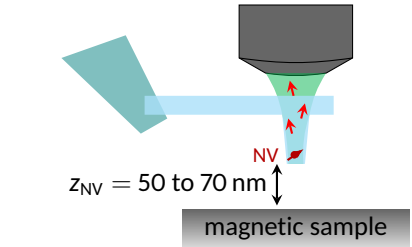

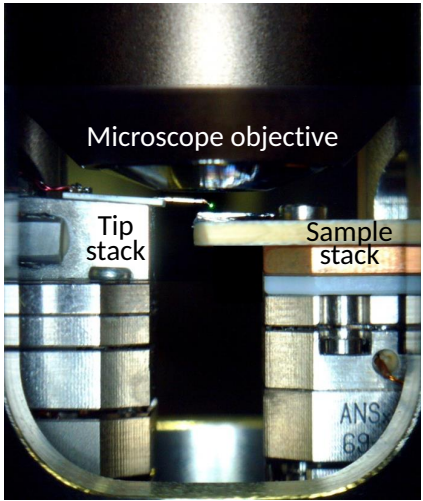

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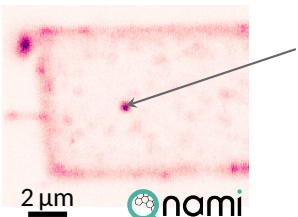
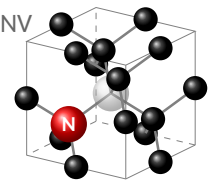
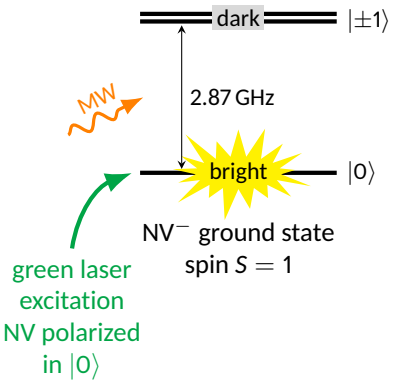




Quantitative field measurements

Spin-dependent fluorescence



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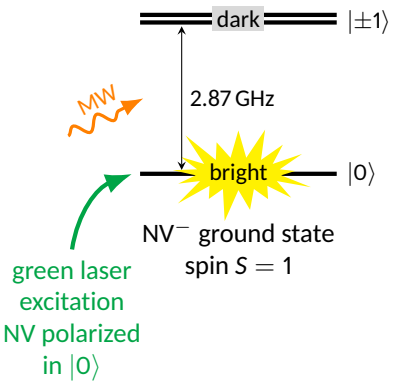
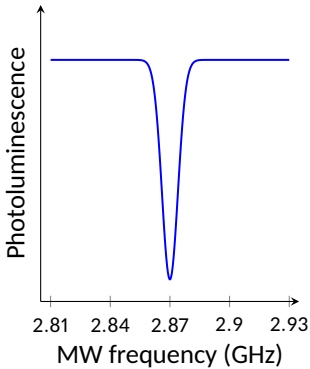


Optically Detected Magnetic Resonance



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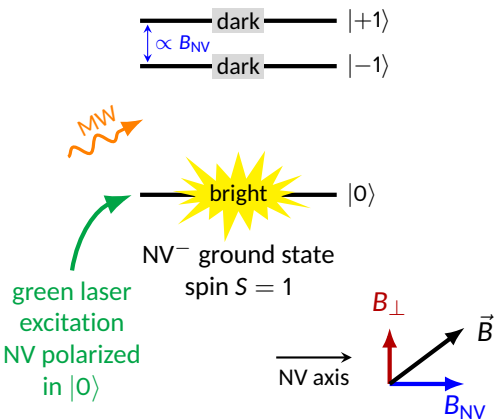

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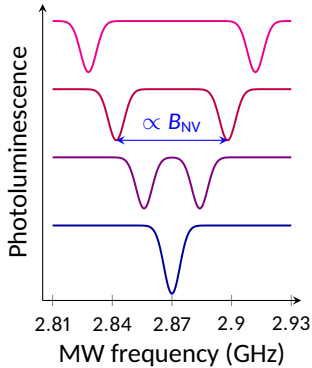

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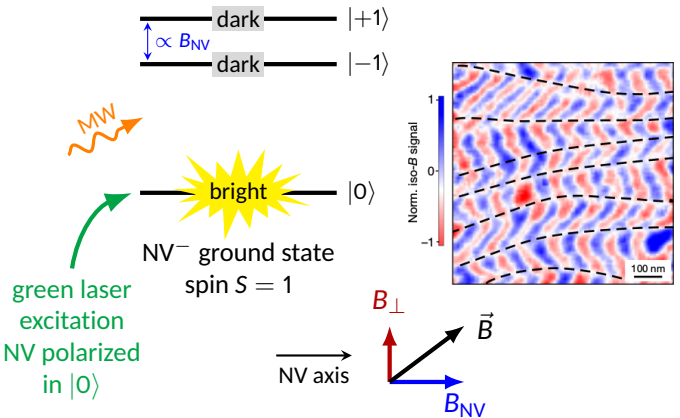

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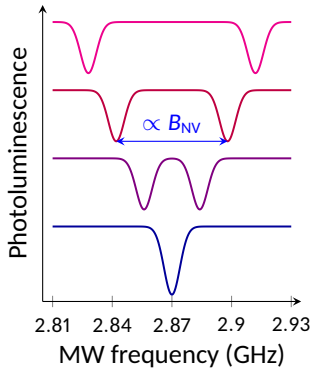


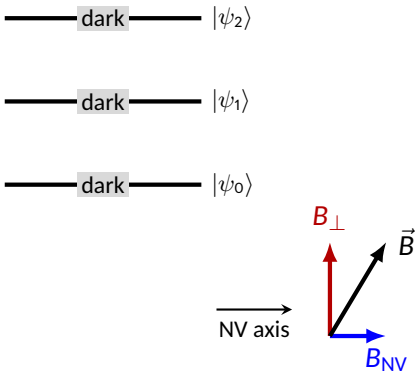
I. Gross *et al.* *Nature* 549 (2017), 252–256

J.-Y. Chauleau *et al.* *Nat. Mater.* (2019), 1–5

→ Sensitivity of a few $\mu T/\sqrt{Hz}$, investigation of antiferromagnets

Quenching of the photoluminescence at high field

Mixing of the spin states



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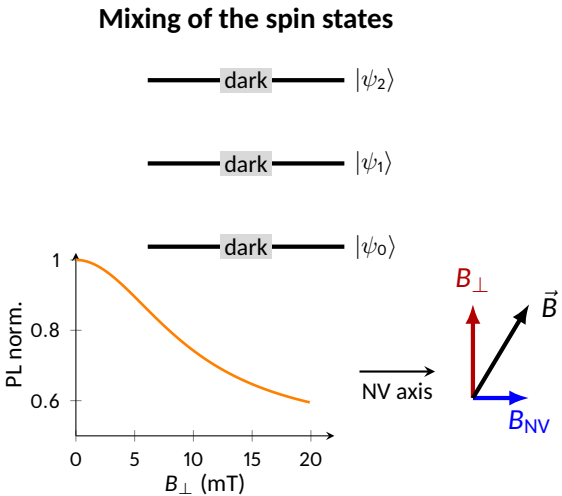

J.-P. Tetienne *et al.* *New J. Phys.* 14 (2012), 103033

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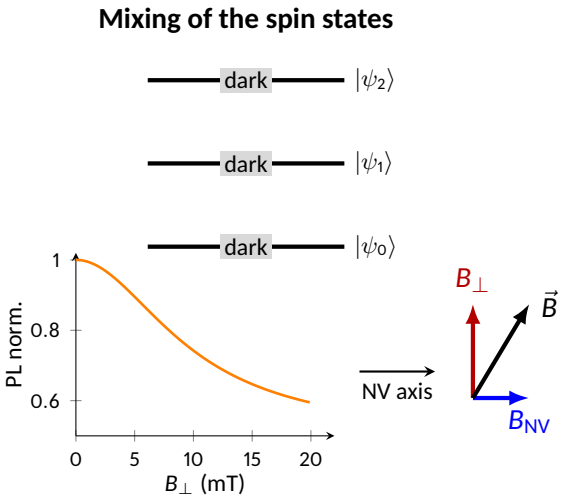

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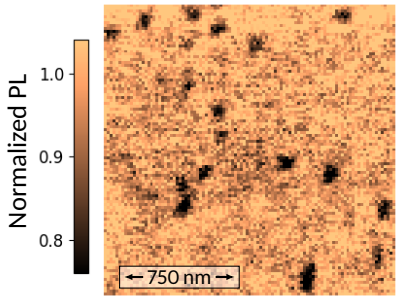
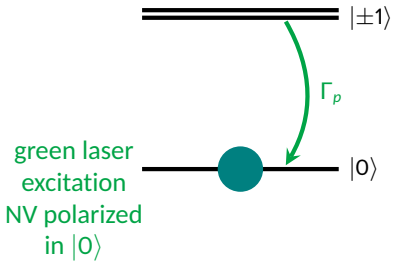


G. Rana *et al.* *submitted soon* (2019)

→ Fast and simple investigation of ferromagnets

A third option: NV center relaxometry



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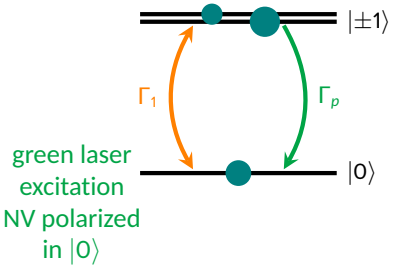

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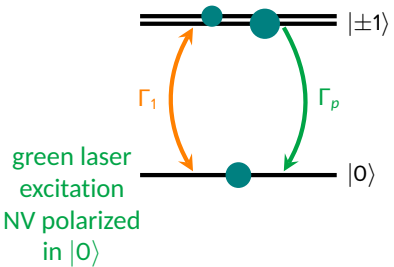

Noise detection:

→ Johnson noise

S. Kolkowitz *et al.* *Science* 347 (2015), 1129–1132

A. Ariyaratne *et al.* *Nat. Commun.* 9 (2018), 2406

→ Fluctuating magnetic particles

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D. Schmid-Lorch *et al.* *Nano Lett.* 15 (2015), 4942–4947

→ Spin waves

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C. Du *et al.* *Science* 357 (2017), 195–198

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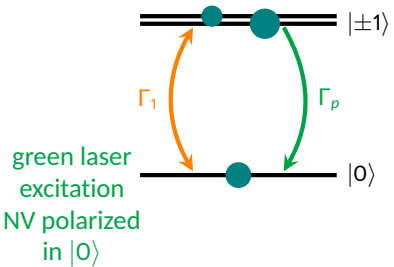

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Theoretical prediction: The difference between the spin waves in domain walls and in magnetic domains could be used to image antiferromagnets.

B. Flebus *et al.* *Phys. Rev. B* 98 (2018), 180409

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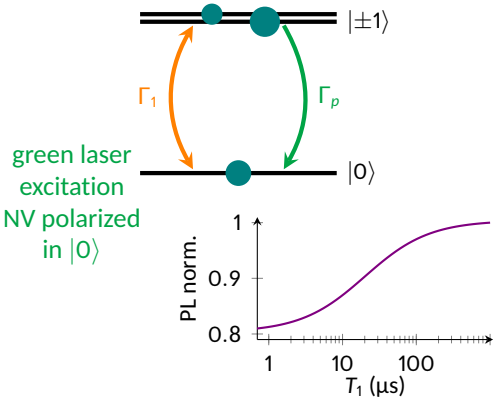

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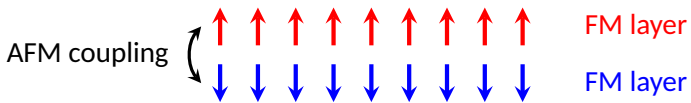
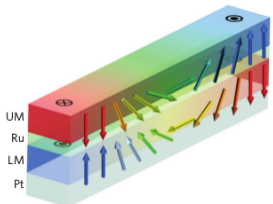
Synthetic antiferromagnets

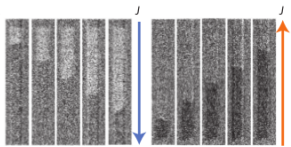
Antiferromagnets: Promising for fast, robust and efficient spintronic devices



R. A. Duine *et al.* *Nat. Phys.* 14 (2018), 217–219

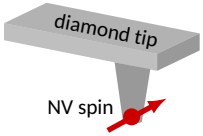
Fast domain wall motion

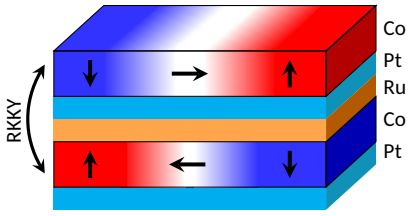




S.-H. Yang *et al.* *Nat. Nano.* 10 (2015), 221–226

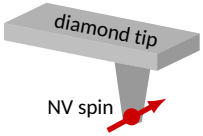
Imaging a domain wall

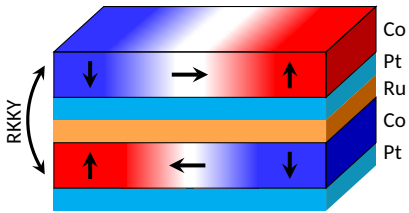


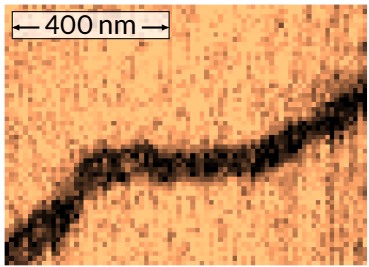


Samples from UMR CNRS/Thales
W. Legrand, F. Ajejas, Y. Sassi, V. Cros

Imaging a domain wall







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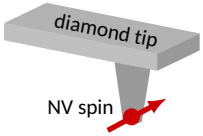

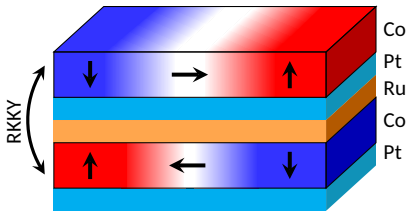

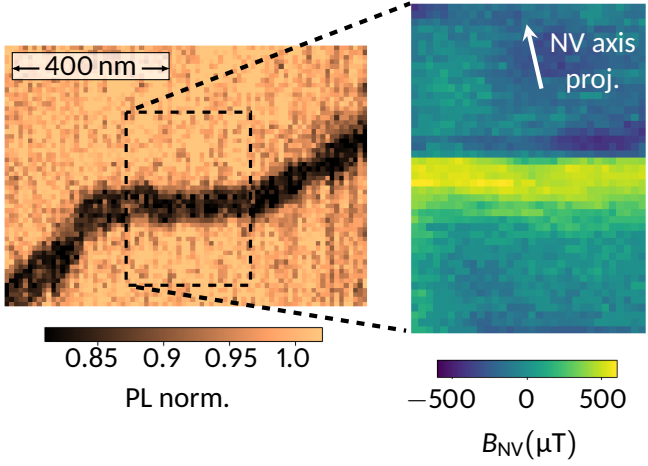

Samples from UMR CNRS/Thales
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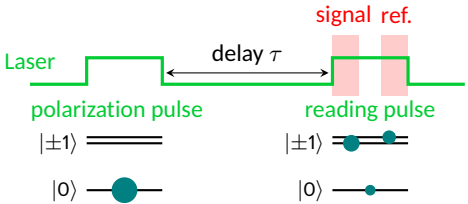
The stray field of the domain wall is too small to be the reason of the PL decrease

Measurements of the spin relaxation time T_1



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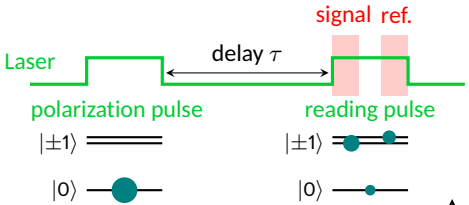

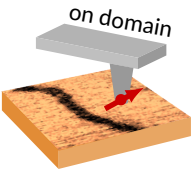

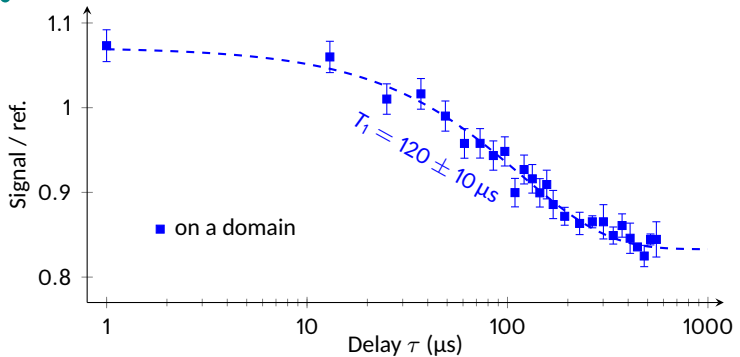

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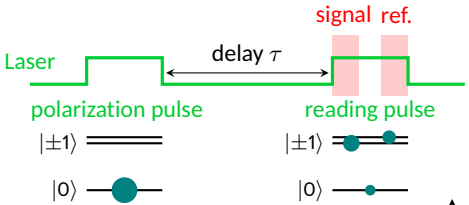

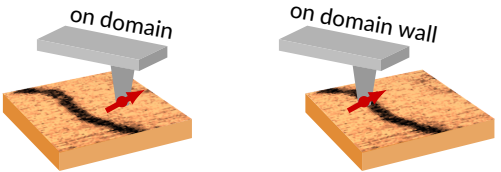

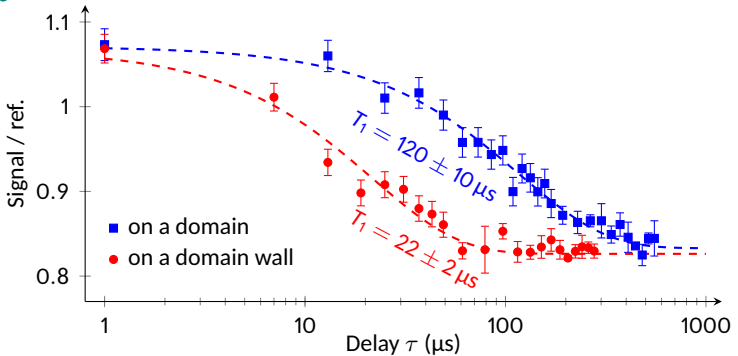

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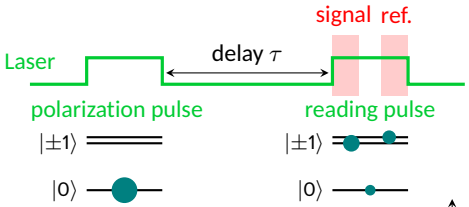
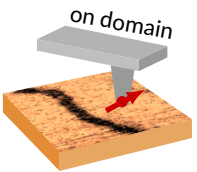
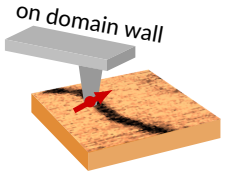
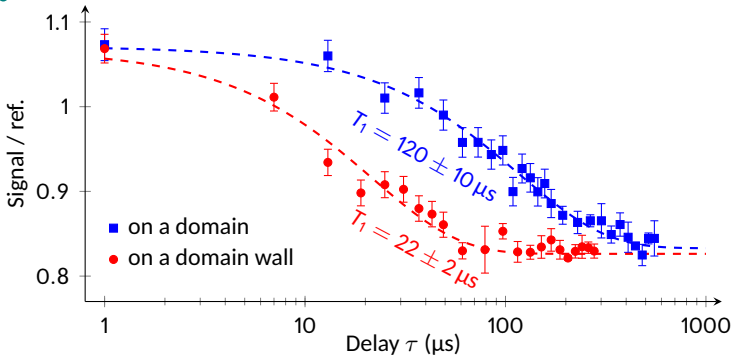






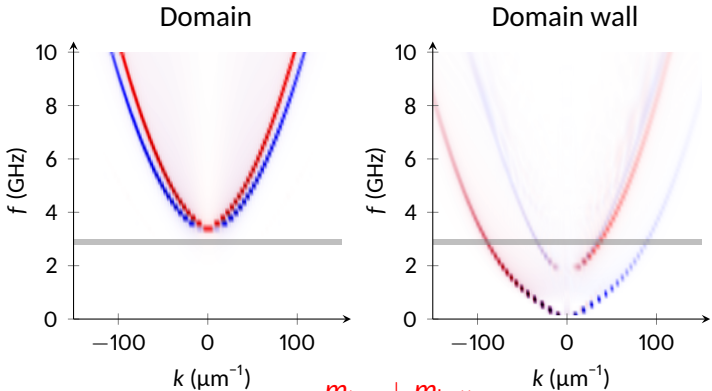
Clear diminution of T_1 above the domain wall

→ **Enhancement of the spin relaxation by magnetic noise**



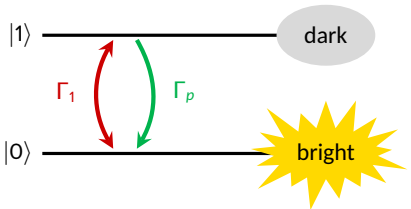
Spin waves in a domain wall

Spin waves have a gapped dispersion inside a magnetic domain but it is **gapless in a domain wall** → **more thermally activated magnons!**



Calculations by J.-V. Kim

Dependence of the PL on the relaxation time



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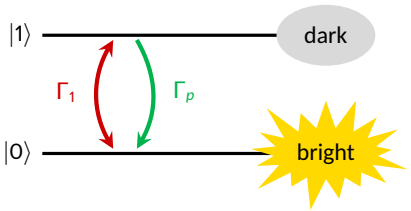

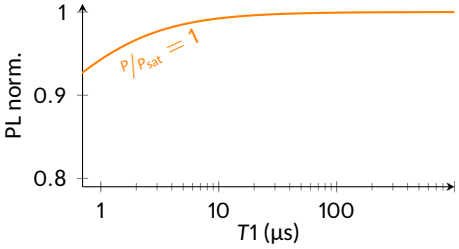

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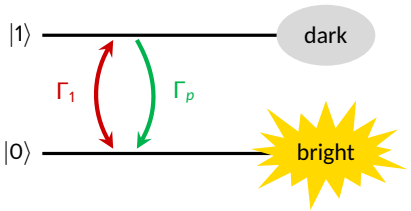
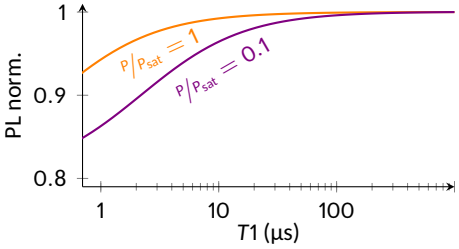
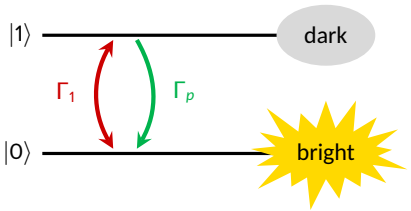
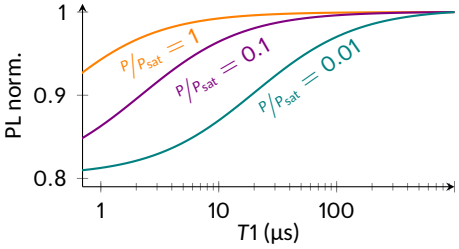


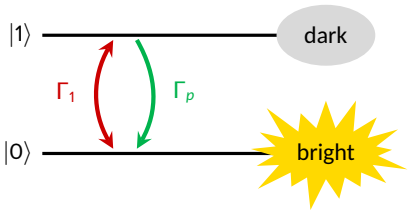


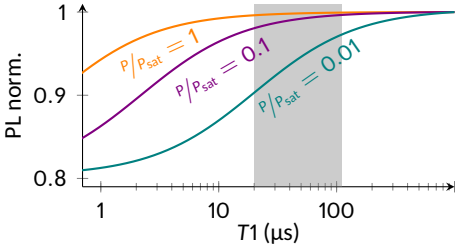
Dependence of the PL on the relaxation time



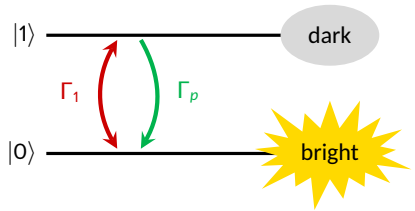


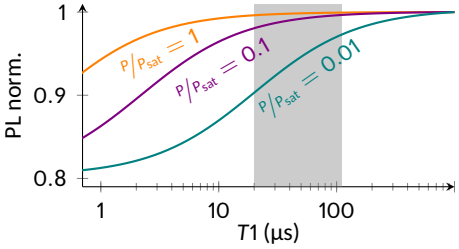
Dependence of the PL on the relaxation time

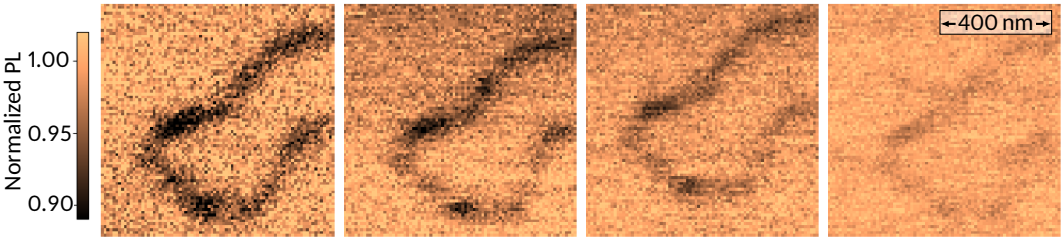




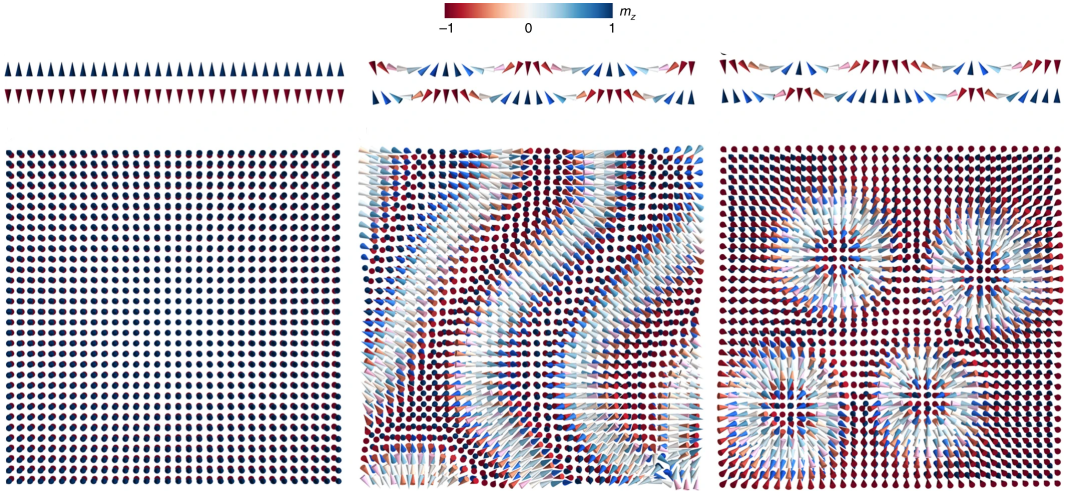
Dependence of the PL on the relaxation time



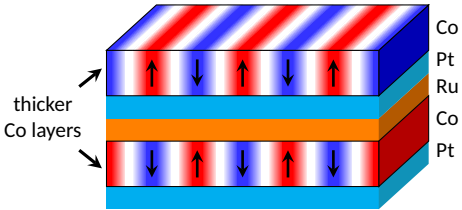




Tuning the magnetic state in a SAF

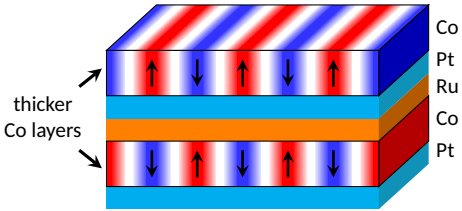


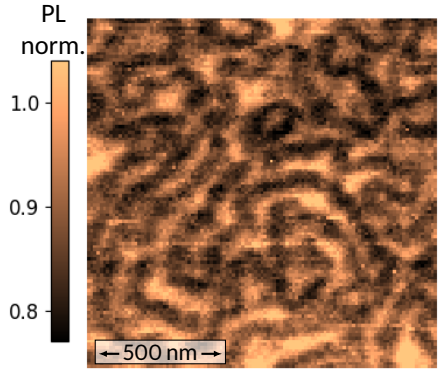
Imaging spin spirals...



→ **Vanishing magnetic anisotropy**

Imaging spin spirals...





→ **Vanishing magnetic anisotropy**

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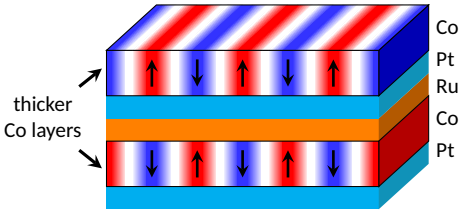
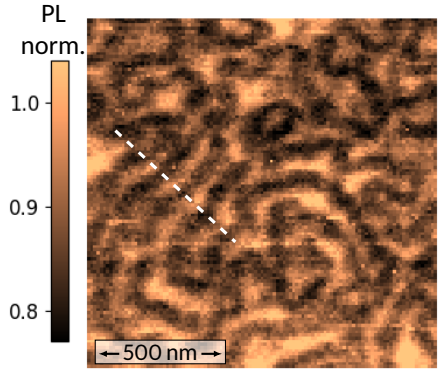
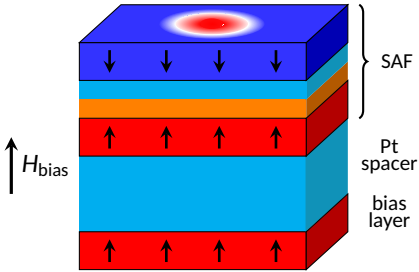


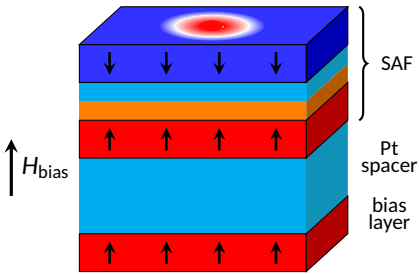
→ **Vanishing magnetic anisotropy**

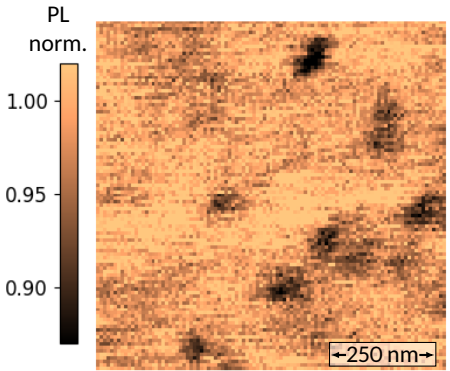


… and magnetic skyrmions!



… and magnetic skyrmions!





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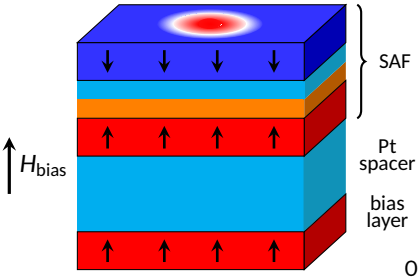
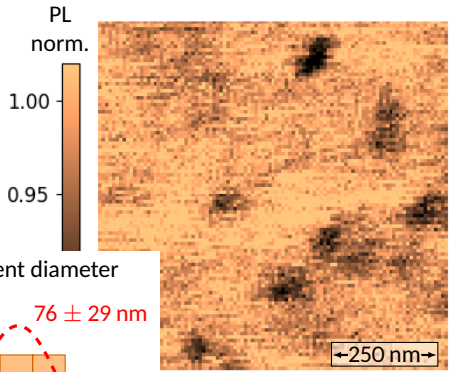
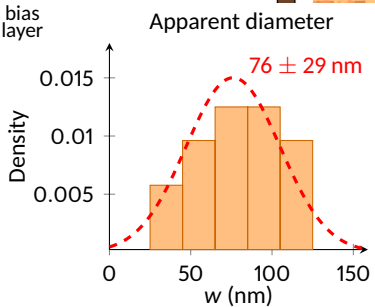
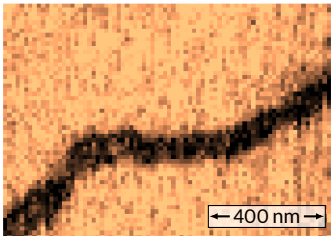


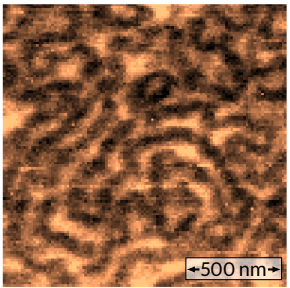


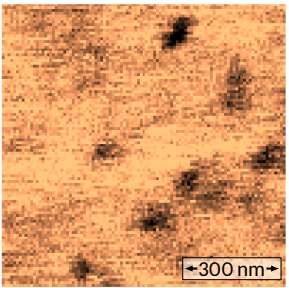


Summary

- Third imaging mode of scanning NV magnetometry
- Not relying on static stray field but on magnetic noise
- Fast, simple, well-suited to study antiferromagnets







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